Suspended Sediment Quality in the Upper St. Clair River, 2015 - 2022

Lisa Richman
Great Lakes Monitoring Unit
Environmental Monitoring and Reporting Branch
Ontario Ministry of Environment, Conservation and Parks
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Thank you to Rosemary Ash and Jenny Winters (MECP), Rupert Joyner and Chris Marvin (ECCC) for their review and comments on this report.

Executive Summary

The St. Clair River was designated as an area of concern (AOC) under the Great Lakes Water Quality Agreement in 1985 because of contaminated fish, degraded benthic communities, beach closures, and other impairments due to poor water and sediment quality (JGLR, 1985). Accordingly, the Canadian Federal and Ontario Provincial governments classified the upper reaches of the St. Clair River into three zones: Zone 1, Zone 2, and Zone 3 for further assessment and remedial actions. In 1996, portions of Zone 1 downstream of the Cole Drain were remediated with the removal of sediment contaminated by volatiles and semi-volatiles, and in 2002-2004 Dow Chemical Canada Inc. dredged contaminated sediment along the shoreline in front of their former property (Richman et al. 2009). This sediment was contaminated with mercury (Hg), hexachlorobenzene (HCB), hexachlorobutadiene (HCBD) and octachlorostyrene (OCS). Subsequently, a sediment remediation strategy was developed for Zones 2 and 3 for three Priority Areas (PAs) located along the shoreline from the Dow/Suncor (Suncor Sunoco Group) property line to approximately the southern end of Stag Island (Figure 1). These PAs were first identified based on high Hg concentrations in sediment and the potential risk of Hg biomagnification in biota, as well as the risk of re-suspension of the contaminated bottom sediment acting as a source to the water column, biota, and downstream areas (Gewurtz et al., 2010; Jia et al., 2010; Richman and Milani, 2010; Richman et al. 2018). The remedial action chosen for the PAs include the placement of an erosion resistant cap in the fall of 2023 or spring of 2024 by Dow.

To measure the success of sediment remedial actions in Zone 1, suspended sediments were collected using sediment traps for contaminant analysis from locations downstream of the former Dow property post-remediation from 2006 to 2022. This data was compared with pre-remediation data collected in 1994/95 and 2001. This report focusses on data collected from 2015-2022. Data from 2006-2011 was presented in Richman et al. (2018). This is an ongoing collaborative study with Environment and Climate Change Canada (ECCC).

Sediment traps were deployed using divers at up to 11 transects along the St. Clair River corridor within Zones 2 and 3, and at one upstream reference location. Transects included 3-5 stations with sediment traps deployed 5 m apart with increasing distance from shore.

The objectives of the study were to:

1) measure concentrations of contaminants of concern (COC) in suspended sediments.

2) look at long-term contaminant trends from 2001-2022 to assess the success of remedial actions along the former Dow property (1996 and 2002-2005).

3) understand the downstream movement of contaminated suspended sediments specifically from the three PAs in Zones 2 and 3.

4) provide data to form the baseline for further comparisons with suspended sediment contaminant concentrations following the placement of the erosion resistant cap.

The focus of the report is on Hg contamination since this is the current COC, however, data was collected for HCB, HCBD and OCS since historically these contaminants were all discharged from the same source. With the completion of the remediation in 2004, these organic compounds were no longer considered COCs.

Suspended sediment collected from the upstream reference transect had total Hg concentrations that were significantly lower than concentrations measured at all transects downstream of the former Dow waterfront which demonstrated the persistence of legacy contamination. Depending on the year, transect 75 (immediately downstream of the former Dow property), had significantly higher concentrations of Hg than concentrations measured at transects extending 9 km downstream. The likely source of the Hg contaminated suspended sediment is residual Hg contaminated bottom sediment from the former Dow property. Bottom sediment collected by Dow in 2019/20 about 100-200 m upstream of transect 75 had total Hg ranging up to 13 µg/g in this area. This area of high contamination will be included in the Dow remedial action.

In general, Hg concentrations in suspended sediment (with only a few exceptions), were not significantly different among the remaining downstream sampling locations suggesting that contaminated sediment along the shoreline was routinely resuspended and moved further downstream.

Using the annual mean suspended sediment Hg concentrations for transects with historical data (2001-2022), the Mann-Kendell Test for trend analysis identified a significant decrease in Hg concentrations through time (Figure 10). This trend analysis suggested that the suspended sediments moving along the Canadian shoreline remain less contaminated with Hg than before the Dow waterfront remediation in 2002-2004. The 2015 - 2022 Hg data for all current and historical stations, with only one exception, did not show any trends through time for recent years suggesting that the likelihood of a further decrease in Hg concentrations would require additional remedial actions. The placement of the erosion resistant cap on the three PAs identified as having high total Hg in the surface sediment (top 15 cm) may result in this improvement in suspended sediment quality moving downstream of these areas.

Annual suspended sediment down-flux (defined as the mass of sediment being deposited per square meter per day) (g/m^2/day) and the down-flux of contaminants (i.e., mass of contaminants associated with the sediment) (Hg: $\mu g/m^2$/day; HCBD, HCB, OCS: ng/m^2/day) was used to assess the movement and quality of suspended sediment from upstream to downstream. Estimated contaminant down-flux rates represented by the mean values for all transects from Zones 2 and 3, were consistently higher in 2001 compared with succeeding years 2007–2022. For Hg, the daily mean down-flux rate in 2001 was 721 $\mu g/m^2$/day, while corresponding rates for 2007–2022 ranged from 80–364 $\mu g/m^2$/day. Similarly, the down-flux for OCS and HCBD downstream of Dow remained lower through time compared with pre-remediation

values in 2001. Due to the high variability in the data within a survey it was not possible to see a trend in HCB concentrations.

The 2022 data will serve as the baseline prior to the placement of the erosion resistant cap in the three Priority Areas, which can then be compared with suspended sediment quality post-remediation. Given the large variability in data within a transect, between transects and between surveys, data collected from earlier surveys should be considered to help interpret post-remediation data. Total Hg data in 2022 at transects 75, 374 and 270 must be interpreted with consideration to the addition of two new locations inshore along the transects and hence the absence of historical offshore stations. The post-remediation survey should include all five locations along these transects mirroring the 2022 stations as well as two additional offshore stations located 5 m apart to replicate the historical sampling design. These additions will help inform the observed changes in the 2022 contamination patterns at these locations and potential improvements in suspended sediment quality due to cap placement.

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Appendix Table 3: Results from the Mann-Kendall test and the magnitude of the trend with the Sen's method in MAKESENS for suspended sediment Hg data for transects with long-term data (2015-2022).

Background:

The St. Clair River was designated as an area of concern (AOC) under the Great Lakes Water Quality Agreement in 1985 because of contaminated fish, degraded benthic communities, beach closures, and other impairments due to poor water and sediment quality (JGLR, 1985). Based on extensive benthic community impairment at that time (Pope, 1993), the Canadian Federal and Ontario Provincial governments classified the upper reaches of the St. Clair River into three zones: Zone 1, Zone 2, and Zone 3 (Figure 1). These areas were intensely studied due to the presence of industrial activity which had resulted in sediment contaminated with compounds that greatly exceeded concentrations upstream in Lake Huron and/or Ontario Provincial Sediment Quality Guidelines. These legacy contaminants included but were not limited to mercury (Hg), hexachlorobenzene (HCB), octachlorostyrene (OCS), polychlorinated biphenyls (PCBs) and hexachlorobutadiene (HCBD). Due to river flow patterns (UGLCCS, 1988), contaminated plumes from shore-based industrial and municipal sources, and re-suspension and deposition of contaminated bottom sediment, remained along the Canadian side of the river close to shore (Chan et al., 1986). Through remedial actions and modernization by local industries, stakeholders and government agencies, environmental conditions within the river have improved through time since the 1980's (Marvin et al., 2004).

In 1994/1995 the Ministry of Environment, Conservation and Parks (MECP) completed a study focused on Zone 1 which included the shoreline from Imperial Oil Ltd and Polysar Ltd. (currently LanXESS) downstream to the Dow Chemical Canada Inc. (Dow) 4th Street sewer (Figure 1). This study included sediment chemistry (surface and core), benthic community structure, sediment bioassays and sediment traps to assess contaminant concentrations in suspended solids. The dataset was used to demonstrate the need for sediment remediation within Zone 1 particularly along the Dow waterfront (Farara and Burt, 1997; Kauss 1999). In 1996, portions of Zone 1 downstream of the Cole Drain were remediated with the removal of sediment contaminated by volatiles and semi-volatiles (HCB, HCBD, OCS and tetrachloroethylene) (Kauss and Nettleton, 1999), and in 2002-2004 Dow dredged contaminated sediment along the shoreline in front of their former property (Richman et al. 2009). This sediment was contaminated with Hg, HCB, HCBD and OCS. Subsequently, a sediment remediation strategy was developed for Zones 2 and 3 for three Priority Areas (PAs) located along the shoreline from the Dow/Suncor (Suncor Sunoco Group) property line to approximately the southern end of Stag Island (Figure 1). These PAs were first identified based on high Hg concentrations in sediment and the potential risk of Hg biomagnification in sport fish that forage in those areas. Additionally, the re-suspension of the contaminated bottom sediment was a source to the water column, biota, and downstream areas (Gewurtz et al., 2010; Jia et al., 2010; Richman and Milani, 2010; Richman et al. 2018). Remediation of the contaminated sediment within these PAs is expected to be undertaken in the fall of 2023 or spring of 2024 through the placement of an erosion resistant cap to be installed by Dow.

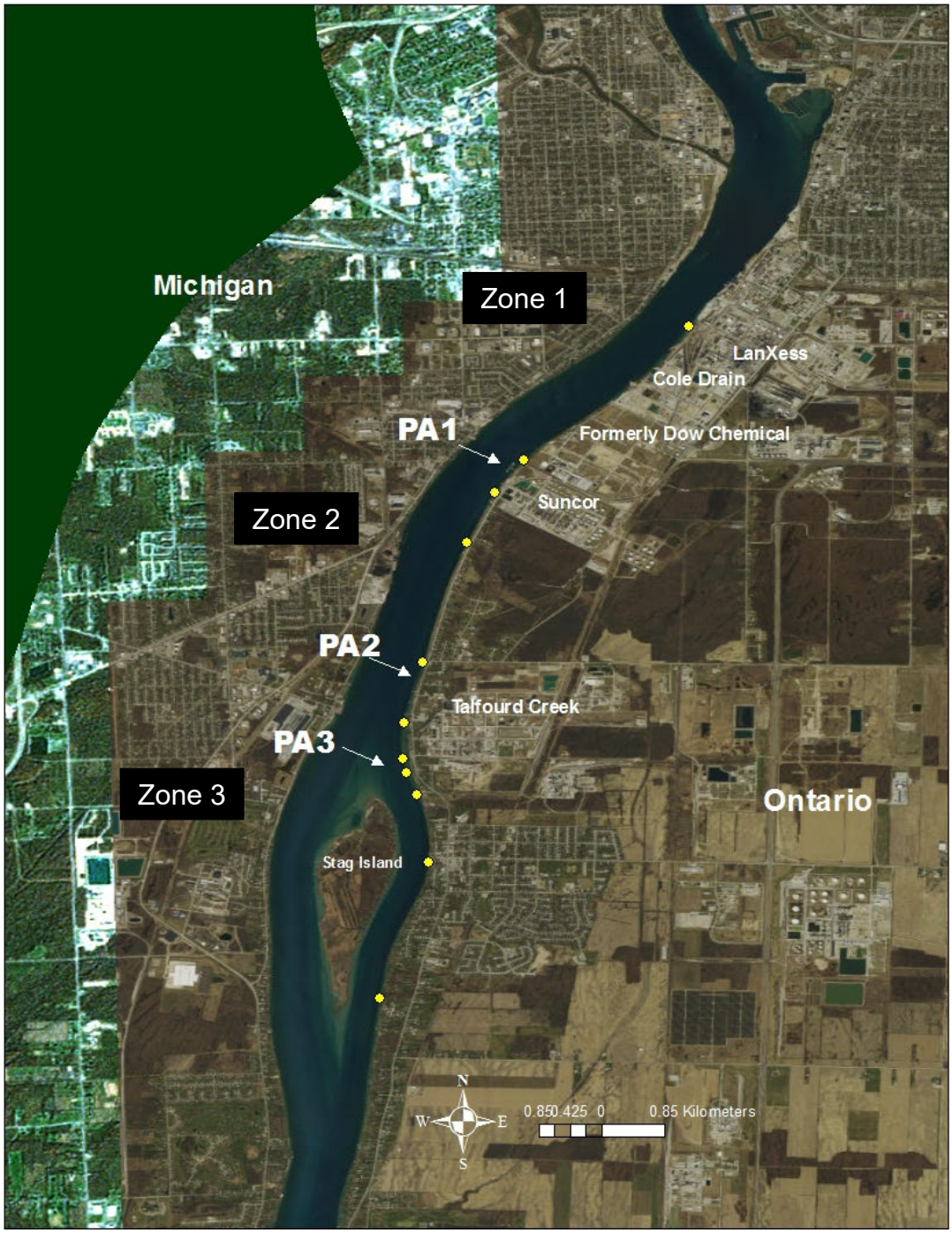


Figure 1: 2015 - 2022 Sediment Trap locations along the St. Clair River corridor, and the three Priority Areas (PAs) designated for sediment remediation.

The collection of suspended sediments using sediment traps for contaminant analysis from locations downstream of the former Dow property post-remediation from 2006 to 2011 allowed for a comparison with pre-remediation data collected in 1994/95 and 2001 to assess the decrease in contamination of suspended sediments due to the remedial actions and possible resuspension and movement of residuals from the remediated

sites (Richman et al. 2018). Considering the sediment remediation strategy for Zones 2 and 3, and the usefulness of data generated from the deployment of sediment traps as a means of measuring the success of remedial action to reduce Hg concentrations on sediment moving downstream, additional sites for monitoring sediment stability and contaminant concentrations were required upstream and downstream of the Priority Areas targeted for capping. This data will serve as a pre-remediation baseline dataset.

This is an ongoing collaborative study with Environment and Climate Change Canada (ECCC).

Objectives: **The objectives of the suspended sediment studies were to**:

1) measure concentrations of contaminants of concern (COC) in suspended sediments.

2) look at long-term contaminant trends from 2001-2022 to assess the success of remedial actions along the former Dow property (1996 and 2002-2005).

3) understand the downstream movement of contaminated suspended sediments specifically from the three PAs in Zones 2 and 3.

4) provide data to form the baseline for further comparisons with suspended sediment contaminant concentrations following the placement of the erosion resistant cap.

Methods

Deployment of Sediment Traps:

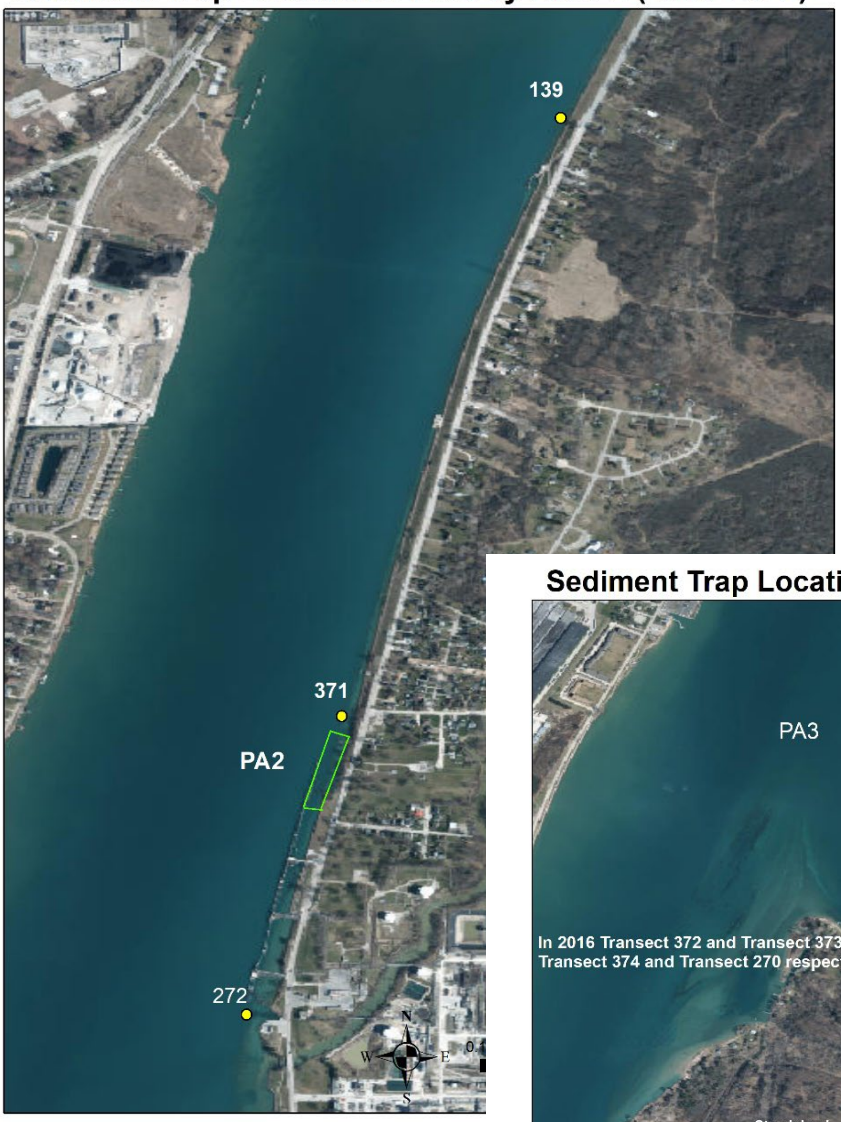
Sediment traps were deployed using divers in 2015 at 11 transects: one upstream (U/S) reference transect (365) and 10 transect within Zones 2 and 3 (Figures 1 & 2). The reference transect was established in 1994 and resampled in 1995, 2009 and 2011. In 2016-2022, traps were deployed at the reference site and at 9 transects within Zones 2 and 3. In 2016, the 2015 transect identified as downstream of PA1 (transect 310) was moved farther downstream and given a new station number: 370. Additionally, the 2015 transects that were upstream of PA3 (station 372) and downstream of PA3 (station 373) were relocated in 2016 to better reflect nearshore suspended sediment and were re-labelled station 374 and 270, respectively.

There were two deployments within a sampling year: spring, and fall, with traps remaining in the water for about two to three months for each deployment to ensure sufficient accumulation of sediment for analysis and to capture potential seasonal differences. Typically, the spring deployment was from May through August, and the fall deployment was from August through November with some variability in dates among the survey years. At each transect, traps were deployed at three stations at increasing distances from shore (each station was 5 m apart) at water depths ranging from 3 m to 8.4 m dependent on the station, year, and spring vs fall deployment (Appendix Table 1).

Figure 2: 2015-2022 Sediment Trap locations in PA1, PA2 and PA3.

Sediment Trap Locations: Priority Area 1 (2015-2022)

Sediment Trap Locations: Priority Area 2 (2015-2022)



Sediment Trap Locations: Priority Area 3 (2015-2022)

In 2022, two additional stations were added along transects 75, 374 and 270 located closer to the nearshore to capture shoreline movement of suspended sediments more accurately.

Divers installed 1.5 m sections of rebar into the bottom substrate and deployed 3 tie-wrapped 10 cm × 80 cm sediment tubes around each post, with 3 posts per transect (5 posts per transect in 2022 at transect 75, 374 and 270). Accordingly, there were typically 9 tubes deployed at each transect (15 tubes in 2022 at transect 75, 374 and 270). Sediment tubes were dug 10-15 cm into the substrate when possible, or alternatively placed on the sediment surface. Deployment methods remained consistent over the course of the study since 1994.

Chemical Analysis:

Upon retrieval, the sediment tubes were stored upright in a walk-in refrigerator for a minimum of one week to allow the sediment to re-settle. Samples remained refrigerated until processing. The surface water was decanted, and sediment was removed from the settling tubes and routinely submitted for analysis of TOC, Hg, particle size, and percent moisture and in 2015-2017 sediment was also submitted for HCB, HCBD, OCS. Wet weight of sediment collected from the tubes was recorded to calculate suspended sediment and contaminant down-flux rates. Samples were analysed for COCs following standard methodologies described in Richman et al. (2018). In all surveys except for spring 2016, the 3 tubes deployed at each of 3-5 locations along a transect were processed separately resulting in 9-15 samples per transect. In 2016, for the spring deployment only, the three tubes at each location were homogenized during processing resulting in 3 samples submitted for analysis per transect.

Data Analysis:

The Kolmogorov-Smirnov Test was used to test suspended sediment contaminant data for normality, and variances were tested for homogeneity. Log_{10} transformed data within each year were compared to assess spatial trends using the One-Way Analysis of Variance (ANOVA) followed by the All Pairwise Multiple Comparison Procedures using the Holm-Sidak method. Due to the inability to measure seasonal differences (spring vs fall) for all parameters because of the large variability in concentrations along a transect and even among the 3 tubes within a location on a transect, average contaminant concentrations for a transect were calculated based on the overall mean concentration from the two deployments, which, depending on the transect and the success of trap retrieval, generally ranged from 16 – 18 data points/transect. In 2016, because of the homogenization of the samples in the spring as described above, mean concentrations were generally based on 12 data points. All statistical procedures were performed using SigmaPlot, from Systat Software, Inc. (San Jose California USA).

Trend through time analysis (i.e., the presence of a monotonic increasing or decreasing trend) for Hg concentrations on suspended sediments from 2001-2022 was assessed using the non-parametric Mann-Kendall test and the slope of a linear trend was estimated with the non-parametric Sen's method.

Down-flux at each transect and for each year was estimated by calculating the dry weight of sediment collected in each trap based on total wet weight of sediment and percent moisture. The dry weight per trap was then multiplied by the number of traps estimated to represent a square metre (i.e., 127 traps based on a 10 cm diameter trap tube), which provided an estimate of areal deposition (g/m^2). The deposition value was then divided by the number of days of deployment and multiplied by the individual chemical concentrations to afford contaminant down-flux estimates per day. A mean for each of the transects was calculated using data from all traps within a transect combining the spring and fall deployments. The annual mean suspended sediment down-flux and corresponding COC down-flux rates for the entire study area (Zone 2 and Zone 3) was calculated by combining annual data from each transect within a year (Table 1). This data was used to assess if there had been a decrease in contaminants associated with suspended sediment moving downstream through the St. Clair River corridor post remediation.

Results and Discussion

Seasonal Trends:

Seasonal trends of Hg concentrations (and the historical COCs: HCB, OCS and HCBD), TOC, and particle size in sediment were inconsistent both within and between survey years due to high variability between stations along a transect and between transects. For example, total Hg concentrations were higher in the spring than the fall in 2015 and 2016 and depending on the transect, the difference was statistically significant; however, in 2017-2022 there did not appear to be any seasonal influence on total Hg concentrations (Figure 3 (2022 data); Appendix Figure 1: data from 2015-2018). Although not statistically significant at all transects, TOC and percent silt-clay were typically lower in the spring compared with the fall for all years of study except for 2017, suggesting sediment transport was related to mostly sand in the spring and finer particles during the fall, while in 2017 there was no apparent seasonal difference (Figure 4 (2022); Appendix Figures 2 & 3: 2015-2018). The high variability in data for various parameters within a transect between seasons can be attributed to variability between the 3 - 5 sampling locations along a transect (i.e., nearshore, middle, and offshore, and two additional nearshore stations introduced in 2022 at three transects), but also due to variability among the three sediment trap tubes bundled even within a sampling location (Figures 5 and 6 (2022); Appendix Figure 4: 2017-2018). Overall, seasonal, and spatial variability was not surprising since time-integrated suspended sediment collection methods such as sediment traps are highly influenced by episodic events such as storms and high winds that may result in significant re-suspension and transport of bottom sediment (Marvin et al., 2007), but the variability within a specific location along a transect was unexpected given that the three tubes were bundled together as one unit.

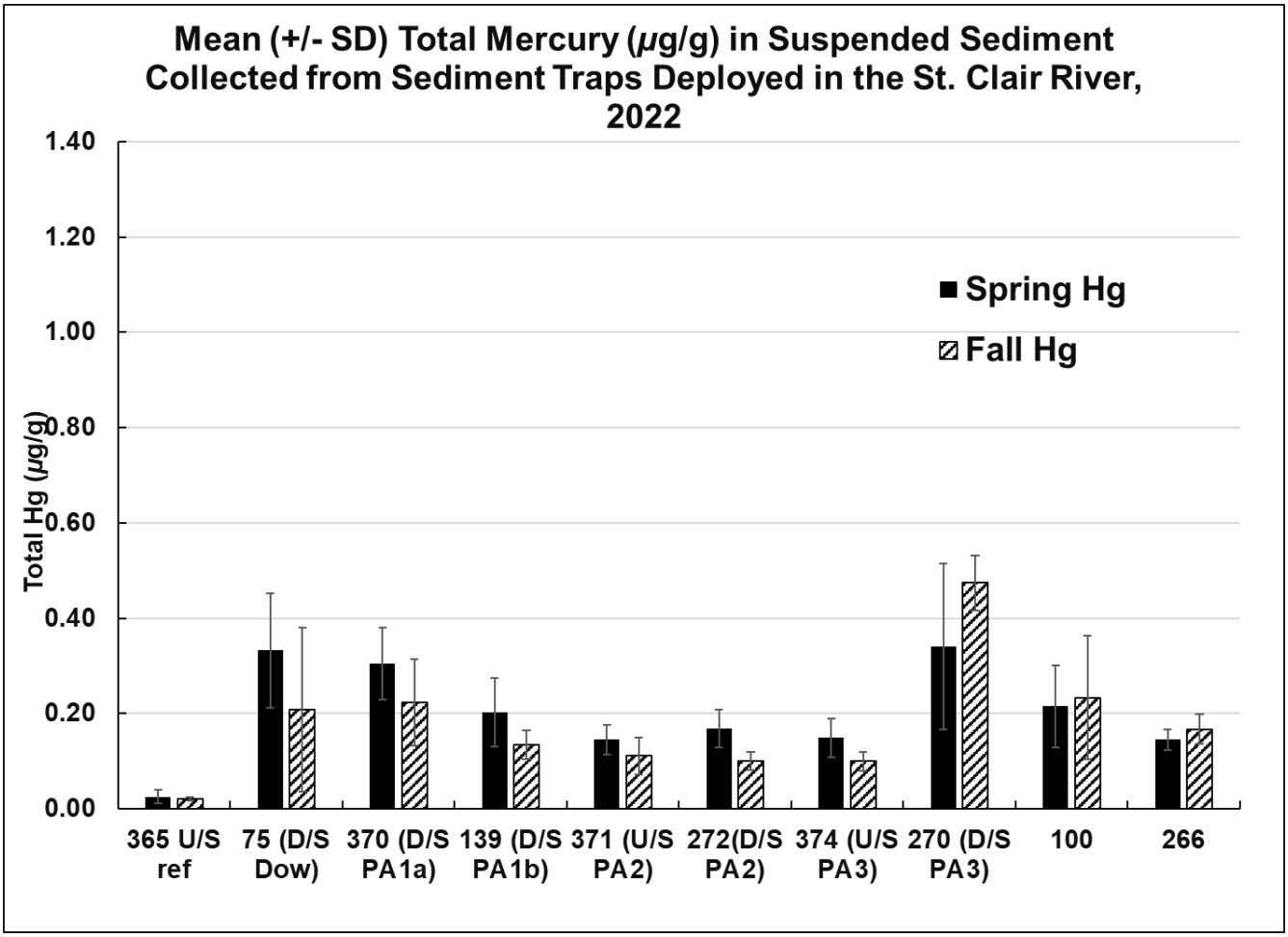
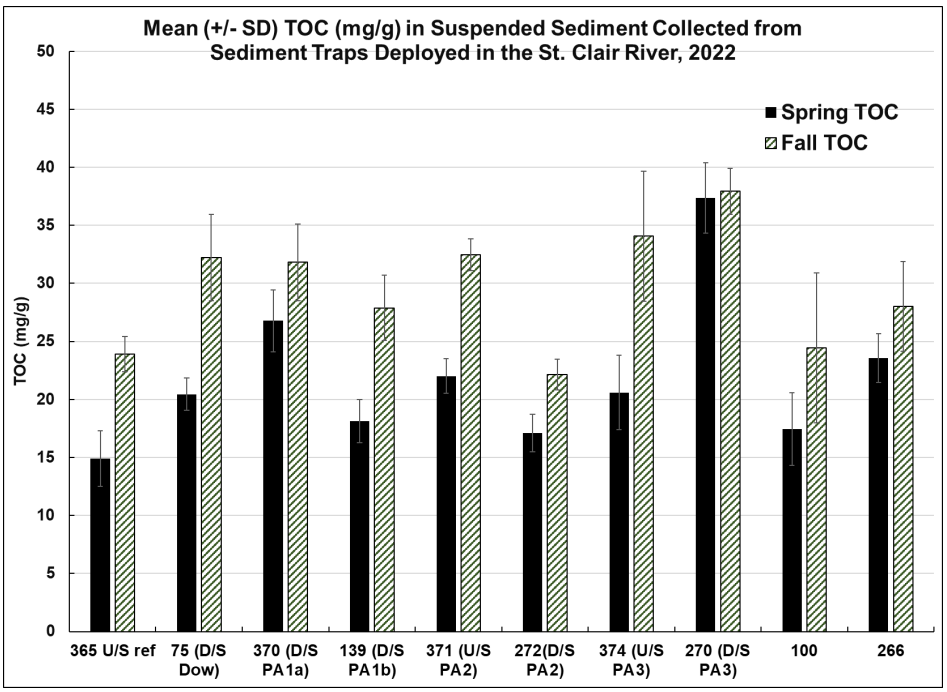


Figure 3: A comparison between spring and fall mean total Hg concentrations (*u*g/g) (± SD) in suspended sediment collected from sediment traps deployed along transects in the St. Clair River corridor, 2022.

a)



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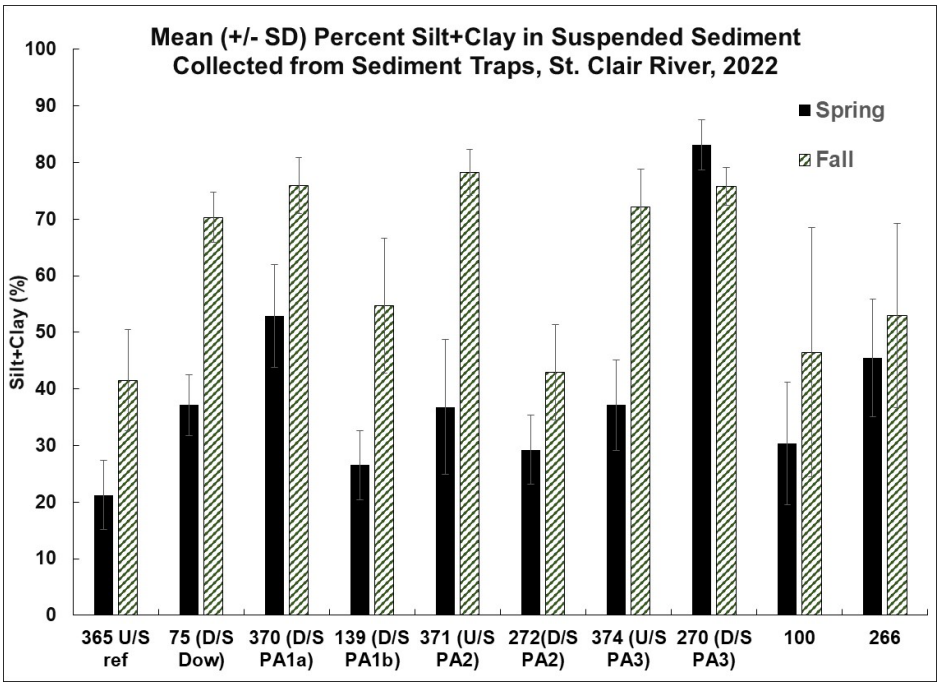
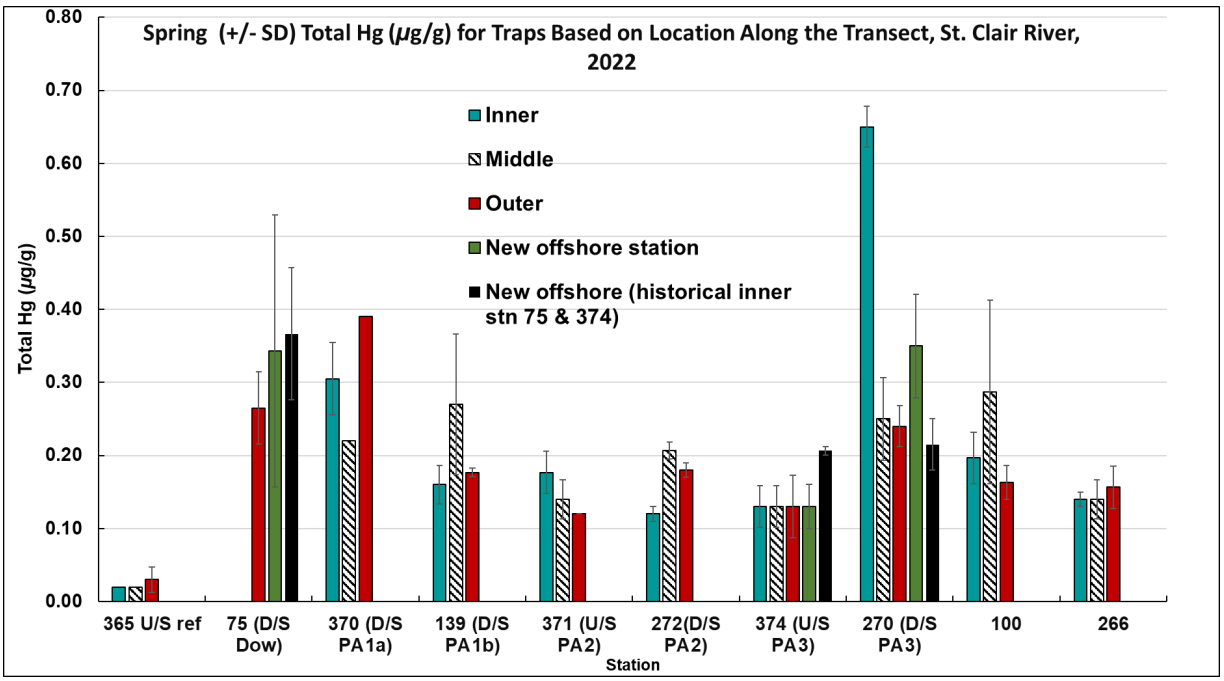


Figure 4: A comparison between spring and fall mean a) total organic carbon (TOC) concentrations (mg/g) (± SD), and b) percent silt+clay in suspended sediment collected from sediment traps deployed along transects in the St. Clair River corridor, 2022.

a)



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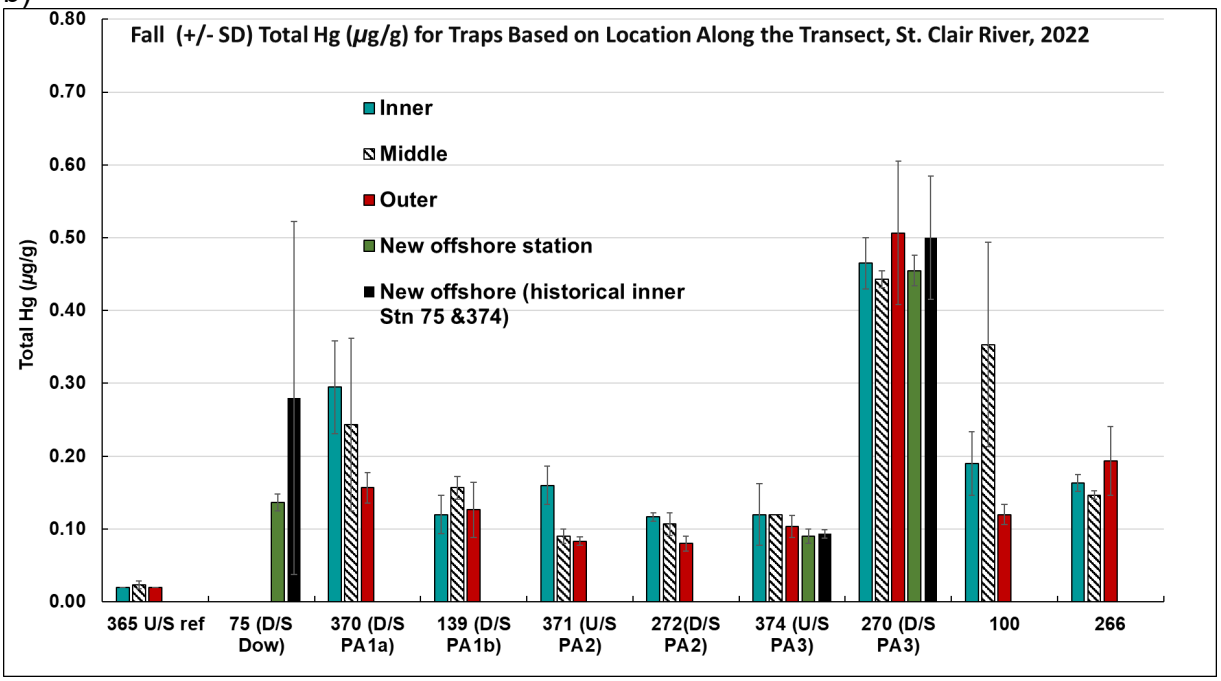
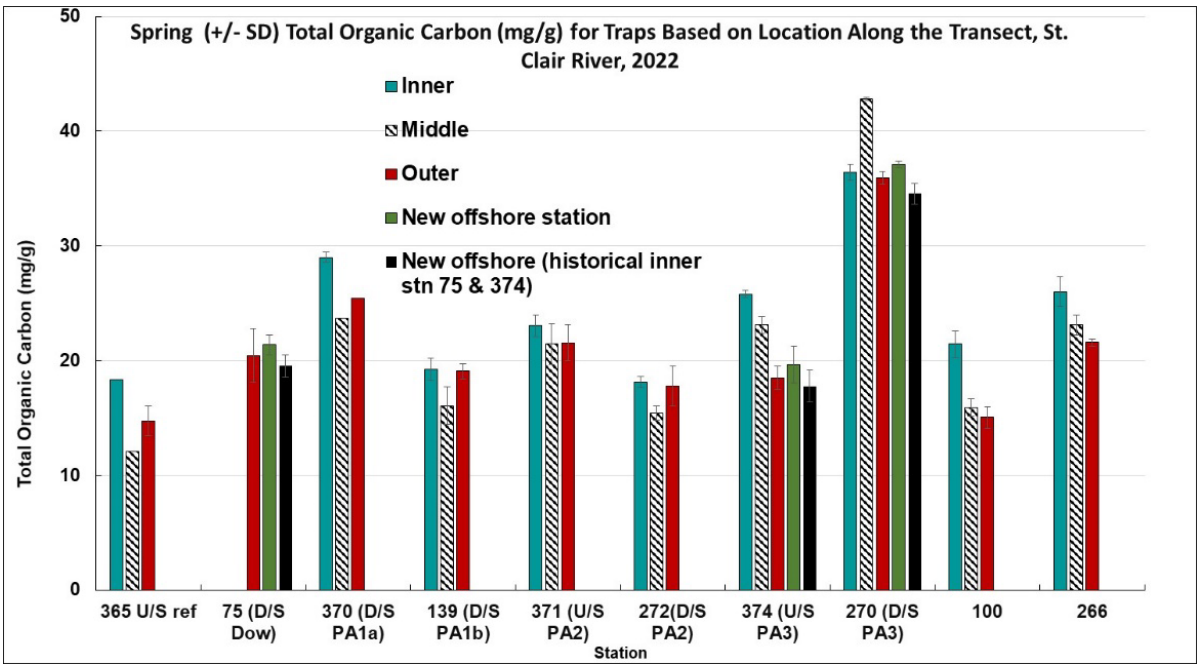


Figure 5: A comparison between a) spring and b) fall mean total Hg concentrations (*u*g/g) (± SD) in suspended sediment collected from sediment traps (n=3 tubes bundled together) deployed at 3-5 locations along a transect beginning at the nearshore (inner) and placed 5 m apart with increasing distance from shore. Transects were located along the St. Clair River corridor, 2022.

a)



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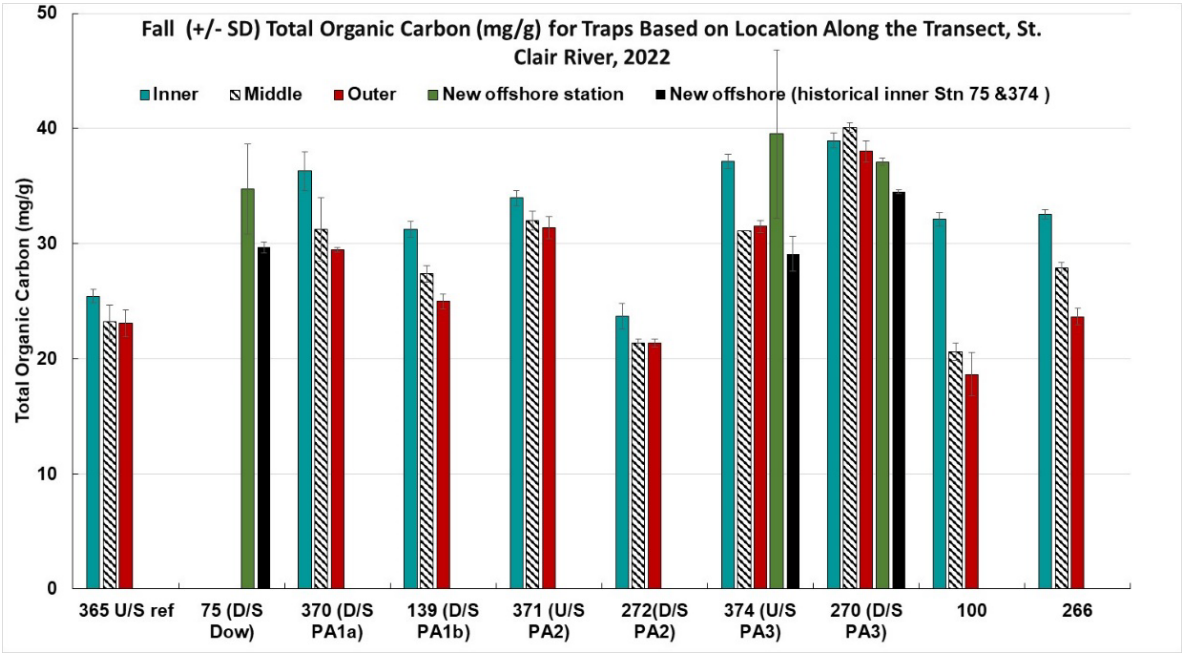


Figure 6: A comparison between a) spring and b) fall mean TOC concentrations (mg/g) (± SD) in suspended sediment collected from sediment traps (n=3 tubes bundled together) deployed at 3-5 locations along a transect beginning at the nearshore (inner) and placed 5 m apart with increasing distance from shore. Transects were located along the St. Clair River corridor, 2022.

Although TOC and particle size were significantly correlated in all survey years, the strength of the relationship varied year to year. For example, from 2016 to 2018 the r^2 ranged from 0.42-0.63 while in 2022 it was 0.83 (Figure 7 (2022); Appendix Figure 6:2015-2018). Total Hg concentrations were not correlated with TOC or particle size in any survey year (Figure 8 (2022); Appendix Figure 7: 2015-2018).

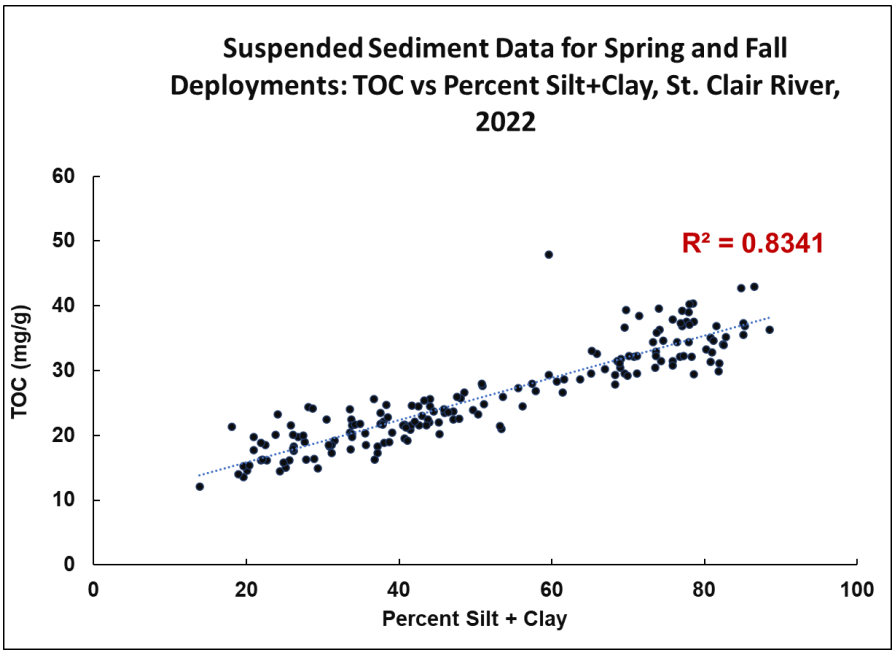
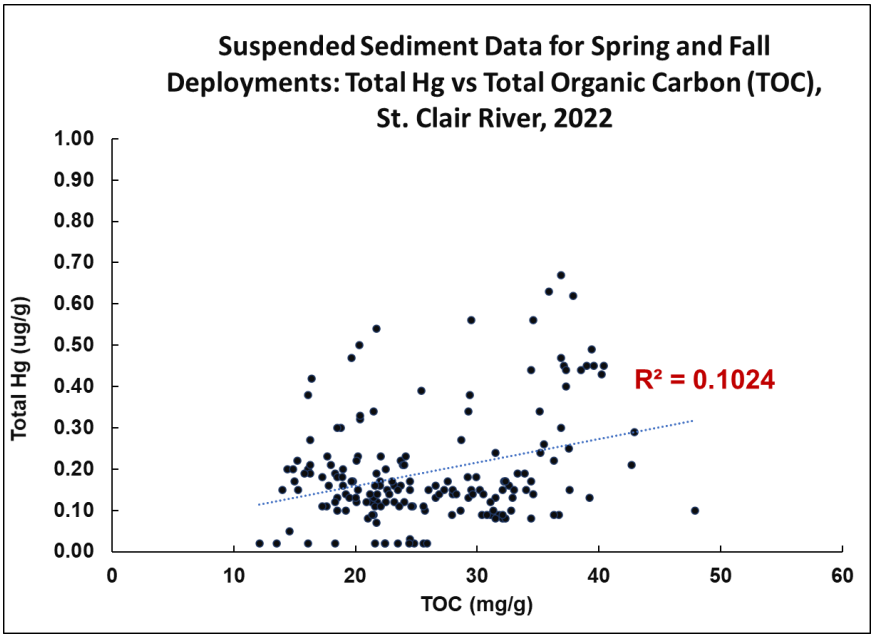


Figure 7: Relationships Between Suspended Sediment TOC Concentrations (mg/g) and Particle Size: Percent Silt+Clay (2022).

a)



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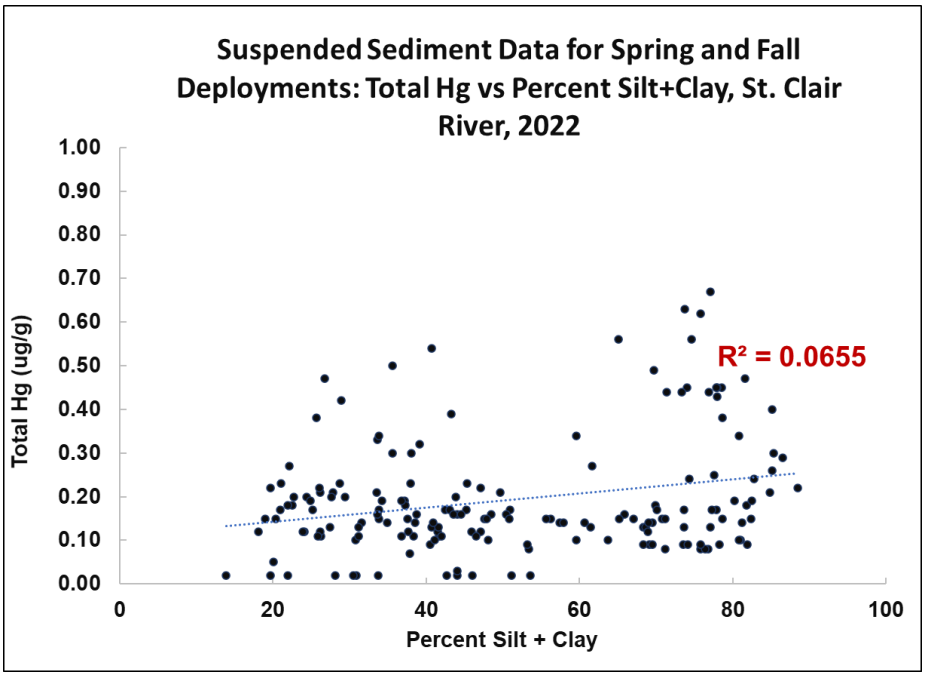
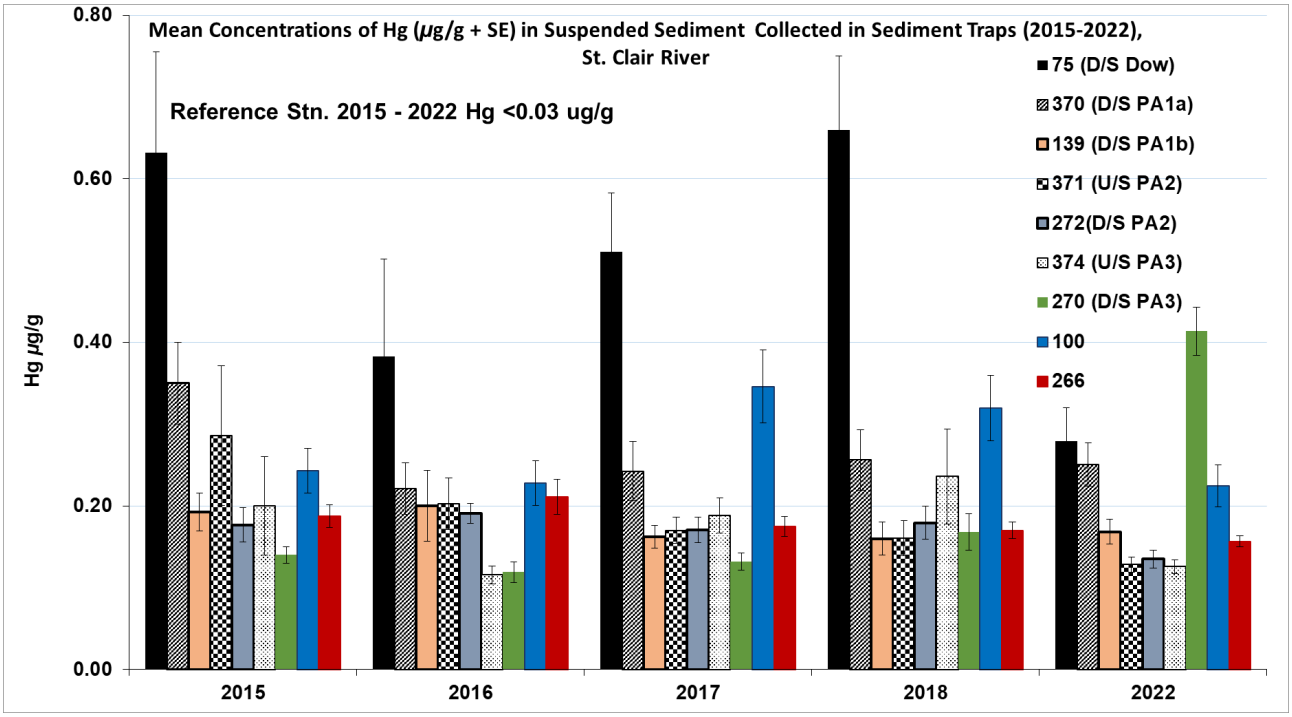


Figure 8: Relationships Between Suspended Sediment Total Mercury Concentrations (ug/g) and TOC Concentrations (mg/L), and Total Mercury (ug/g) vs Percent Silt+Clay.

Sediment Transport Patterns:

Given the high variability and lack of a consistent seasonal pattern for parameters, the seasonal data were combined for a comparison of Hg concentrations (and TOC, particle size and other COCs) among transects within a survey year and between years to assess trends through time. Using $\log_{10}$ transformed data, the one-way ANOVA showed that for each year of study there was a significant difference in Hg concentrations in suspended sediment between transects (F values ranged from 21.5 - 76; $p<0.001$). The Pairwise Multiple Comparison Procedures using the Holm-Sidak method showed that suspended sediment collected from the reference transect had Hg concentrations that were significantly lower than suspended sediment collected downstream of the Dow waterfront (T values ranged from >7.1 - 24; $p<0.001$). Depending on the year, transect 75 (immediately downstream of the former Dow property), had significantly higher concentrations of Hg than concentrations measured at the other downstream stations (Figure 9a). For example, in 2017, 2018 and 2022 transect 75 had significantly higher mean Hg concentrations than all but one or two downstream transects. In 2015 and 2016, although concentrations were greater than all downstream transects, the higher concentrations were significant at only a few locations due to high variability within a transect. The likely source of the Hg contaminated suspended sediment collected at transect 75 is residual Hg contaminated bottom sediment from the Dow property (which extended from the Dow 1st St. sewer to transect 75), or the area between the Cole Drain and Dow. Historical bottom sediment data showed no evidence of Hg contamination,

a)



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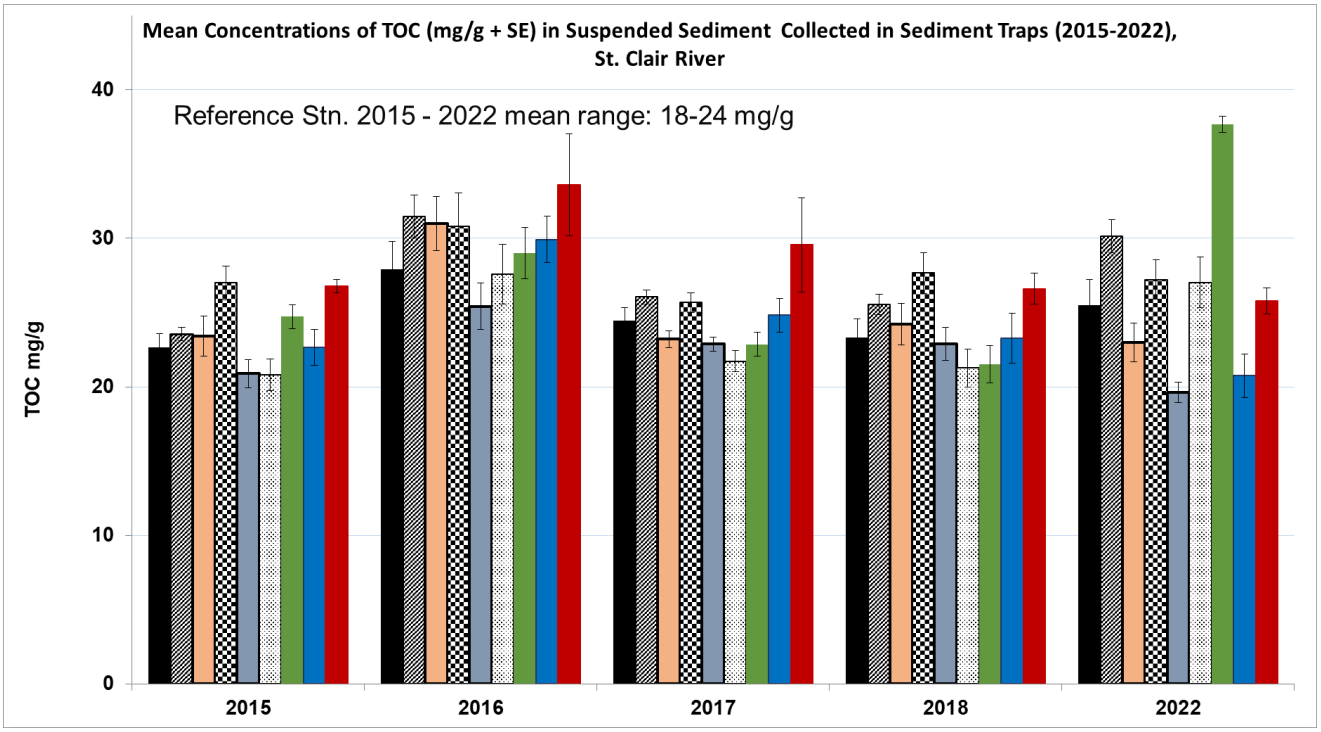


Figure 9: a) Mean Hg concentrations (*u*g/g) (± SE) and b) TOC (mg/g) in suspended sediment collected from traps located along the St. Clair River corridor from 2015-2022.

upstream of the Cole Drain (Farara and Burt 1997) and bottom sediment collected downstream of the Cole Drain in 2008 ranged from 0.05 – 3 *µg*/g Hg (Richman 2008). Additionally, sediment along the Dow waterfront prior to the remediation had Hg concentrations that ranged from 0.26 – 244 *µg*/g (URS 2001) suggesting that there may have been high Hg contamination of residuals following remediation. Confirmation sampling of high residual contamination was not possible post remediation due to the presence of "fish mix" (gravel size layer of clean material) added to the remediated area to reduce potential resuspension of residuals. However, in 2019 and 2020 Dow collected surface sediment from the three PAs including several locations about 100-200 m upstream of transect 75 to update the data collected by MECP in 2010-2012 (Richman 2011; Richman 2012; Parsons and Anchor QEA, 2021). Total Hg in the surface sediment (0 - 15 cm) ranged up to 13 µg/g in this area and could be the source of contaminated suspended sediment collected in traps at transect 75. This area of high contamination will be included in the Dow remedial action.

Transect 75 in 2022 had the lowest total Hg concentration since 2015 although the suspended sediment still had significantly higher Hg than most downstream transects ($T > 3.4$; $p < .01$), except for transect 270 and 100. Two additional stations were added along this transect with the inner, middle, and offshore stations being moved closer to shore than in previous surveys. In fact, the farthest offshore station in 2022 was in the same location as the inshore station in previous years. It is possible that this relocation of the stations resulted in the collection of suspended sediment with lower total Hg concentrations compared with previous surveys. A follow up survey post-placement of the erosion resistant cap should include these same five locations in addition to two more stations further offshore to replicate the historical middle and outer stations. This could help inform the 2022 decrease in Hg at this transect. These same circumstances apply to the two transects upstream and downstream of PA3. Moving the stations closer to shore upstream of PA3 at transect 374 may have resulted in the collection of suspended sediment with lower Hg concentrations compared to data from 2015-2018, while transect 270 (downstream of PA3) had suspended sediments with Hg concentrations significantly higher than previous years ($F=39.7$; $T>8.9$; $p<0.001$) (Figure 9a).

In general, Hg concentrations in suspended sediment, with a few exceptions (e.g., transect 100), were not significantly different among the remaining sampling locations in the river which extended about 9 km downstream of the Dow/Suncor property line. The data suggested that contaminated sediment is routinely resuspended and moves downstream, when compared with Hg concentrations at the upstream reference site. The 2022 data for transect 374 when compared with 270 could suggest that PA3 was contributing resuspended sediment with higher Hg than upstream sites. This may not have been observed in previous years when the traps were located farther from shore. Post-remediation monitoring could confirm if this hypothesis is correct.

TOC concentrations (Figure 9b) were similar among the transects within a survey year and even between years from 2015-2022.

Temporal Trends:

Using the annual mean suspended sediment Hg concentrations for transects with historical data (2001-2022), the Mann-Kendell Test for trend analysis identified a significant decrease (Z values ranged from 2.4-3.5; p values ranged from <0.05 to <0.001) in Hg concentrations at transects 139, 272, 100 and 266 through time (Figure 10: Appendix Table 2). The trend for transect 75 was also decreasing but it was not statistically significant. This trend analysis suggested that the suspended sediments moving along the Canadian shoreline remain less contaminated with Hg than before the Dow waterfront remediation in 2002-2004. The 2015-2022 Hg data for all current and historical stations did not show any trend through time for recent years except for transect 371 where there was a significant decreasing trend (Appendix Table 3). This data from 2015-2022 suggested that the likelihood of a further decrease in Hg concentrations on sediment moving through the St. Clair River corridor would require additional remedial actions. The placement of the erosion resistant cap on the three PAs identified as having high Hg in the surface sediment (top 15 cm) may result in this improvement in suspended sediment quality moving downstream of these areas.

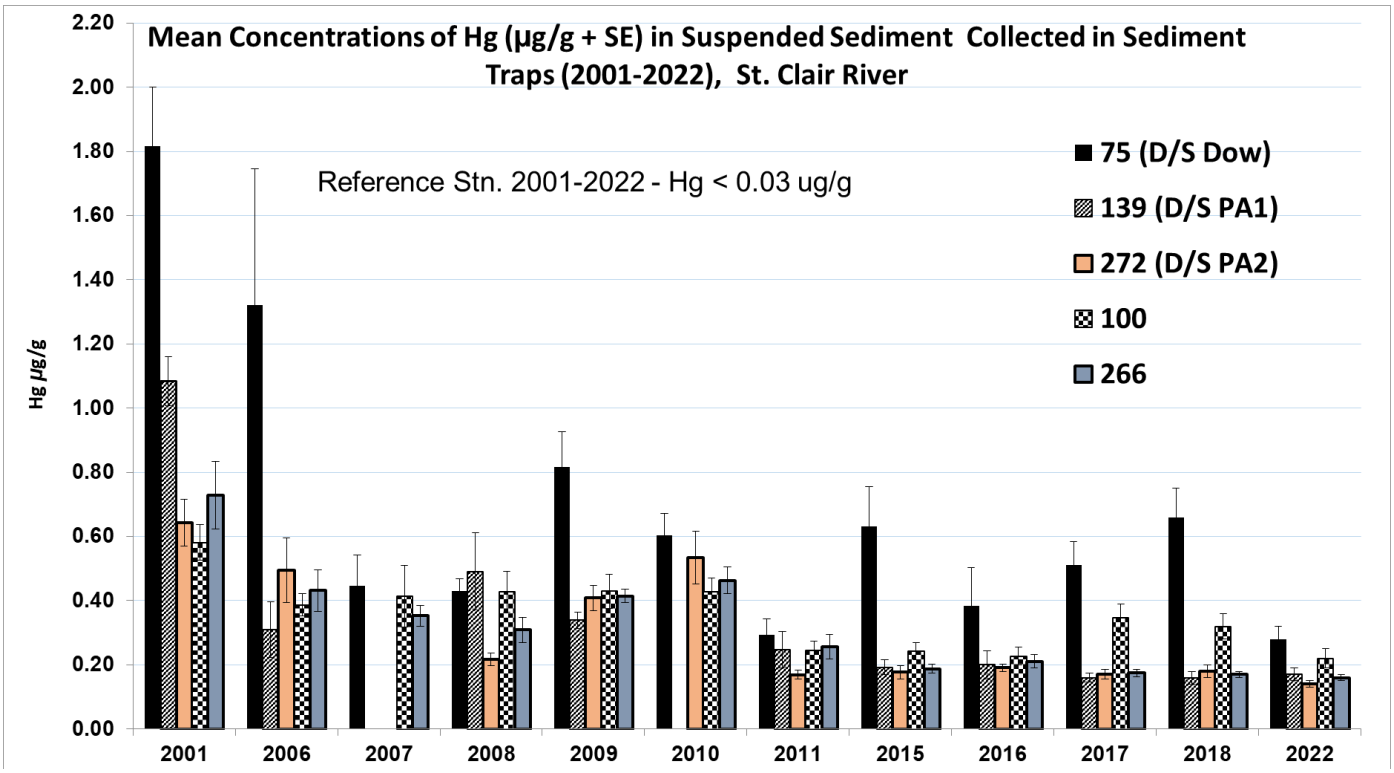


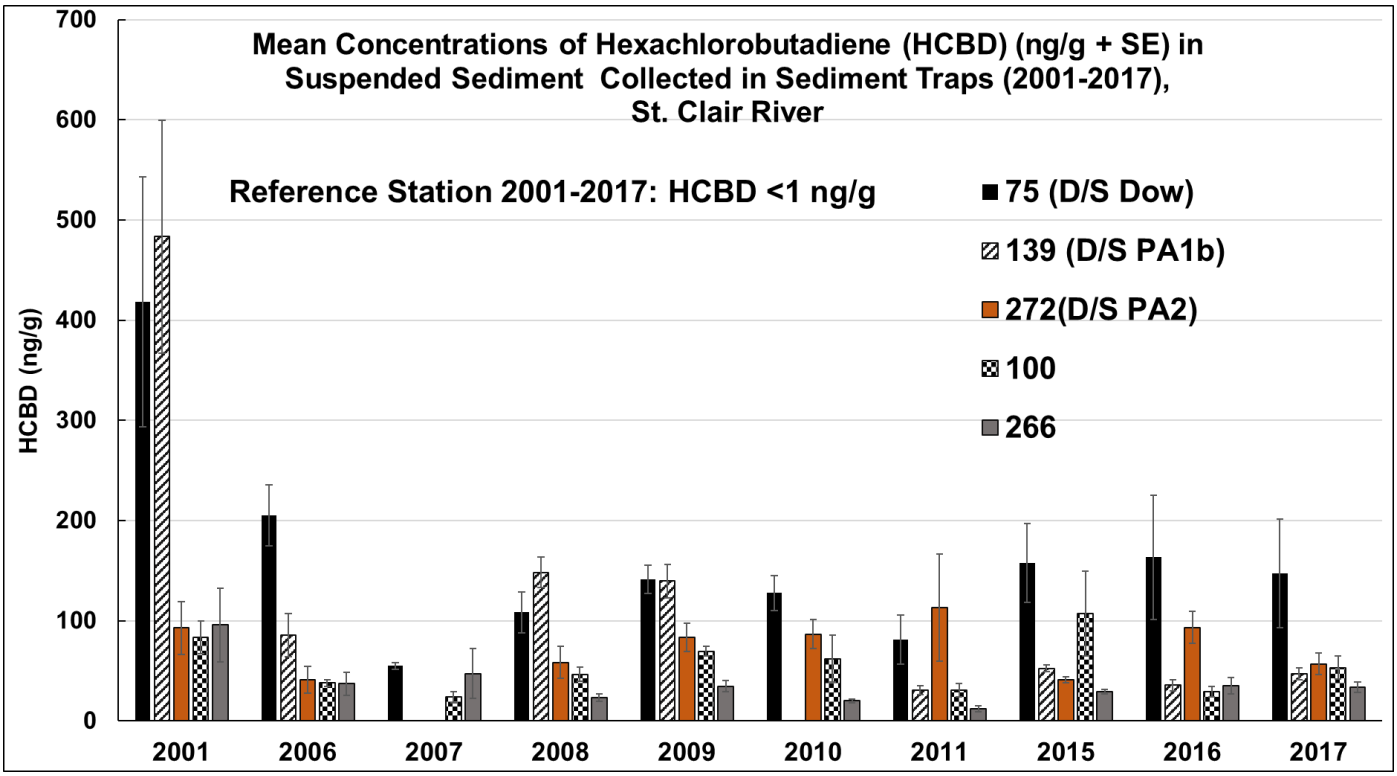
Figure 10: Mean Hg concentrations (*u*g/g) (± SE) in suspended sediment collected from sediment traps located along the St. Clair River corridor from 2001-2022. This figure includes only the stations with historical data.

Historical Contaminants of Concern:

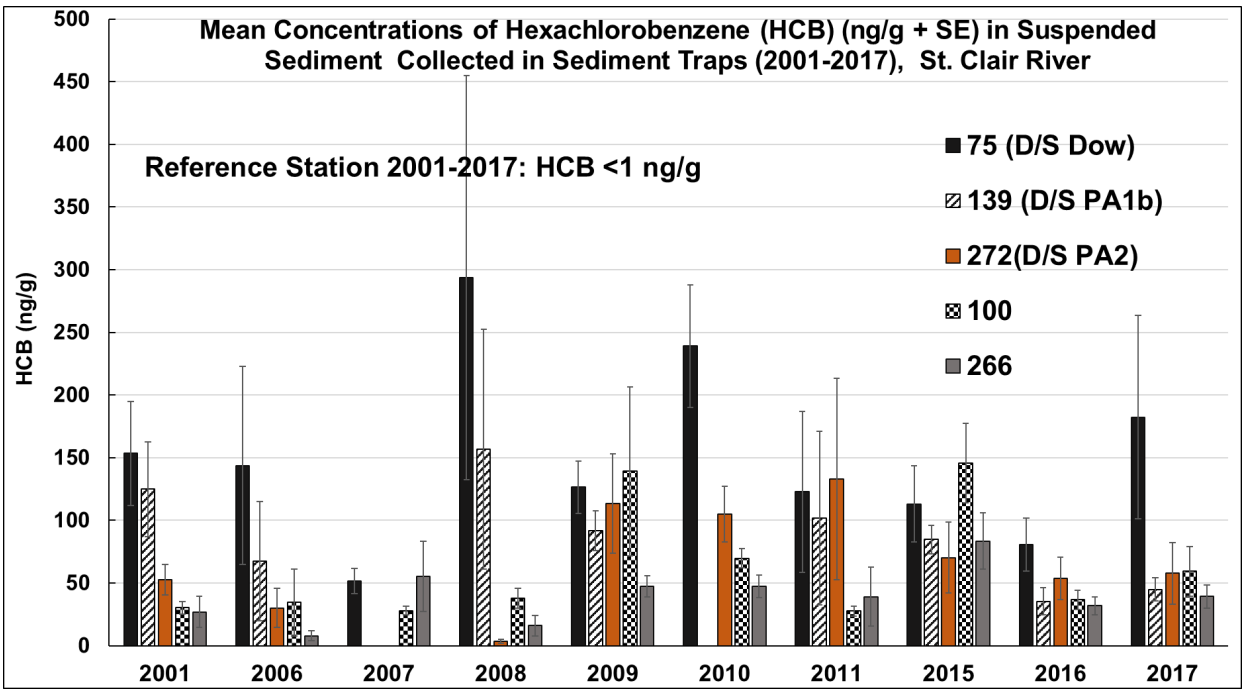
HCB, HCBD and OCS were historically associated with discharges from Dow, and during the Cole Drain and Dow sediment remediation these compounds were considered COCs due to high concentrations in surface sediment and at depth. With the completion of the remediation in 2004, these organic compounds were no longer considered COCs (ENVIRON 2009). However, since the historical source was the same as for Hg, their association and movement on resuspended sediment through the St. Clair River corridor remained of interest to determine if the remedial actions improved suspended sediment quality for these parameters.

Spatial patterns of suspended sediment contamination for HCBD and HCB were like total Hg with the highest concentrations present at transect 75 closest to the Dow property, and then a decrease with increasing distance downstream within any year of sampling (Figure 11). For OCS, this pattern was observed initially but by 2009 concentrations of OCS were similar among all transects along the St. Clair River shoreline and remained lower than pre-remediation concentrations in 2001. With only a few exceptions, HCBD concentrations at most transects have also remained consistently lower since 2006 than those reported for 2001, but for HCB annual variability was high among the transects and between years, with no improvement in HCB concentrations through time.

a)



b)



c)

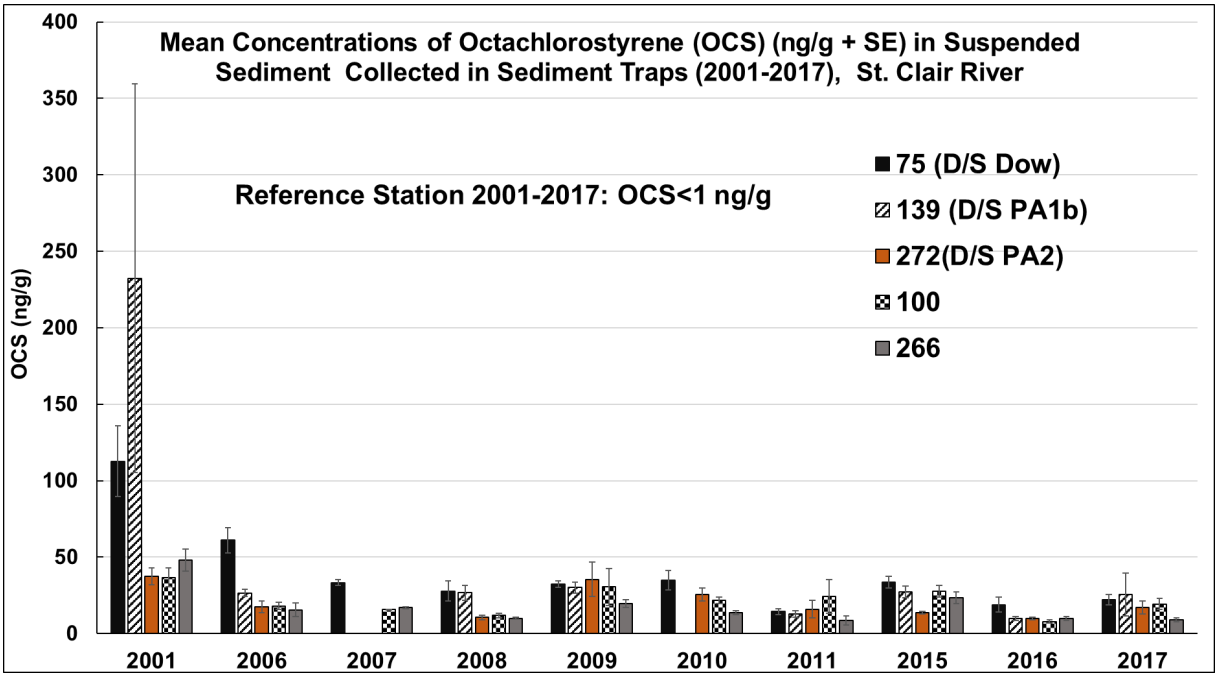


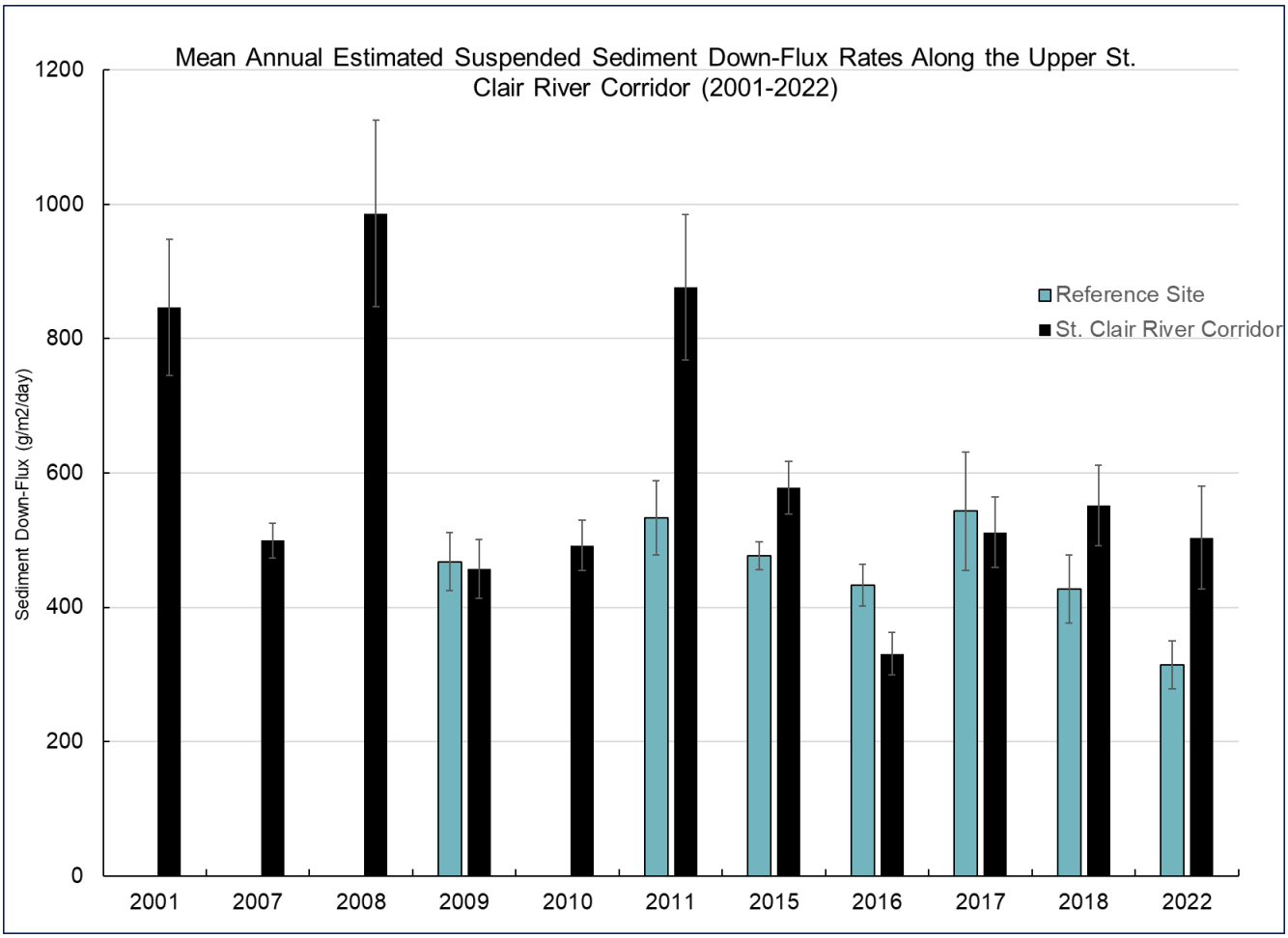
Figure 11: a) Mean hexachlorobutadiene concentrations (ng/g ± SE); b) hexachlorobenzene concentrations and c) octachlorostyrene concentrations in suspended sediment collected from sediment traps located along the St. Clair River corridor from 2001-2017. This figure includes only the stations with historical data.

Sediment down-flux (g m $^{-2}$ day $^{-1}$) and Mercury down-flux:

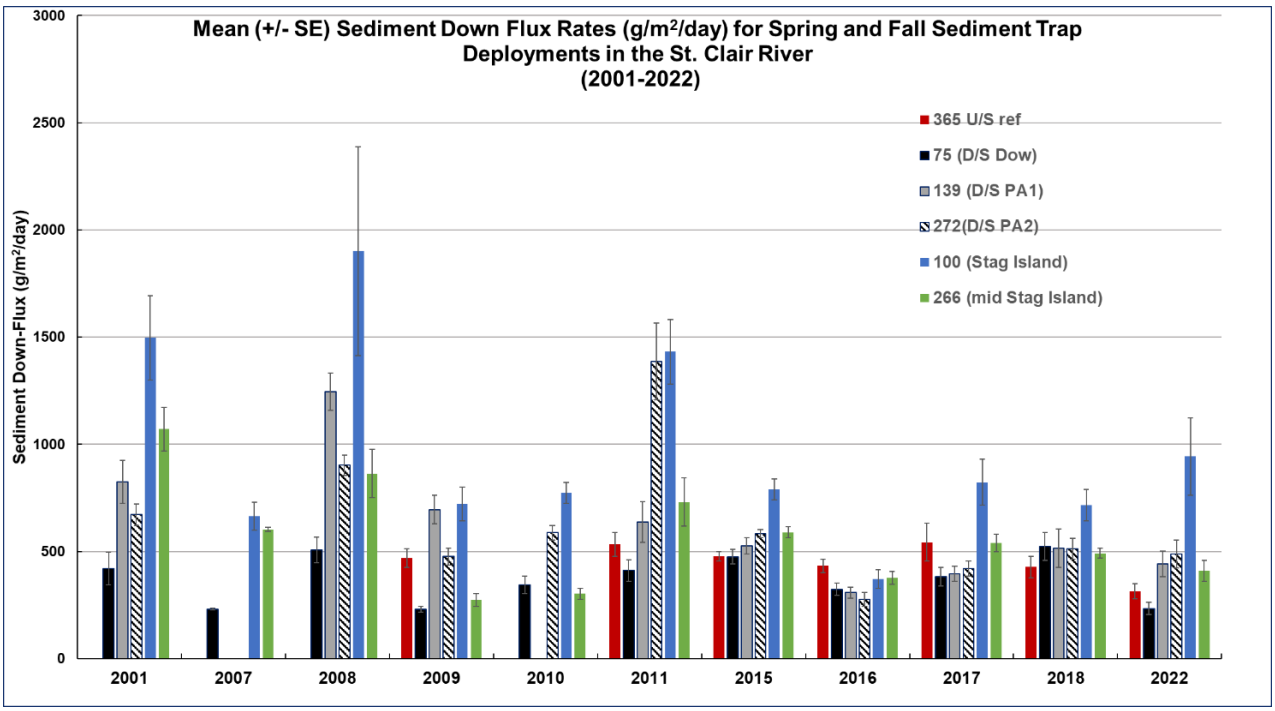
Suspended sediment down-flux (defined as the mass of sediment being deposited per square meter per day) (g/m^2 /day) and the down-flux for COCs (i.e., mass of contaminants associated with the sediment) (Hg: μg/m^2 /day; HCBD, HCB, OCS: ng/m^2 /day) was used to assess the movement and quality of suspended sediment from upstream to downstream (Table 1). The data describing the contamination of suspended sediment moving through the Upper St. Clair River was also compared to the upstream reference station to assess sediment quality moving into the river from Lake Huron upstream of historical sources.

Suspended sediment down-flux was not available at the reference stations until 2009. A comparison between the reference sites and the mean annual sediment down-flux for all the transects deployed downstream within Zones 2 and 3 suggested that except for 2011, a similar mass of sediment was moving downstream along the nearshore (Figure 12a). Data for individual stations in Figure 12b showed the variability among the transects within a survey and identified the stations where a greater or smaller mass of sediment was deposited.

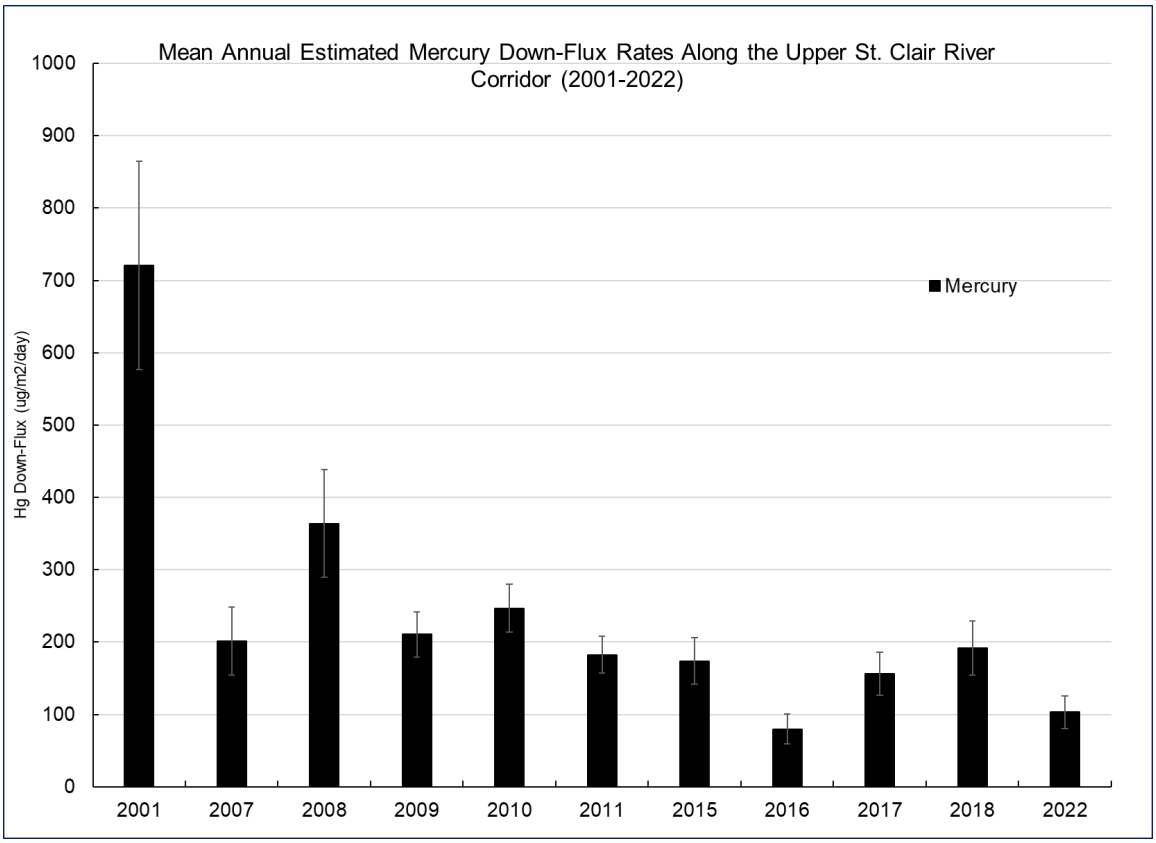
a)



b)


Mean (+/- SE) Sediment Down Flux Rates (g/m²/day) for Spring and Fall Sediment Trap Deployments in the St. Clair River (2001-2022)
Sediment Down-Flux (g/m²/day)
3000
2500
2000
1500
1000
500
0
365 U/S ref
75 (D/S Dow)
139 (D/S PA1)
272(D/S PA2)
100 (Stag Island)
266 (mid Stag Island)
2001
2007
2008
2009
2010
2011
2015
2016
2017
2018
2022

c)


Mean Annual Estimated Mercury Down-Flux Rates Along the Upper St. Clair River Corridor (2001-2022)
Hg Down-Flux (ug/m2/day)
1000
900
800
700
600
500
400
300
200
100
0
Mercury
2001
2007
2008
2009
2010
2011
2015
2016
2017
2018
2022

d)

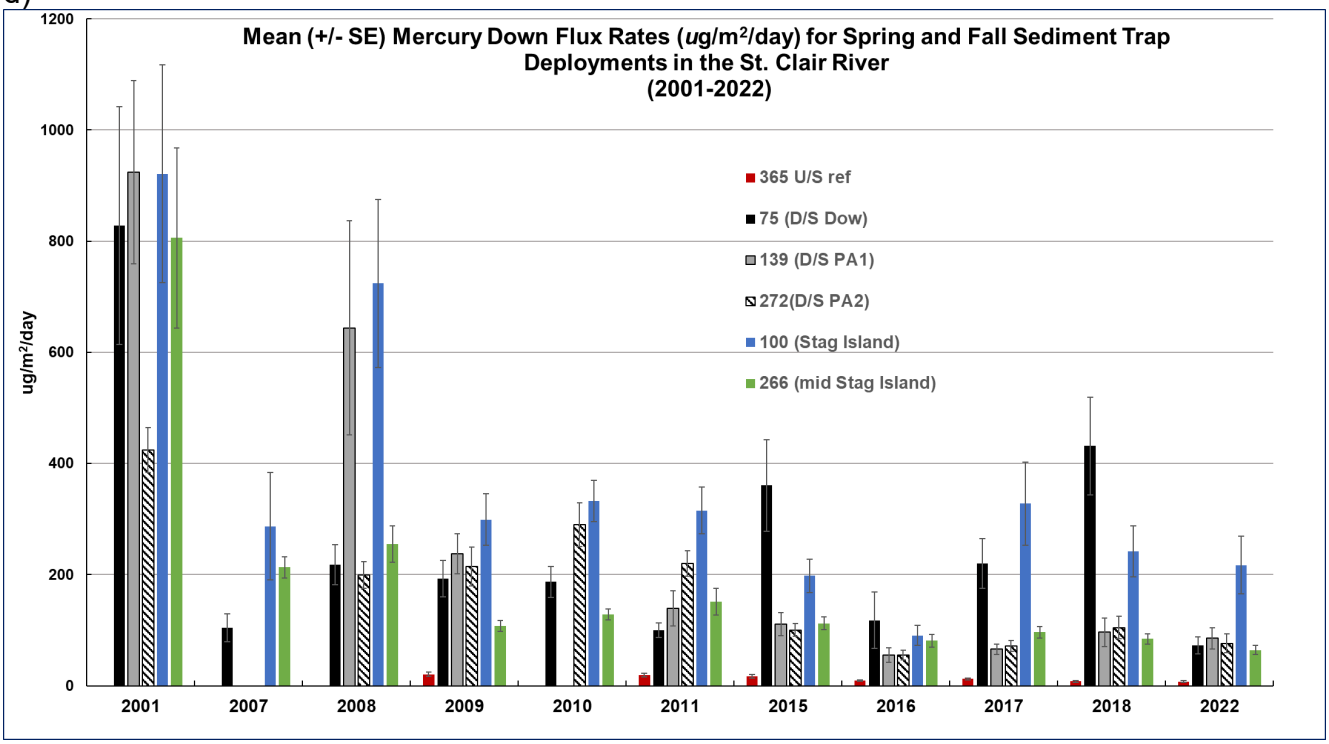


Figure 12: a) Mean (+/- SE) estimated annual suspended sediment down-flux rates (g/m^2/day); b) mean (+/- SE) estimated annual suspended sediment down-flux rates (g/m^2/day) using individual station estimates; c) mean (+/- SE) estimated annual mercury down-flux (ug/m^2/day) and d) mean (+/- SE) estimated annual mercury down-flux (ug/m^2/day) using individual station estimates (2001-2022).

Except for HCB, estimated contaminant down-flux rates represented by the mean values from Zones 2 and 3, were consistently higher in 2001 compared with succeeding years 2007–2022 (Table 1). For Hg, the daily mean down-flux rate in 2001 was 721 μg/m^2 /day, while corresponding rates for 2007–2022 ranged from 80–364 μg/m^2 /day. Similarly, the down-flux for OCS and HCBD downstream of Dow remained lower through time compared with pre-remediation values in 2001. The contaminant down-flux rates are influenced by both the mass of sediment being deposited in a location and the concentration of the contaminant present on the sediment particles. The long-term dataset suggested that the remediation of the Dow waterfront was successful at reducing the contamination of resuspended sediment by removing a source of contaminants to the nearshore downstream areas. It is unclear why HCB did not respond in the same manner.

For all parameters down-flux along the shoreline remained higher than at the reference station (Table1). For Hg the down-flux at the reference site in 2022 was 7 μg/m^2 /day which is 14 times lower than Hg down-flux along the shoreline downstream of the former Dow waterfront which had a mean of 103 μg/m^2 /day. Organic contaminants were below the detection limit at the reference station, and so not unexpected, the enrichment of these compounds downstream of the historical sources remains present.

TABLE 1: Mean and standard error (SE) estimated suspended sediment down-flux rates and contaminant down-flux for the St. Clair River. 2001-2022. Upper St. Clair River: Based on mean down flux estimates from all sediment traps deployed along the shoreline within a survey year.

Transect	Year	Suspended Sediment		Mercury		HCBD		HCB		OCS		TOC	
		$g/m^2/day$		$ug/m^2/day$		$ng/m^2/day$		$ng/m^2/day$		$ng/m^2/day$		$mg/m^2/day$	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Ref. Stn. (341)	2009	468	43	21	4	ND [a]		ND		ND		7477	371
Ref. Stn. (365)	2011	533	55	19	3	ND		ND		ND		11818	1339
	2015	477	21	17	4							8910	405
	2016	433	31	9	1	ND		ND		ND		9968	777
	2017	543	88	12	2	ND		ND		ND		9936	1327
	2018	427	50	8	2							7229	582
	2022	314	36	7	1							6005	389
Upper St. Clair River	2001	847	101	721	144	169	58	46	15	74	41	20871	1600
Upper St. Clair River	2007	499	26	201	47	19	7	22	8	9	1	17178	850
Upper St. Clair River	2008	986	139	364	75	76	28	81	47	16	4	28347	2387
Upper St. Clair River	2009	457	44	211	31	44	8	43	12	13	4	10566	871
Upper St. Clair River	2010	492	38	247	33	35	10	47	10	11	9	14469	1090
Upper St. Clair River	2011	876	108	183	26	52	44	75	52	12	4	25271	3871
Upper St. Clair River	2015	578	39	174	32							13333	796
Upper St. Clair River	2016	331	32	80	20	24	8	15	5	4	1	9061	1018
Upper St. Clair River	2017	512	52	156	30	38	12	46	20	29	3	12879	1638
Upper St. Clair River	2018	552	60	192	38							12225	1054
Upper St. Clair River	2022	503	77	103	22							9933	1096

Conclusions and Recommendations for Future Studies.

Suspended sediment collected from the upstream reference transect had total Hg concentrations that were significantly lower than concentrations measured at all transects downstream of the former Dow waterfront which demonstrated the persistence of legacy contamination. Depending on the year, transect 75 (immediately downstream of the former Dow property), had significantly higher concentrations of Hg than concentrations measured at transects extending 9 km downstream. The likely source of the Hg contaminated suspended sediment is residual Hg contaminated bottom sediment from the former Dow property.

In general, Hg concentrations in suspended sediment (with only a few exceptions), were not significantly different among the remaining downstream sampling locations suggesting that contaminated sediment along the shoreline was routinely resuspended and moved further downstream.

Using the annual mean suspended sediment Hg concentrations for transects with historical data (2001-2022), the Mann-Kendell Test for trend analysis identified a significant decrease in Hg concentrations through time. This trend analysis suggested that the suspended sediments moving along the Canadian shoreline remain less contaminated with Hg than before the Dow waterfront remediation in 2002-2004. The 2015 - 2022 Hg data for all current and historical stations, with only one exception, did not show any trends through time for recent years suggesting that the likelihood of a further decrease in Hg concentrations would require additional remedial actions. The placement of the erosion resistant cap on the three PAs identified as having high total Hg in the surface sediment (top 15 cm) may result in this improvement in suspended sediment quality moving downstream of these areas.

Annual suspended sediment down-flux (defined as the mass of sediment being deposited per square meter per day) ($g/m^2/day$) and the down-flux of contaminants (i.e., mass of contaminants associated with the sediment) (Hg: $\mu g/m^2/day$; HCBD, HCB, OCS: $ng/m^2/day$) was used to assess the movement and quality of suspended sediment from upstream to downstream. Estimated contaminant down-flux rates represented by the mean values for all transects from Zones 2 and 3, were consistently higher in 2001 compared with succeeding years 2007–2022. For Hg, the daily mean down-flux rate in 2001 was 721 $\mu g/m^2/day$, while corresponding rates for 2007–2022 ranged from 80–364 $\mu g/m^2/day$. Similarly, the down-flux for OCS and HCBD downstream of Dow remained lower through time compared with pre-remediation values in 2001. Due to the high variability in the data within a survey it was not possible to see a trend in HCB concentrations.

The 2022 data will serve as the baseline prior to the placement of the erosion resistant cap in the three Priority Areas, which can then be compared with suspended sediment quality post-remediation. Given the large variability in data within a transect, between transects and between surveys, data collected from earlier surveys should be

considered to help interpret post-remediation data. Total Hg data in 2022 at transects 75, 374 and 270 must be interpreted with consideration to the addition of two new locations inshore along the transects and hence the absence of historical offshore stations. The post-remediation survey should include all five locations along these transects mirroring the 2022 stations as well as two additional offshore stations located 5 m apart to replicate the historical sampling design. These additions will help inform the observed changes in the 2022 contamination patterns at these locations and potential improvements in suspended sediment quality due to cap placement.

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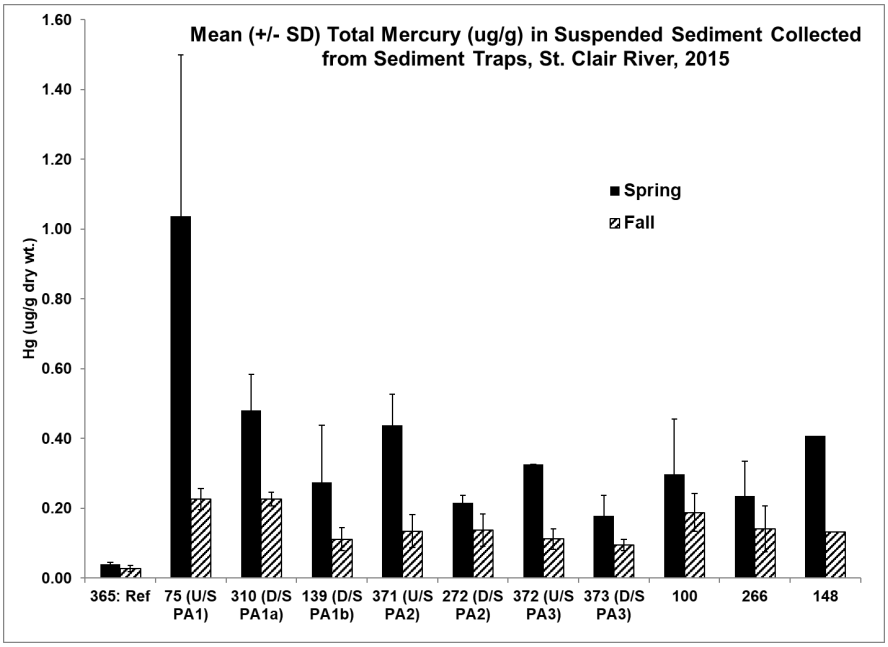
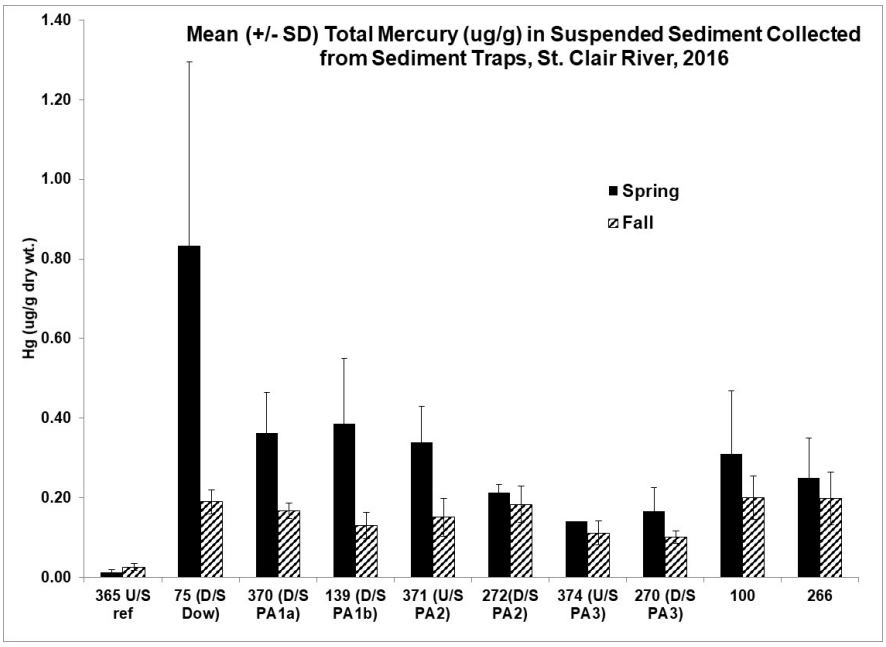
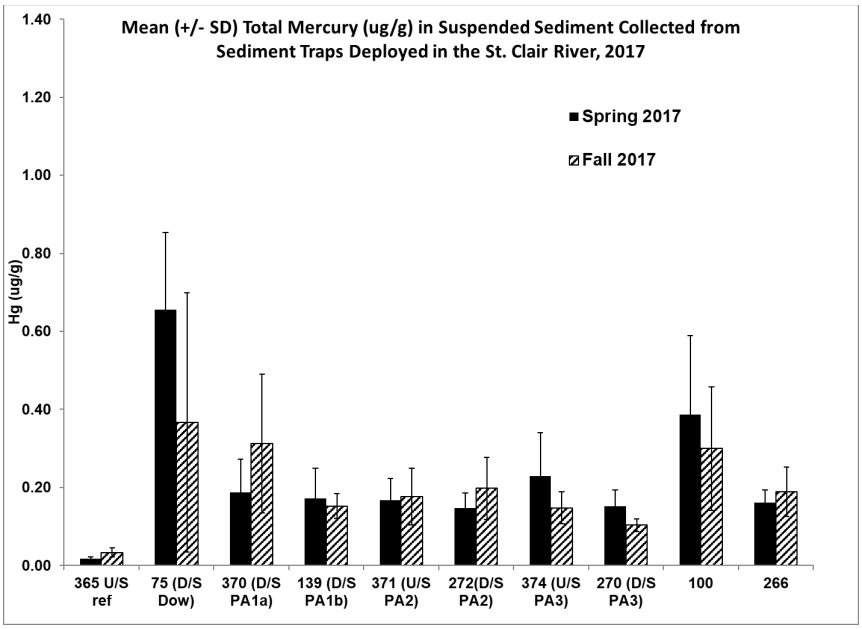
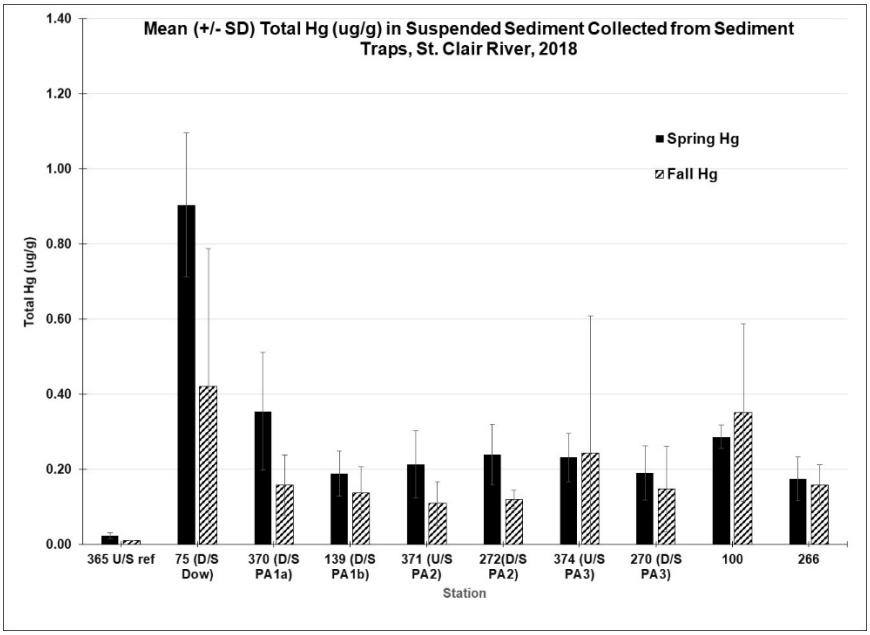
Appendix:

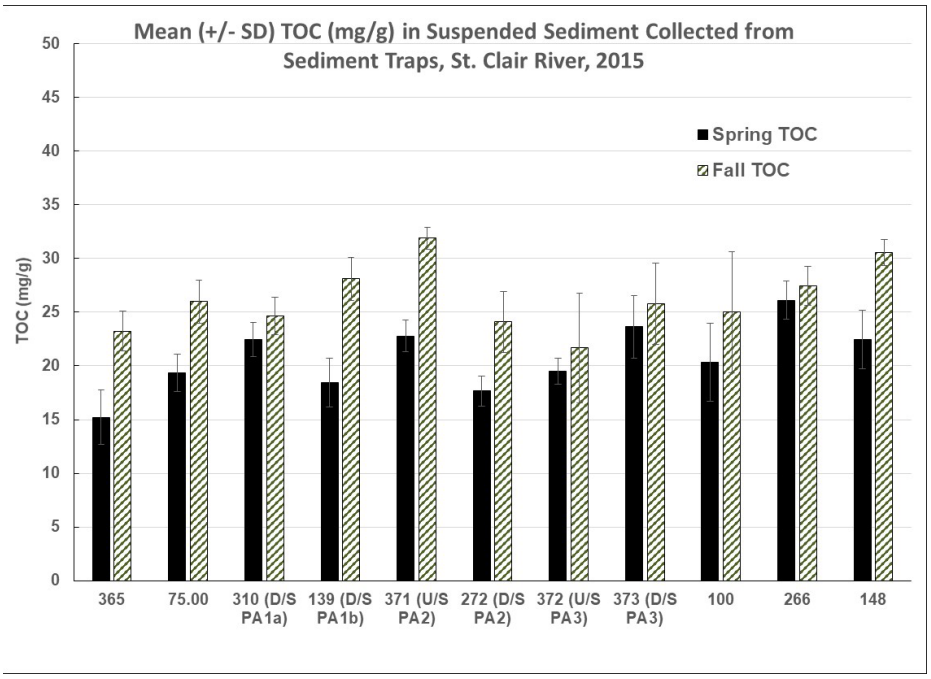

Mean (+/- SD) Total Mercury (ug/g) in Suspended Sediment Collected from Sediment Traps, St. Clair River, 2015
Hg (ug/g dry wt.)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Spring
Fall
365: Ref
75 (U/S PA1)
310 (D/S PA1a)
139 (D/S PA1b)
371 (U/S PA2)
272 (D/S PA2)
372 (U/S PA3)
373 (D/S PA3)
100
266
148

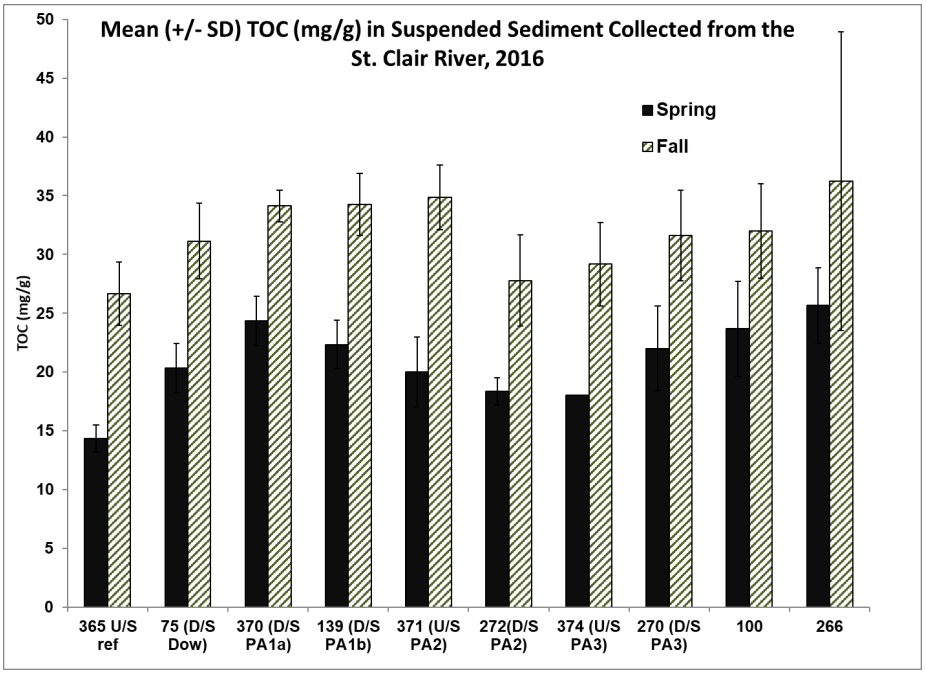

Mean (+/- SD) Total Mercury (ug/g) in Suspended Sediment Collected from Sediment Traps, St. Clair River, 2016
Hg (ug/g dry wt.)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Spring
Fall
365 U/S ref
75 (D/S Dow)
370 (D/S PA1a)
139 (D/S PA1b)
371 (U/S PA2)
272(D/S PA2)
374 (U/S PA3)
270 (D/S PA3)
100
266

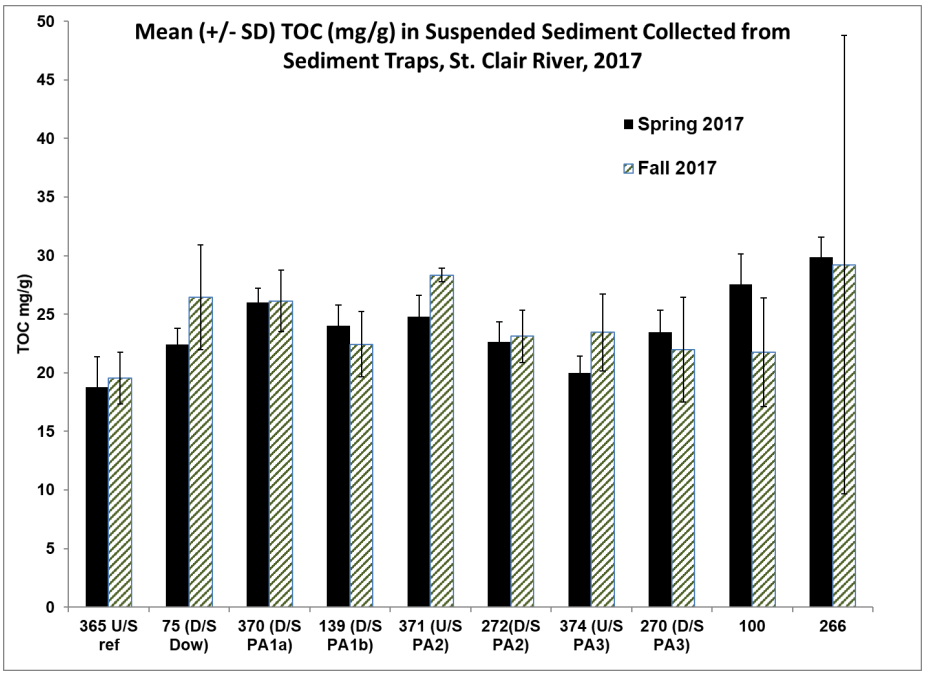


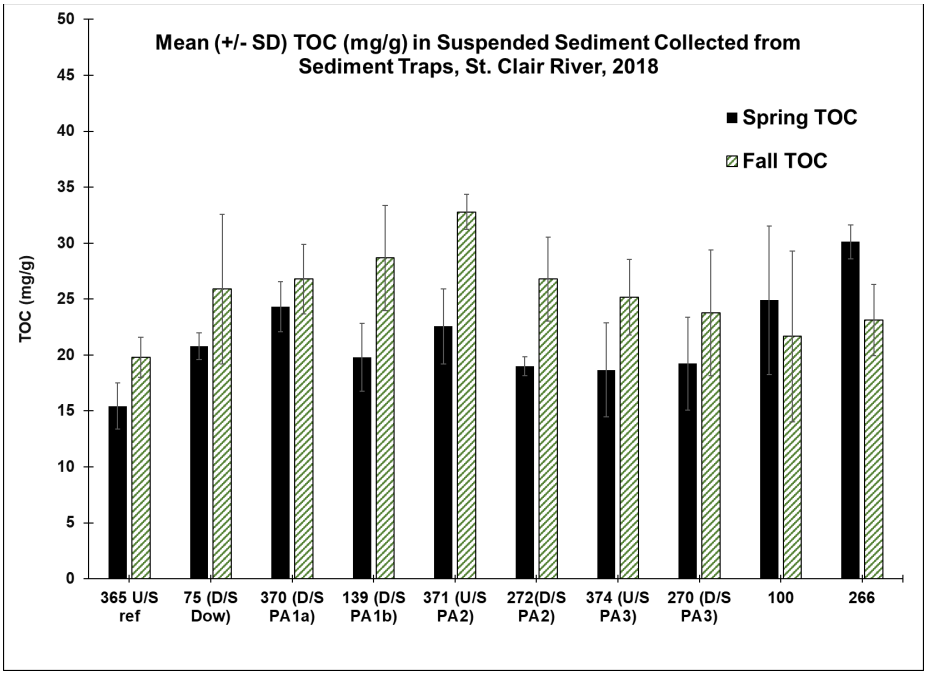


Appendix Figure 1: A comparison between spring and fall mean total Hg concentrations (μg/g) ($\pm$ SD) in suspended sediment collected from sediment traps deployed along transects in the St. Clair River corridor, 2015 - 2018.

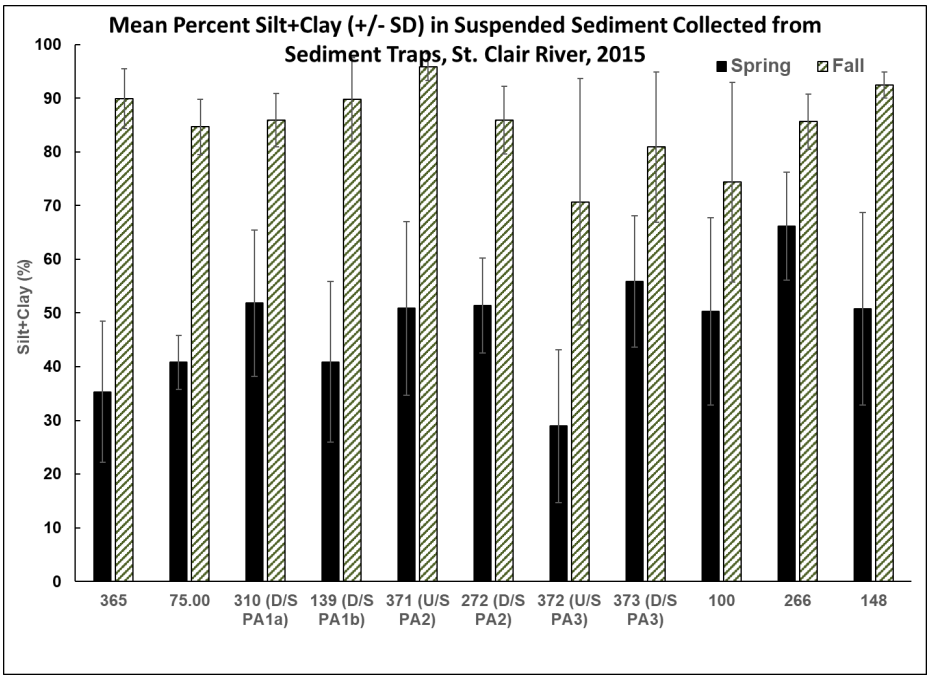

Mean (+/- SD) TOC (mg/g) in Suspended Sediment Collected from Sediment Traps, St. Clair River, 2015
Spring TOC
Fall TOC
TOC (mg/g)
0
5
10
15
20
25
30
35
40
45
50
365
75.00
310 (D/S PA1a)
139 (D/S PA1b)
371 (U/S PA2)
272 (D/S PA2)
372 (U/S PA3)
373 (D/S PA3)
100
266
148

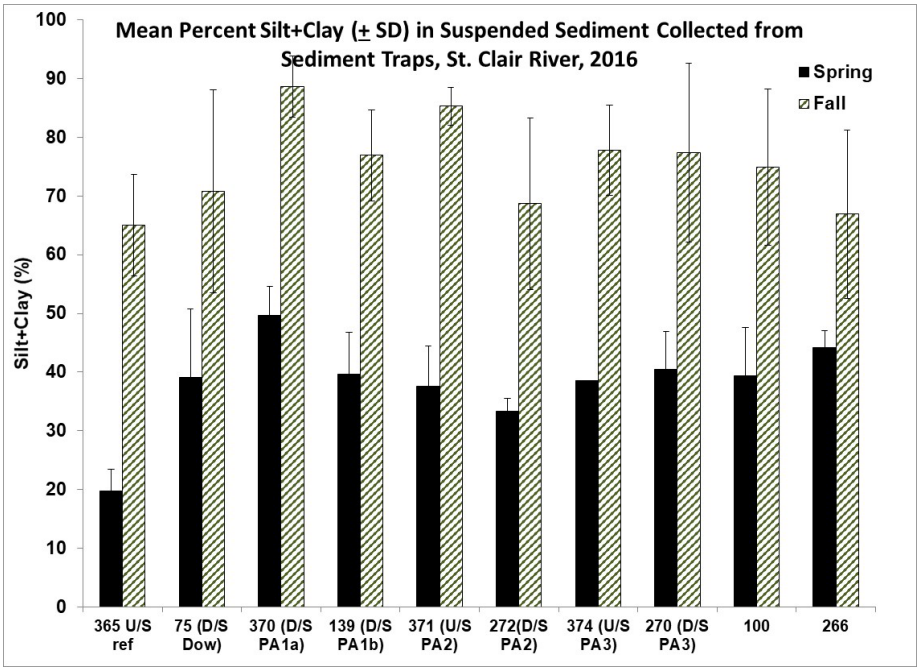

Mean (+/- SD) TOC (mg/g) in Suspended Sediment Collected from the St. Clair River, 2016
Spring
Fall
TOC (mg/g)
0
5
10
15
20
25
30
35
40
45
50
365 U/S ref
75 (D/S Dow)
370 (D/S PA1a)
139 (D/S PA1b)
371 (U/S PA2)
272(D/S PA2)
374 (U/S PA3)
270 (D/S PA3)
100
266

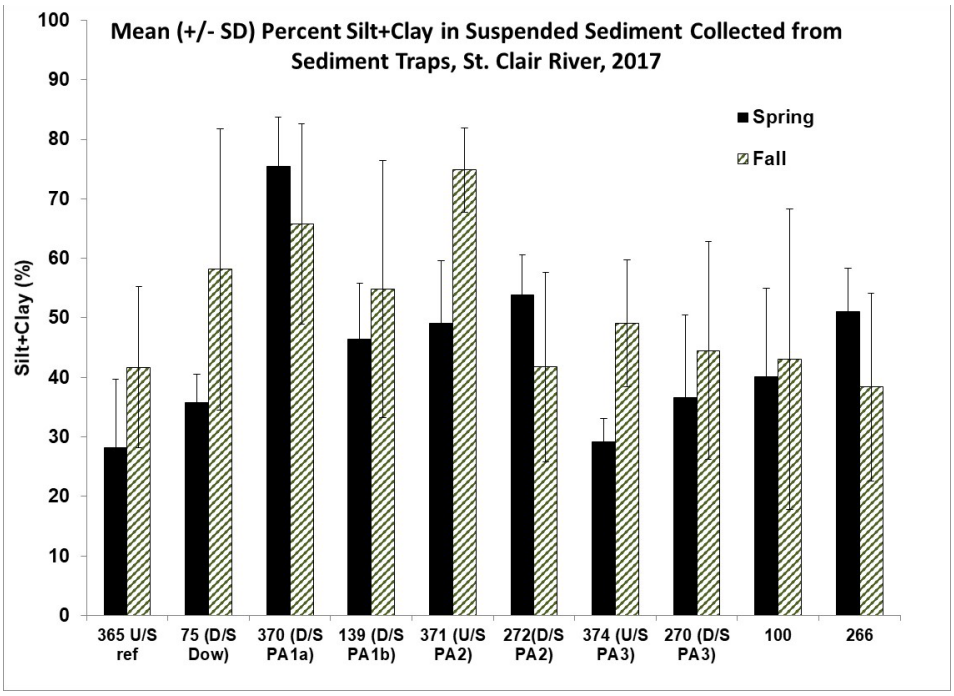


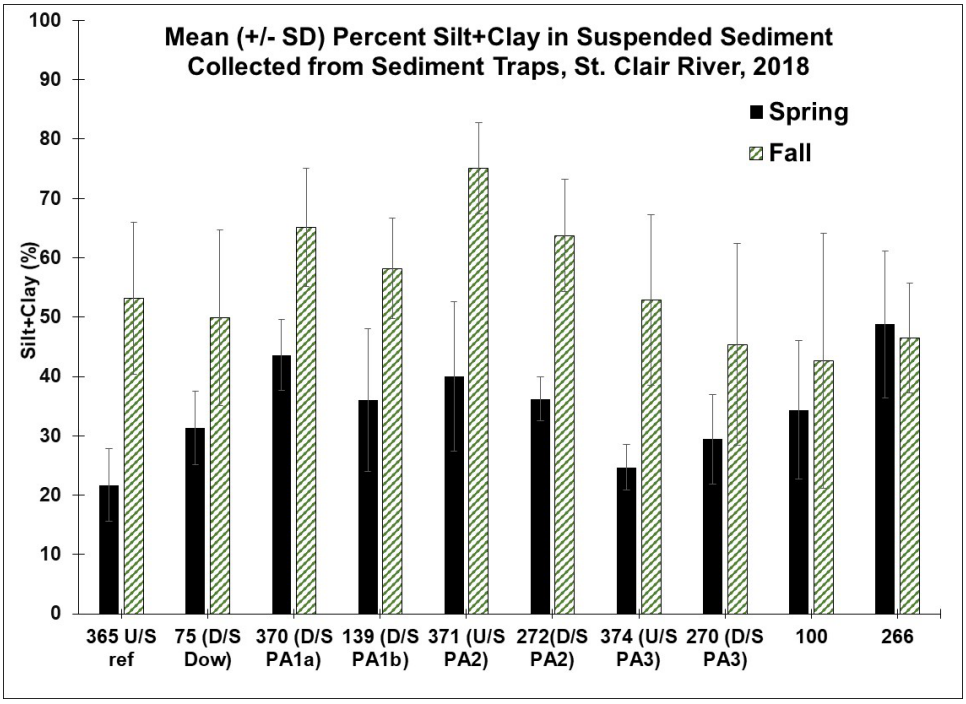


Appendix Figure 2: A comparison between spring and fall mean Total Organic Carbon concentrations (mg/g) (± SD) in suspended sediment collected from sediment traps deployed along transects in the St. Clair River corridor, 2015 - 2018.


Mean Percent Silt+Clay (+/- SD) in Suspended Sediment Collected from Sediment Traps, St. Clair River, 2015
Spring
Fall
Silt+Clay (%)
100
90
80
70
60
50
40
30
20
10
0
365
75.00
310 (D/S PA1a)
139 (D/S PA1b)
371 (U/S PA2)
272 (D/S PA2)
372 (U/S PA3)
373 (D/S PA3)
100
266
148

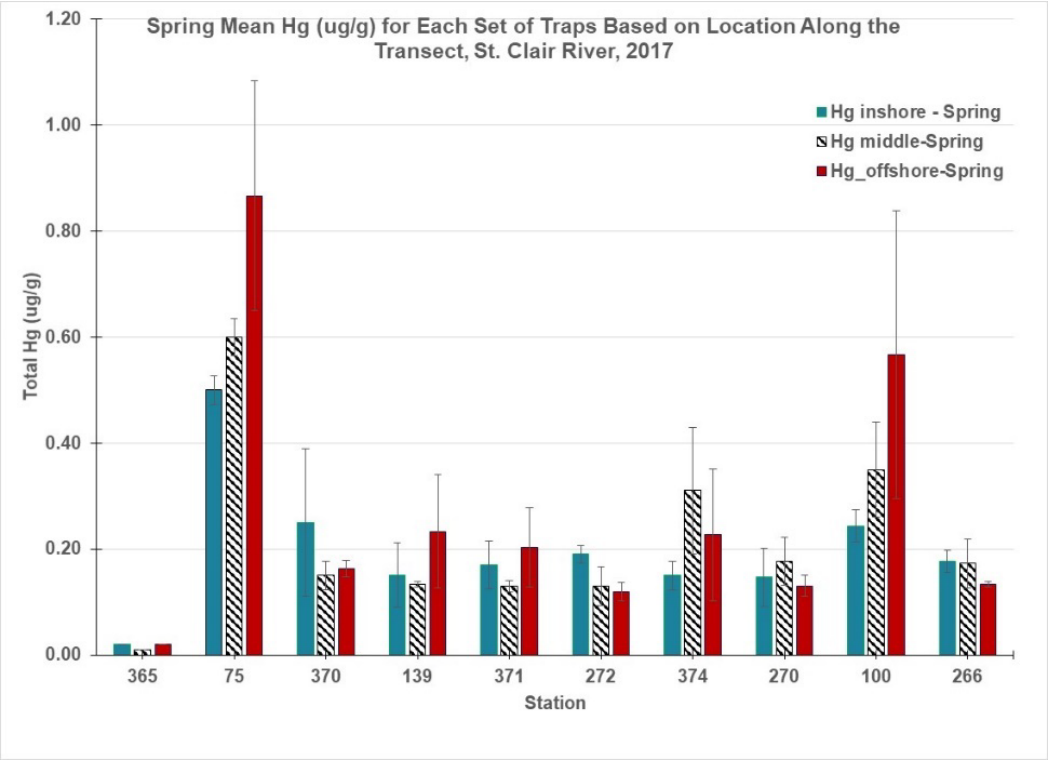

Mean Percent Silt+Clay (± SD) in Suspended Sediment Collected from Sediment Traps, St. Clair River, 2016
Spring
Fall
Silt+Clay (%)
100
90
80
70
60
50
40
30
20
10
0
365 U/S ref
75 (D/S Dow)
370 (D/S PA1a)
139 (D/S PA1b)
371 (U/S PA2)
272(D/S PA2)
374 (U/S PA3)
270 (D/S PA3)
100
266

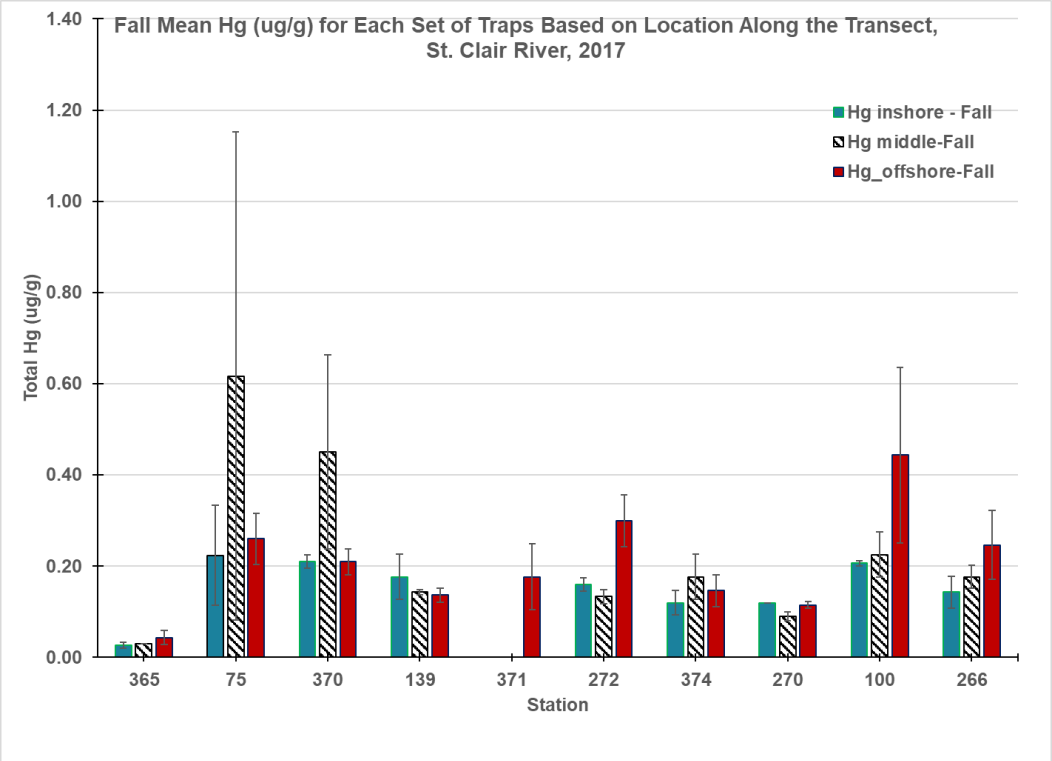




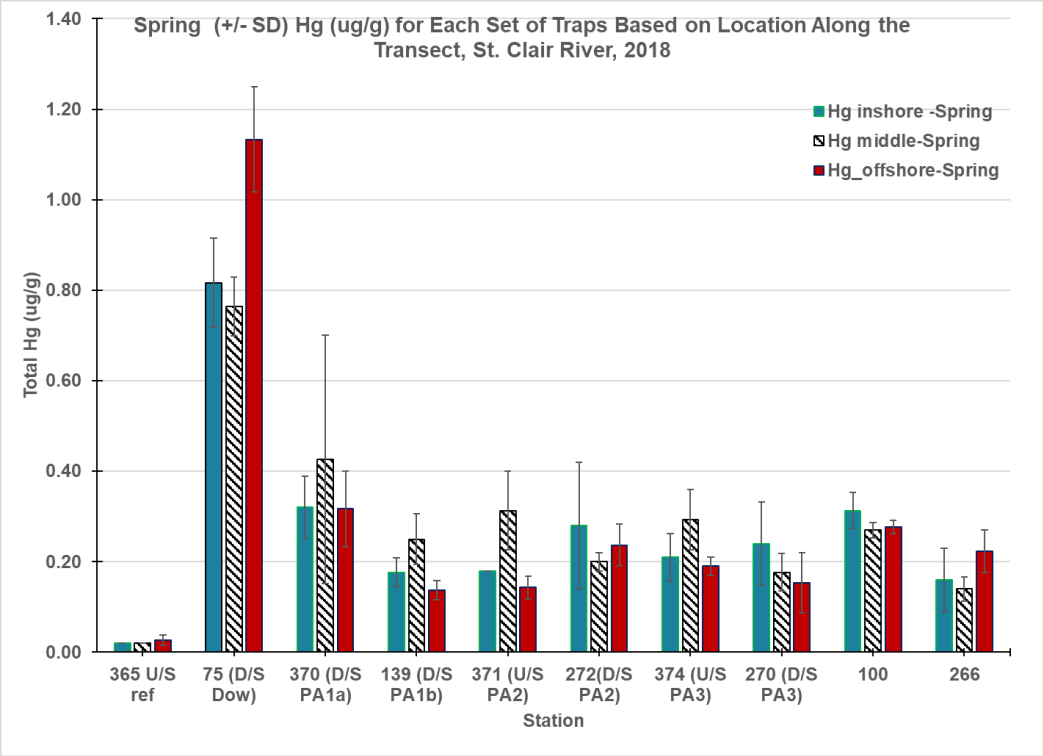
Appendix Figure 3: A comparison between spring and fall mean Percent Silt + Clay (± SD) in suspended sediment collected from sediment traps deployed along transects in the St. Clair River corridor, 2015 - 2018.

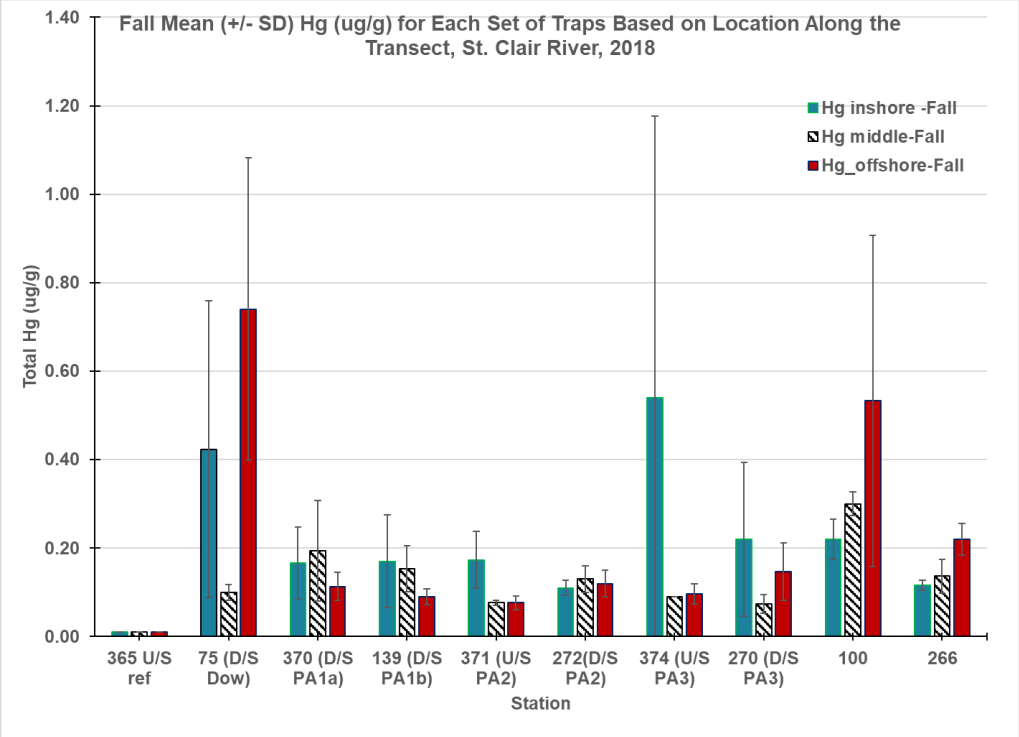
a)


Spring Mean Hg (ug/g) for Each Set of Traps Based on Location Along the Transect, St. Clair River, 2017
Hg inshore - Spring
Hg middle-Spring
Hg_offshore-Spring
Total Hg (ug/g)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
365
75
370
139
371
272
374
270
100
266
Station


Fall Mean Hg (ug/g) for Each Set of Traps Based on Location Along the Transect, St. Clair River, 2017
Hg inshore - Fall
Hg middle-Fall
Hg_offshore-Fall
Total Hg (ug/g)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
365
75
370
139
371
272
374
270
100
266
Station

b)

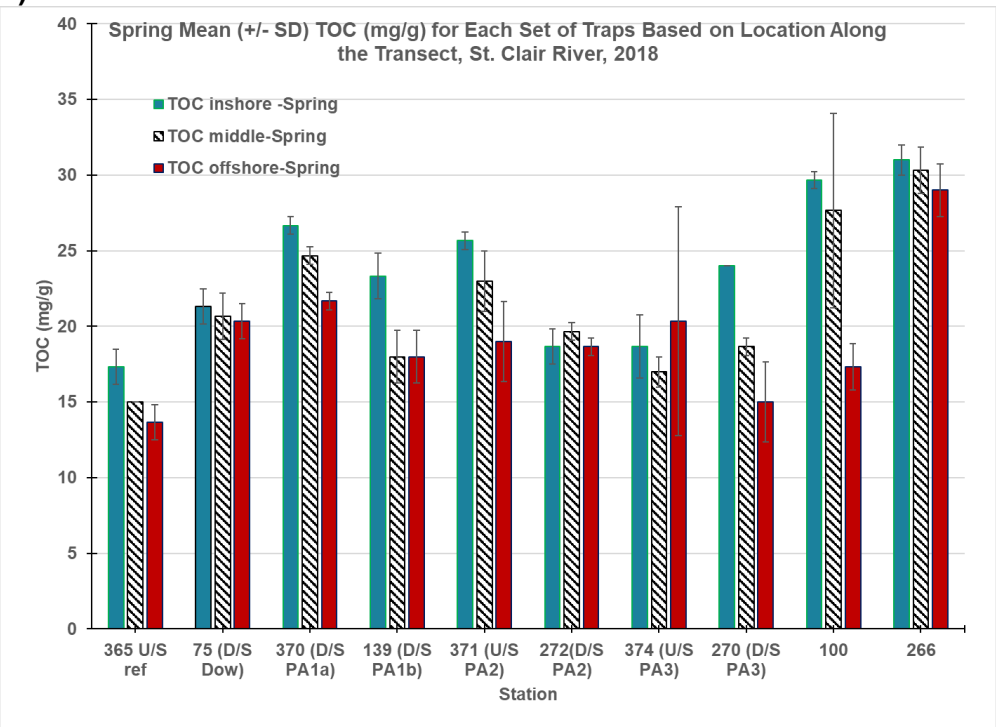




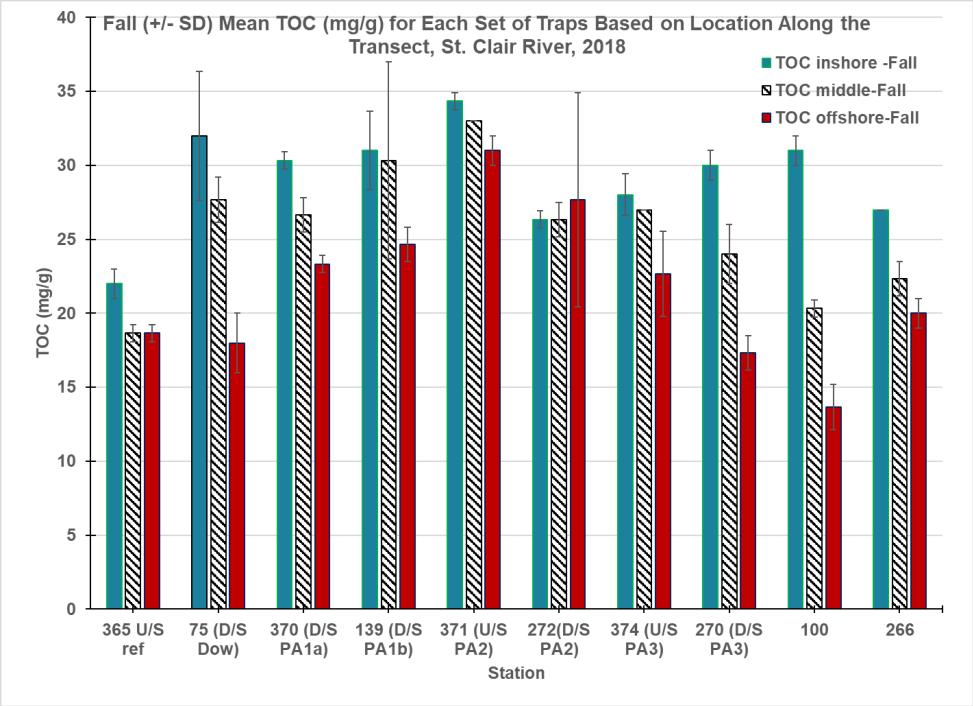
Appendix Figure 4: A comparison between spring and fall mean total Hg concentrations (*µ*g/g) (± SD) in suspended sediment collected from sediment traps (n=3 tubes bundled together) deployed at 3 locations along a transect beginning at the

nearshore (inner) and placed 5 m apart with increasing distance from shore. Transects were located along the St. Clair River corridor: a) 2017 and b) 2018.

a)

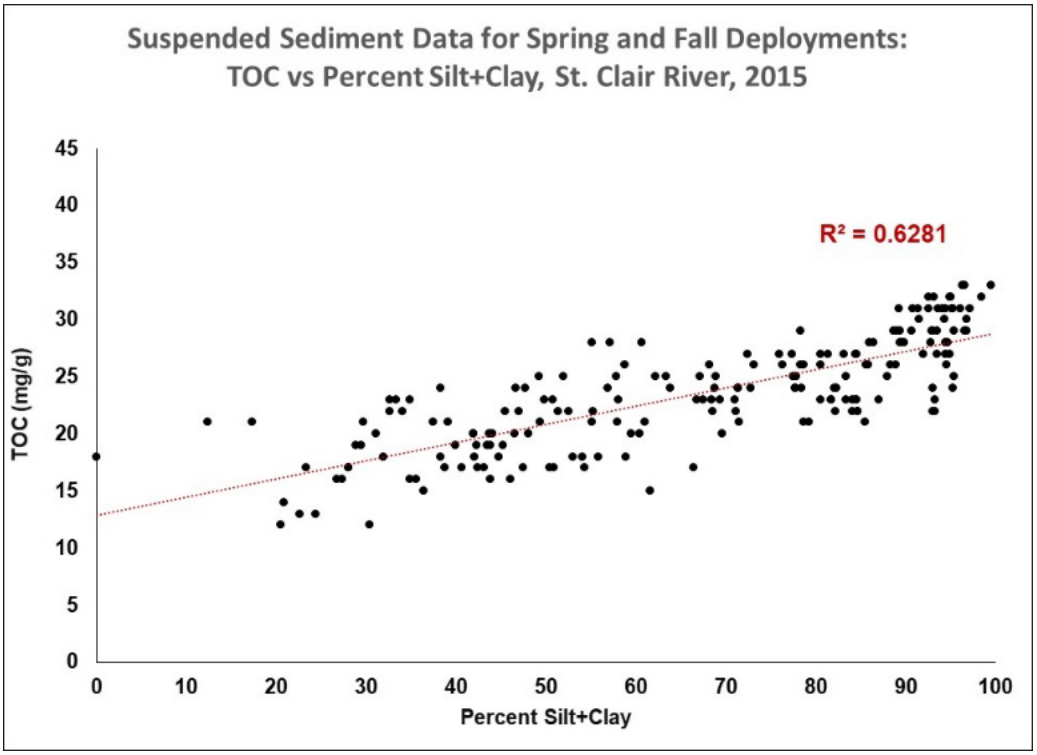


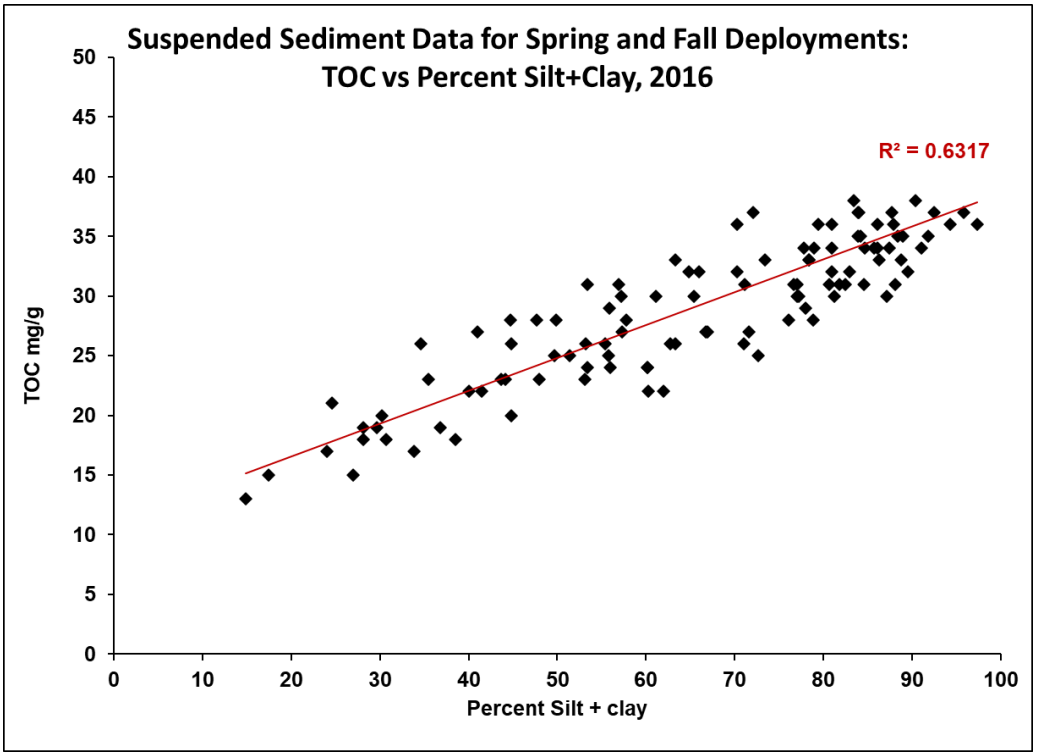
b)

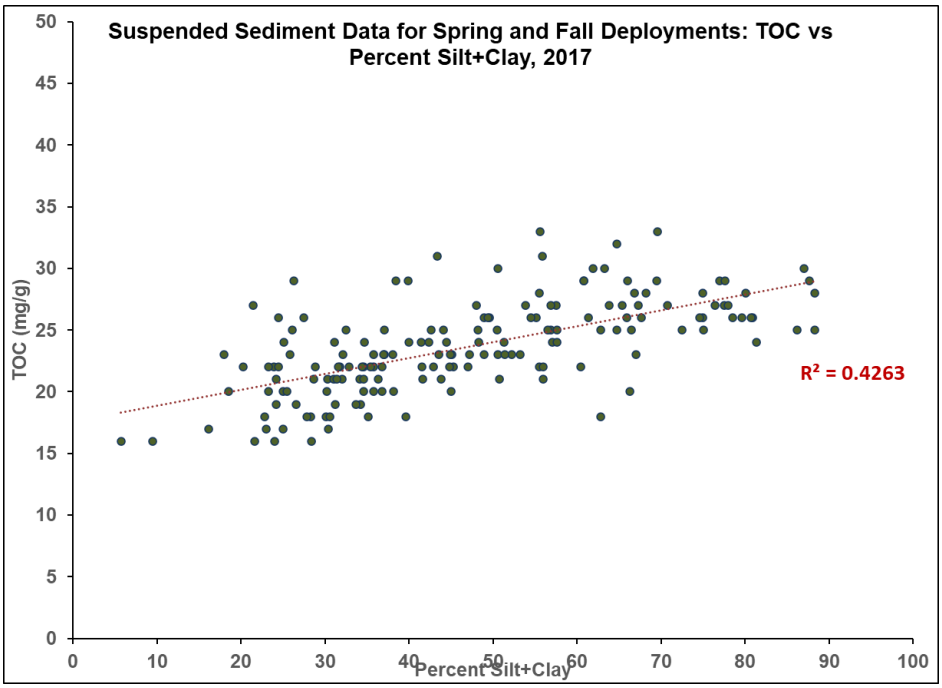


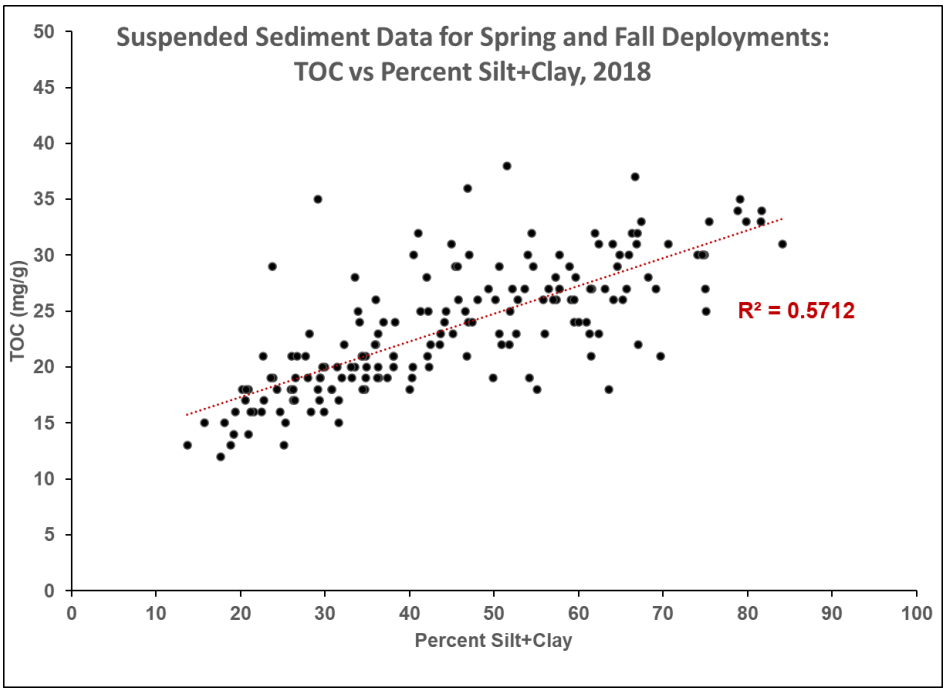
Appendix Figure 5: A comparison between a) spring and b) fall mean total TOC concentrations (mg/g) (± SD) in suspended sediment collected from sediment traps

(n=3 tubes bundled together) deployed at 3 locations along a transect with increasing distance from shore. Transects were located along the St. Clair River corridor, 2018.

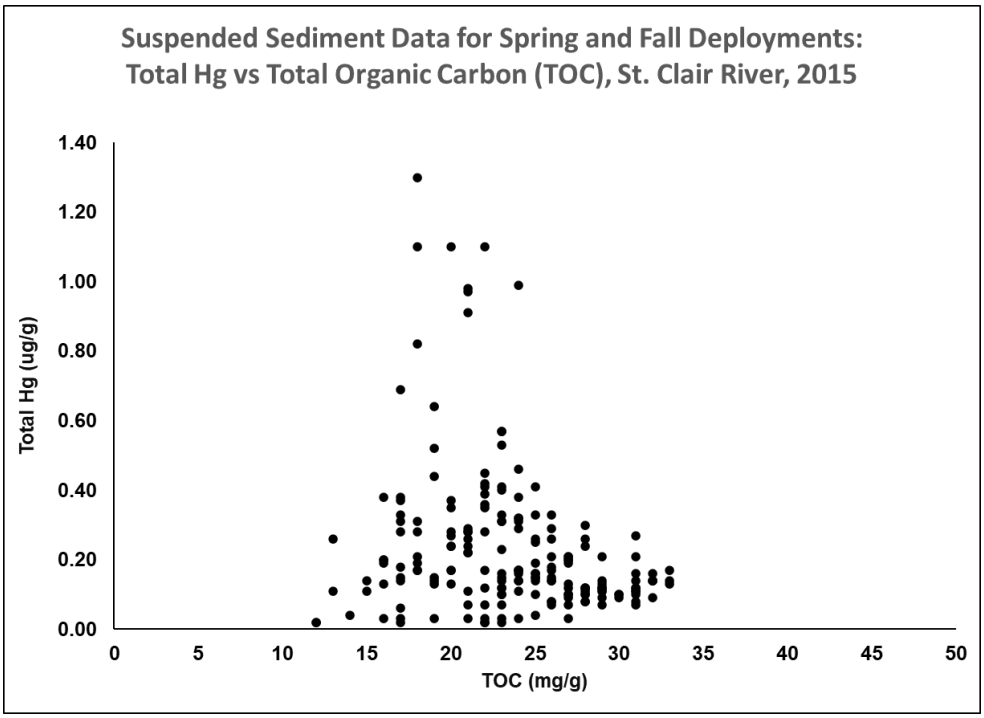


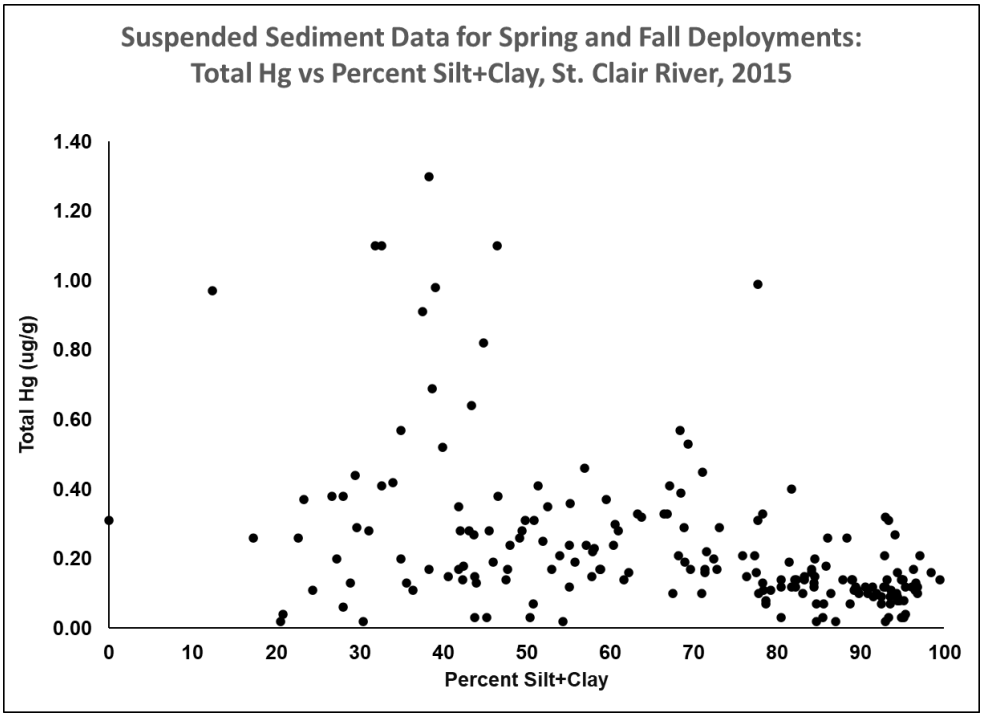


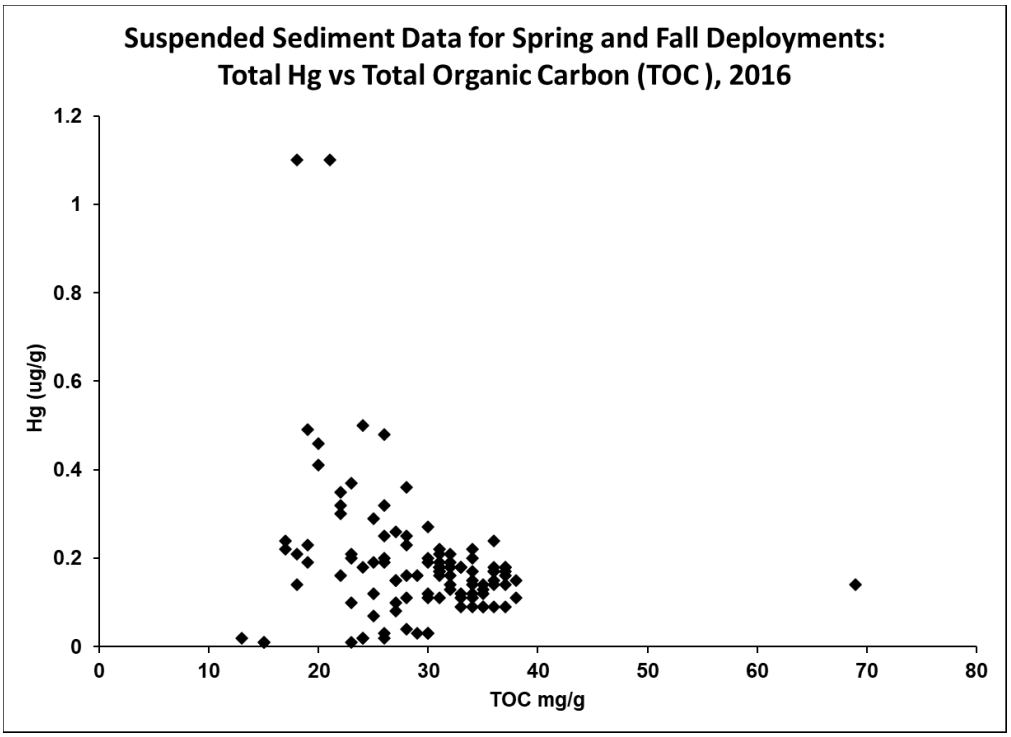


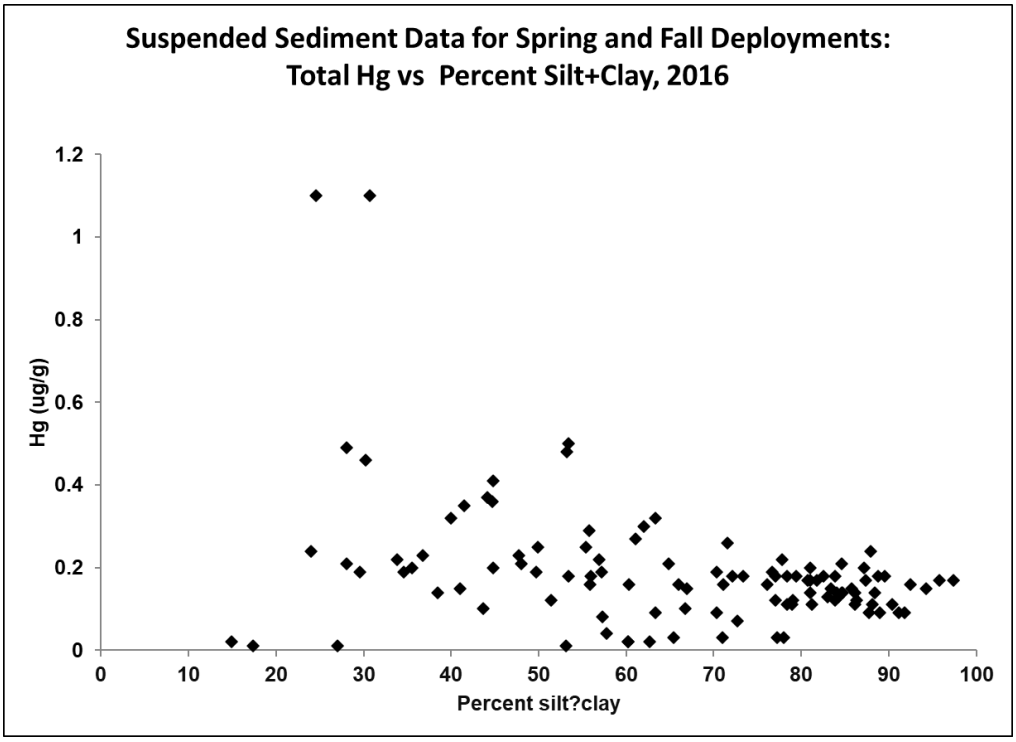


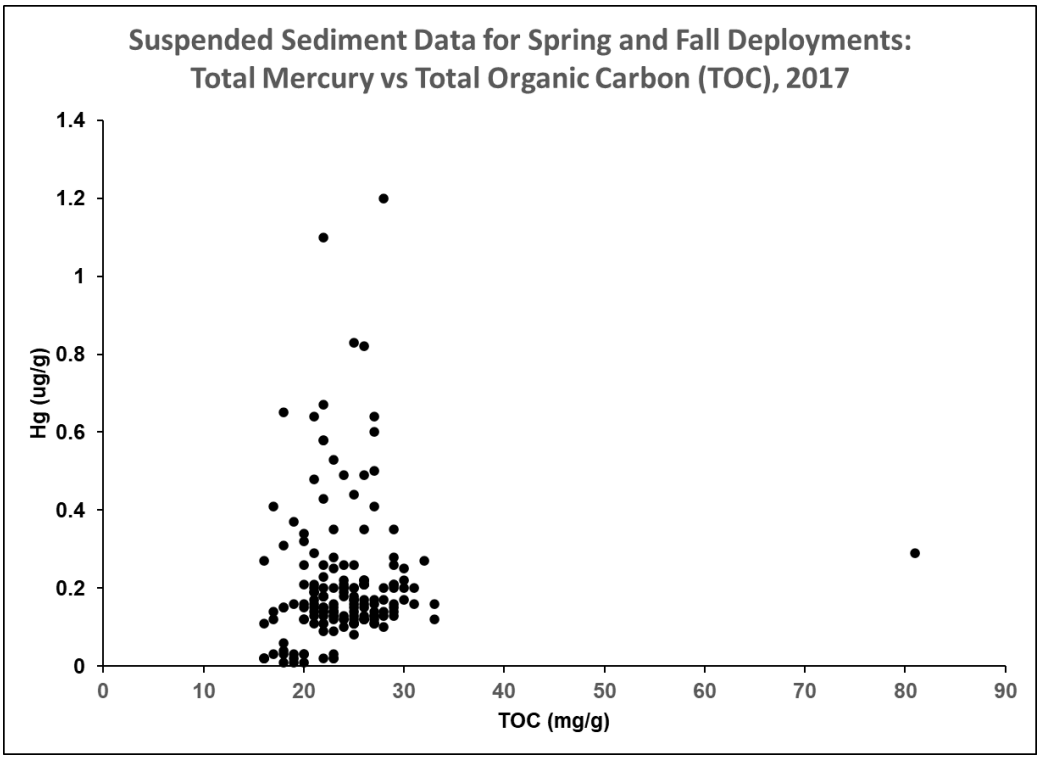
Appendix Figure 6: Relationships Between Suspended Sediment TOC Concentrations and Particle Size (2015-2018).

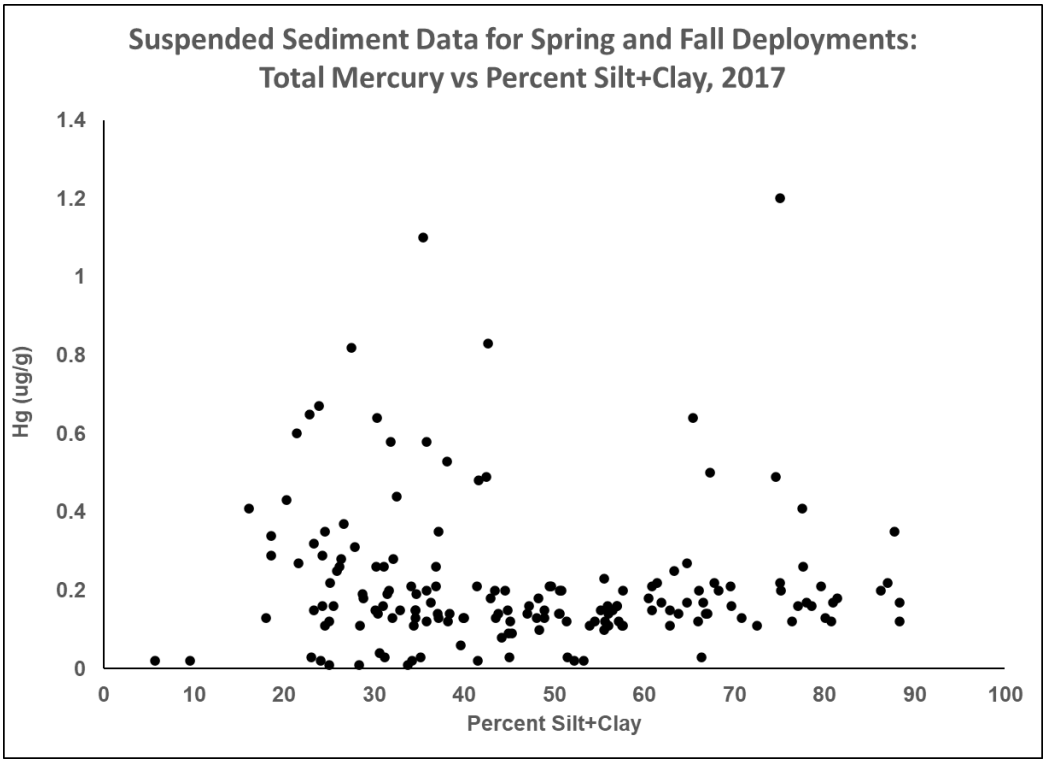

Suspended Sediment Data for Spring and Fall Deployments:
Total Hg vs Total Organic Carbon (TOC), St. Clair River, 2015
Total Hg (ug/g)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
5
10
15
20
25
30
35
40
45
50
TOC (mg/g)

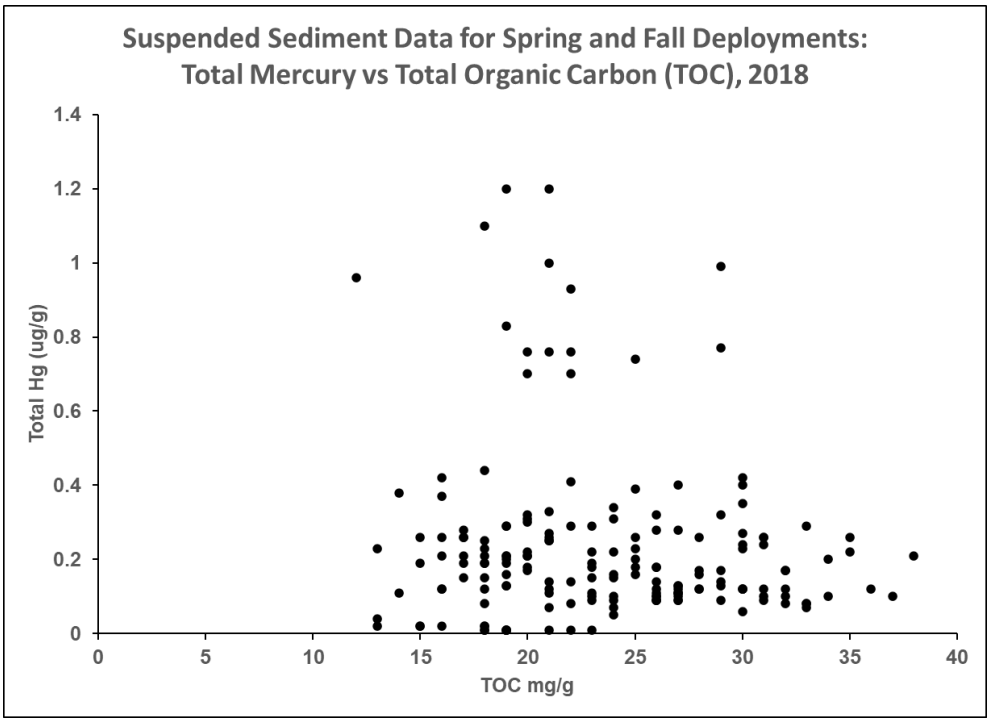

Suspended Sediment Data for Spring and Fall Deployments:
Total Hg vs Percent Silt+Clay, St. Clair River, 2015
Total Hg (ug/g)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
10
20
30
40
50
60
70
80
90
100
Percent Silt+Clay

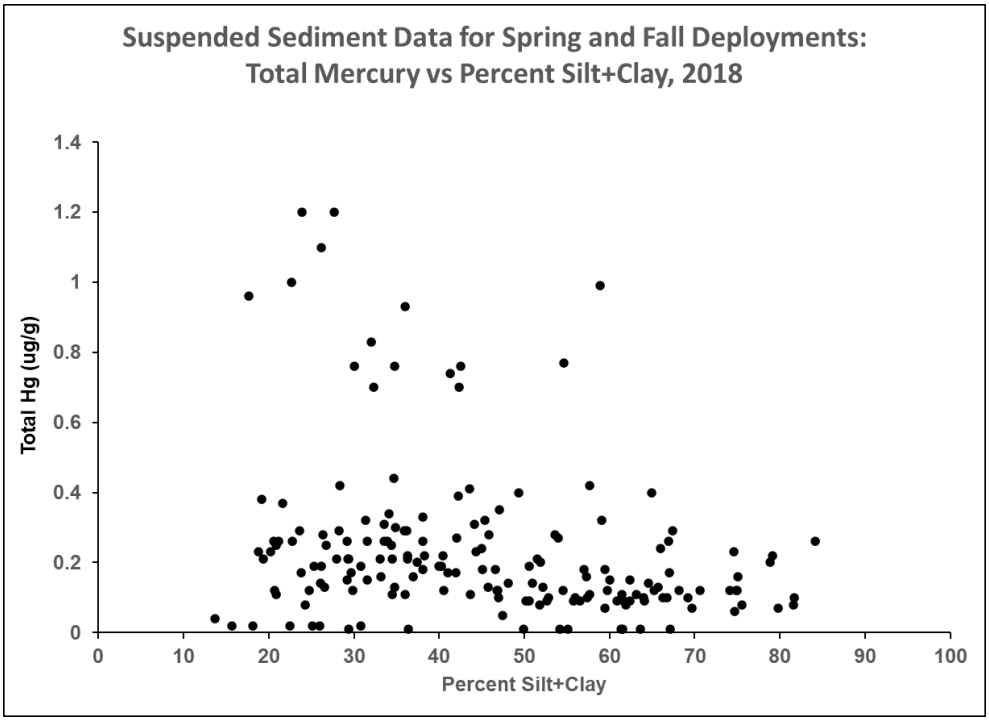

Suspended Sediment Data for Spring and Fall Deployments:
Total Hg vs Total Organic Carbon (TOC), 2016
Hg (ug/g)
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
TOC mg/g


Suspended Sediment Data for Spring and Fall Deployments:
Total Hg vs Percent Silt+Clay, 2016
Hg (ug/g)
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
90
100
Percent silt?clay


Suspended Sediment Data for Spring and Fall Deployments:
Total Mercury vs Total Organic Carbon (TOC), 2017
Hg (ug/g)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
90
TOC (mg/g)


Suspended Sediment Data for Spring and Fall Deployments:
Total Mercury vs Percent Silt+Clay, 2017
Hg (ug/g)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
90
100
Percent Silt+Clay





Appendix Figure 7: Relationships Between Suspended Sediment Total Mercury Concentrations and TOC Concentrations, and Total Mercury vs Percent Silt+Clay (2015-2018).

Appendix Table 1: Transect and Station Locations for the Sediment Traps Deployed in the St. Clair River for the Collection of Suspended Sediments from 2015-2022.
Sediment traps were deployed along a transect at 3-5 locations every 5 m with increasing distance from shore.
In 2022, two additional locations were established closer to shore along 3 exisiting transect.
Deployment was typically in April or May, traps were refurbished mid summer and then removed in Novemeber.

2022

Site #	Subsite	Latitude	Longitude	Depth In (m)		Date In	Time In	Tubes In	Depth Out&In	Date Out & In	Time Out & In	Tubes Out	Tubes In	Date Out	Time Out	Depth Out	Tubes Out	Comments
	Inshore	42 57.1993	82 25.4401	4.9	Historical	24/05/2022	1558	3	4.9	08-Aug-22	1242	3	3	22-Nov	1540	4.6	3	
365	Middle	42 57.1996	82 25.4427	6.1	Historical	24/05/2022	1558	3	6.1	|	|	3	3	22-Nov	1540	5.9	3	
	Offshore	42 57.2000	82 25.4467	7.2	Historical	24/05/2022	1558	3	7.1	|	|	3	3	22-Nov	1540	6.9	3	
		42 56.219	82 26.635	1.3	3 meters from sheetpile wall	25/05/2022	1303	6	1.2	08-Aug-22	1308	0	6	22-Nov				Tube Bundle missing
75		42 56.221	82 26.638	1.5	5m offshore	25/05/2022	1303	6	1.5	|	|	0	6	22-Nov				Tube Bundle missing
		42 56.223	82 26.643	1.9	5m offshore	25/05/2022	1303	6	2.0	|	|	6	6	22-Nov				Tube Bundle missing
		42 56.223	82 26.646	3.8	5m offshore	25/05/2022	1303	3	3.7	|	|	3	3	22-Nov	1520	3.4	6	
		42 56.224	82 26.649	5.4	Historical "inshore" stn	25/05/2022	1303	3	5.5	|	|	3	3	22-Nov	1520	5.2	6	
	Inshore	42 55.936	82 26.878	2.3	new loc	25/05/2022	1201	6	2.5	08-Aug-22	1334	6	6	22-Nov	1508	2.2	3	
370	Middle	42 55.936	82 26.881	4.0	5m offshore	25/05/2022	1201	3	4.0	|	|	3	3	22-Nov	1508	3.8	3	
	Offshore	42 55.936	82 26.889	4.8	5m offshore	25/05/2022	1201	3	4.8	|	|	3	3	22-Nov	1508	4.5	3	
	Inshore	42 55.6238	82 27.0630	4.7	Historical	25/05/2022	1103	3	4.8	09-Aug-22	1047	3	3	22-Nov	1436	4.6	3	
139	Middle	42 55.6244	82 27.0660	5.7	Historical	25/05/2022	1103	3	5.9	|	|	3	3	22-Nov	1436	5.6	3	
	Offshore	42 55.6256	82 27.0703	6.7	Historical	25/05/2022	1103	3	7.0	|	|	3	3	22-Nov	1436	6.5	3	
	Inshore	42 54.7419	82 27.3834	4.2	Historical	25/05/2022	1038	3	4.1	09-Aug-22	1020	3	3	22-Nov	1420	3.8	3	
371	Middle	42 54.7432	82 27.3873	5.3	Historical	25/05/2022	1038	3	5.6	|	|	3	3	22-Nov	1420	5.2	3	
	Offshore	42 54.7443	82 27.3904	6.3	Historical	25/05/2022	1038	3	6.5	|	|	3	3	22-Nov	1420	6.2	3	
	Upstream	42 54.309	82 27.529	7.3	align with flow from shell dock	25/05/2022	956	3	7.3	09-Aug-22	1011	3	3	22-Nov	1403	7.1	3	
272	Mid	42 54.3065	82 27.5285	7.1	Historical location	25/05/2022	956	3	7.0	|	|	3	3	22-Nov	1403	7.0	3	
	Downstream	42 54.304	82 27.530	7.1	directly downstream	25/05/2022	956	3	7.2	|	|	3	3	22-Nov	1403	6.9	3	
		42 54.195	82 27.532	1.5	new loc	24/05/2022	1512	6	1.5	08-Aug-22	1448	6	6	22-Nov	1335	1.2	6	
374				1.6	5m offshore	24/05/2022	1512	6	1.6	|	|	6	6	22-Nov	1335	1.4	4	Lost 2 Tubes in bundle of 6
		42 54.195	82 27.536	2.1	5m offshore	24/05/2022	1512	6	2.1	|	|	6	6	22-Nov	1335	1.9	6	
				3.2	5m offshore	24/05/2022	1512	3	3.2	|	|	3	3	22-Nov	1335	3.0	6	
		42 54.195	82 27.541	4.8	historical location inshore	24/05/2022	1512	3	4.8	|	|	3	3	22-Nov	1335	4.4	6	Historical "inshore" stn
		42 53.882	82 27.453	1.4	<2m depth close to shore	24/05/2022	1408	6	1.4	08-Aug-22	1415	6	6	22-Nov	1312	1.1	4	Lost 2 Tubes in bundle of 6
270		42 53.889	82 27.456	1.4	5m offshore	24/05/2022	1408	6	1.4	|	|	6	6	22-Nov	1312	1.2	6	
		42 53.888	82 27.461	1.5	5m offshore	24/05/2022	1408	6	1.5	|	|	0	6	22-Nov	1312	1.2	6	
		42 53.888	82 27.464	1.5	5m offshore	24/05/2022	1408	6	1.5	|	|	6	6	22-Nov	1312	1.3	5	Lost 1 Tubes in bundle of 6
		42 53.888	82 27.465	1.6	5m offshore	24/05/2022	1408	6	1.6	|	|	6	6	22-Nov	1312	1.4	6	
	Inshore	42 53.7837	82 27.4299	4.5	Historical	24/05/2022	1309	3	5.0	09-Aug-22	0936	3	3	22-Nov	1257	4.4	3	
100	Middle	42 53.7829	82 27.4338	5.6	Historical	24/05/2022	1309	3	6.0	|	|	3	3	22-Nov	1257	5.6	3	
	Offshore	42 53.7824	82 27.4368	6.7	Historical	24/05/2022	1309	3	7.0	|	|	3	3	22-Nov	1257	6.6	2	Lost 1 Tubes in bundle of 3
	Inshore	42 53.2871	82 27.3428	2.9	Historical	24/05/2022	1239	3	3.0	09-Aug-22	0909	3	3	22-Nov	1239	2.7	3	
266	Middle	42 53.2882	82 27.3463	4.1	Historical	24/05/2022	1239	3	4.4	|	|	3	3	22-Nov	1239	4.1	3	
	Offshore	42.53.2881	82 27.3500	5.3	Historical	24/05/2022	1239	3	5.6	|	|	3	3	22-Nov	1239	5.2	3	

2018

Site #	Subsite	Latitude	Longitude	Depth In (m)	Date In	Time In	Tubes In	Depth Out&In	Date Out & In	Time Out & In	Tubes Out	Tubes In	Date Out	Time Out	Depth Out	Tubes Out	Comments
	Inshore	42 57.1993	82 25.4401	4.7	April 24,2018	1225	3	5.2	July 18,2018	1201	3	3	Dec 17,2018	1718	5.1	3	
365	Middle	42 57.1996	82 25.4427	5.7	April 24,2018	1225	3	5.8	July 18,2018	1201	3	3	Dec 17,2018	1718	5.8	3	
	Offshore	42 57.2000	82 25.4467	7.0	April 24,2018	1225	3	7.1	July 18,2018	1201	3	3	Dec 17,2018	1718	7.1	3	
	Inshore	42 56.2236	82 26.6473	5.4	April 24,2018	1215	3	5.6	July 18,2018	1120	3	3	Dec 17,2018	1643	5.5	3	
75	Middle	42 56.2242	82 26.6524	6.1	April 24,2018	1215	3	6.3	July 18,2018	1120	3	3	Dec 17,2018	1643	6.2	3	
	Offshore	42 56.2263	82 26.6554	6.8	April 24,2018	1215	3	7.0	July 18,2018	1120	3	3	Dec 17,2018	1643	6.8	3	
	Inshore	42 55.9383	82 26.8867	4.9	April 24,2018	1125	3	5.0	July 18,2018	1055	3	3	Dec 17,2018	1624	4.8	3	
370	Middle	42 55.9400	82 26.8883	5.8	April 24,2018	1125	3	6.1	July 18,2018	1055	3	3	Dec 17,2018	1624	5.8	3	
	Offshore	42 55.9417	82 26.8917	7.0	April 24,2018	1125	3	7.1	July 18,2018	1055	3	3	Dec 17,2018	1624	7.0	3	
	Inshore	42 55.6238	82 27.0630	4.8	April 24,2018	1100	3	4.9	July 18,2018	1020	3	3	Dec 17,2018	1604	4.8	3	
139	Middle	42 55.6244	82 27.0660	5.7	April 24,2018	1100	3	5.9	July 18,2018	1020	3	3	Dec 17,2018	1604	5.6	3	
	Offshore	42 55.6256	82 27.0703	6.7	April 24,2018	1100	3	6.9	July 18,2018	1020	3	3	Dec 17,2018	1604	6.7	3	
	Inshore	42 54.7419	82 27.3834	4.0	April 24,2018	1030	3	4.2	July 18,2018	0950	3	3	Dec 17,2018	1544	4.0	3	
371	Middle	42 54.7432	82 27.3873	5.4	April 24,2018	1030	3	5.5	July 18,2018	0950	3	3	Dec 17,2018	1544	5.4	3	
	Offshore	42 54.7443	82 27.3904	6.4	April 24,2018	1030	3	6.6	July 18,2018	0950	3	3	Dec 17,2018	1544	6.5	3	
	Inshore	42 54.3062	82 27.5252	5.6	April 24,2018	0950	3	5.7	July 17,2018	1608	3	3	Dec 17,2018	1450	5.7	3	
272	Middle	42 54.3065	82 27.5285	7.2	April 24,2018	0950	3	7.0	July 17,2018	1608	3	3	Dec 17,2018	1450	7.0	3	
	Offshore	42 54.3073	82 27.5310	8.1	April 24,2018	0950	3	8.1	July 17,2018	1608	3	3	Dec 17,2018	1450	8.1	3	
	Inshore	42 54.1948	82 27.5449	4.7	April 24,2018	0930	3	4.9	July 17,2018	1516	3	3	Dec 17,2018	1522	4.6	2	
374	Middle	42 54.1949	82 27.5489	6.0	April 24,2018	0930	3	6.0	July 17,2018	1516	3	0	Dec 17,2018	1522	6.0	1	
	Offshore	42 54.1965	82 27.5516	7.0	April 24,2018	0930	3	7.1	July 17,2018	1516	3	0	Dec 17,2018	1522	6.8	3	
	Inshore	42 53.8706	82 27.4750	4.8	April 23,2018	1455	3	5.2	July 17,2018	1444	3	3	Dec 17,2018	1428	5.1	3	
270	Middle	42 53.8691	82 27.4791	6.1	April 23,2018	1455	3	6.4	July 17,2018	1444	3	3	Dec 17,2018	1428	6.2	3	
	Offshore	42 53.8693	82 27.4833	6.8	April 23,2018	1455	3	7.1	July 17,2018	1444	3	3	Dec 17,2018	1428	6.9	3	
	Inshore	42 53.7837	82 27.4299	4.7	April 23,2018	1415	3	4.9	July 17,2018	1420	3	3	Dec 17,2018	1406	4.5	3	
100	Middle	42 53.7829	82 27.4338	5.7	April 23,2018	1415	3	6.0	July 17,2018	1420	3	3	Dec 17,2018	1406	5.7	3	
	Offshore	42 53.7824	82 27.4368	6.7	April 23,2018	1415	3	7.1	July 17,2018	1420	3	3	Dec 17,2018	1406	6.9	3	
	Inshore	42 53.2871	82 27.3428	4.4	April 23,2018	1400	3	4.4	July 17,2018	1350	3	3	Dec 17,2018	1347	4.2	3	
266	Middle	42 53.2882	82 27.3463	5.4	April 23,2018	1400	3	5.6	July 17,2018	1350	3	3	Dec 17,2018	1347	5.3	3	
	Offshore	42.53.2881	82 27.3500	6.7	April 23,2018	1400	3	7.0	July 17,2018	1350	3	3	Dec 17,2018	1347	6.7	3	

2017

Site #	Subsite	Latitude	Longitude	Depth In (m)	Date In	Time In	Tubes In	Depth Out&In	Date Out & In	Time Out & In	Tubes Out	Tubes In	Date Out	Time Out	Depth Out	Tubes Out	Comments
	Inshore	42 57.1993	82 25.4401	4.8	May 3,2017	1415	3	5.0	July 5,2017	1204	3	3	Nov 7,2017	1505	5.0	3	
365	Middle	42 57.1996	82 25.4427	5.8	May 3,2017	1415	3	6.0	July 5,2017	1204	3	3	Nov 7,2017	1505	5.9	3	
	Offshore	42 57.2000	82 25.4467	7.6	May 3,2017	1415	3	7.2	July 5,2017	1204	3	3	Nov 7,2017	1505	6.2	3	
	Inshore	42 56.2236	82 26.6473	5.3	May 3,2017	1310	3	5.0	July 5,2017	1135	3	3	Nov 7,2017	1439	5.4	3	
75	Middle	42 56.2242	82 26.6524	6.0	May 3,2017	1310	3	6.3	July 5,2017	1135	3	3	Nov 7,2017	1439	6.2	3	
	Offshore	42 56.2263	82 26.6554	6.8	May 3,2017	1310	3	7.0	July 5,2017	1135	3	3	Nov 7,2017	1439	6.8	3	
	Inshore	42 55.9383	82 26.8867	4.7	May 3,2017	1240	3	4.6	July 5,2017	1110	3	3	Nov 7,2017	1404	4.7	2	
370	Middle	42 55.9400	82 26.8883	5.8	May 3,2017	1240	3	6.0	July 5,2017	1110	3	3	Nov 7,2017	1404	6.0	3	
	Offshore	42 55.9417	82 26.8917	6.9	May 3,2017	1240	3	7.2	July 5,2017	1110	3	3	Nov 7,2017	1404	7.0	3	
	Inshore	42 55.6238	82 27.0630	4.8	May 3,2017	1110	3	4.7	July 5,2017	1025	3	3	Nov 7,2017	1348	4.9	3	
139	Middle	42 55.6244	82 27.0660	5.8	May 3,2017	1110	3	5.9	July 5,2017	1025	3	3	Nov 7,2017	1348	5.8	3	
	Offshore	42 55.6256	82 27.0703	6.8	May 3,2017	1110	3	6.9	July 5,2017	1025	3	3	Nov 7,2017	1348	6.8	3	
	Inshore	42 54.7419	82 27.3834	4.0	May 3,2017	1057	3	4.0	July 5,2017	1010	3	3	Nov 7,2017	1320	4.0	3	
371	Middle	42 54.7432	82 27.3873	5.4	May 3,2017	1057	3	5.5	July 5,2017	1010	3	3	Nov 7,2017	1320	5.4	3	
	Offshore	42 54.7443	82 27.3904	6.4	May 3,2017	1057	3	6.2	July 5,2017	1010	3	3	Nov 7,2017	1320	6.4	3	
	Inshore	42 54.3062	82 27.5252	6.0	May 3,2017	1040	3	5.7	July 4,2017	1525	3	3	Nov 7,2017	1144	5.9	2	
272	Middle	42 54.3065	82 27.5285	7.4	May 3,2017	1040	3	7.2	July 4,2017	1525	3	3	Nov 7,2017	1144	7.1	3	
	Offshore	42 54.3073	82 27.5310	8.2	May 3,2017	1040	3	8.4	July 4,2017	1525	3	3	Nov 7,2017	1144	8.1	3	
	Inshore	42 54.1948	82 27.5449	4.8	May 3,2017	1005	3	4.5	July 4,2017	1505	3	3	Nov 7,2017	1120	4.9	3	
374	Middle	42 54.1949	82 27.5489	6.0	May 3,2017	1005	3	5.8	July 4,2017	1505	3	3	Nov 7,2017	1120	5.8	3	
	Offshore	42 54.1965	82 27.5516	7.0	May 3,2017	1005	3	7.2	July 4,2017	1505	3	3	Nov 7,2017	1120	6.2	3	
	Inshore	42 53.8706	82 27.4750	5.1	May 3,2017	0950	3	5.1	July 4,2017	1450	3	3	Nov 7,2017	1030	5.2	1	
270	Middle	42 53.8691	82 27.4791	6.4	May 3,2017	0950	3	6.5	July 4,2017	1450	3	3	Nov 7,2017	1030	6.6	3	
	Offshore	42 53.8693	82 27.4833	7.1	May 3,2017	0950	3	7.0	July 4,2017	1450	3	3	Nov 7,2017	1030	7.6	3	
	Inshore	42 53.7837	82 27.4299	4.6	May 3,2017	0915	3	4.6	July 4,2017	1410	3	3	Nov 7,2017	1020	4.6	3	
100	Middle	42 53.7829	82 27.4338	6.0	May 3,2017	0915	3	6.2	July 4,2017	1410	3	3	Nov 7,2017	1020	5.7	3	
	Offshore	42 53.7824	82 27.4368	7.1	May 3,2017	0915	3	7.2	July 4,2017	1410	3	3	Nov 7,2017	1020	7.1	3	
	Inshore	42 53.2871	82 27.3428	4.6	May 3,2017	0830	3	4.7	July 4,2017	1350	3	3	Nov 7,2017	0950	4.2	3	
266	Middle	42 53.2882	82 27.3463	5.5	May 3,2017	0830	3	5.2	July 4,2017	1350	3	3	Nov 7,2017	0950	5.5	3	
	Offshore	42.53.2881	82 27.3500	7.0	May 3,2017	0830	3	7.0	July 4,2017	1350	3	3	Nov 7,2017	0950	7.0	3	

2016

Site #	Subsite	Latitude	Longitude	Depth In (m)	Date In	Time In	Tubes In	Depth Out&In	Date Out & In	Time Out & In	Tubes Out	Tubes In	Date Out	Time Out	Depth Out	Tubes Out	Comments
	Inshore	42 57.1993	82 25.4401	4.9	May 11,2016	1158	3	5.0	July 26,2016	1125	3	3	Nov. 23 2016	1020	5.2	3	Found on a 45 degree angle
365	Middle	42 57.1996	82 25.4427	5.8	May 11,2016	1158	3	5.9	July 26,2016	1125	3	3	Nov. 23 2016	1020	6.1	3	top covered in macrophytes
	Offshore	42 57.2000	82 25.4467	7.0	May 11,2016	1158	3	7.1	July 26,2016	1125	3	3	Nov. 23 2016	1020	7.3	3	Nov. 23
	Inshore	42 56.2236	82 26.6473	5.3	May 11,2016	1058	3	5.4	July 26,2016	1100	3	3	Nov. 23 2016	1042	5.6	3	
75	Middle	42 56.2242	82 26.6524	6.1	May 11,2016	1058	3	6.2	July 26,2016	1100	3	3	Nov. 23 2016	1042	6.4	3	
	Offshore	42 56.2263	82 26.6554	6.7	May 11,2016	1058	3	6.8	July 26,2016	1100	3	3	Nov. 23 2016	1042	7.0	3	
	Inshore	42 55.9383	82 26.8867	4.8	May 11,2016	0946	3	7.0	July 26,2016	1030	3	3	Nov. 23 2016	1105	5.3	3	Light macrophyte coverage
370	Middle	42 55.9400	82 26.8883	5.7	May 11,2016	0946	3	5.9	July 26,2016	1030	3	3	Nov. 23 2016	1105	6.1	3	Some sediment interference
	Offshore	42 55.9417	82 26.8917	6.8	May 11,2016	0946	3	5.1	July 26,2016	1030	3	3	Nov. 23 2016	1105	7.2	3	for entire transect - July 26
	Inshore	42 55.6238	82 27.0630	4.8	May 10,2016	1502	3	4.6	July 26,2016	0945	3	3	Nov. 23 2016	1125	4.8	3	Photos taken - July 26
139	Middle	42 55.6244	82 27.0660	5.7	May 10,2016	1502	3	5.5	July 26,2016	0945	3	3	Nov. 23 2016	1125	5.7	3	Some macrophytes at all
	Offshore	42 55.6256	82 27.0703	6.6	May 10,2016	1502	3	6.5	July 26,2016	0945	3	3	Nov. 23 2016	1125	6.7	3	three sites - Nov. 23
	Inshore	42 54.7419	82 27.3834	4.0	May 10,2016	1410	3	3.9	July 26,2016	0918	3	3	Nov. 23 2016	1147	4.1	3	
371	Middle	42 54.7432	82 27.3873	5.4	May 10,2016	1410	3	5.4	July 26,2016	0918	3	3	Nov. 23 2016	1147	5.6	3	Macrophytes all around & over
	Offshore	42 54.7443	82 27.3904	6.3	May 10,2016	1410	3	6.3	July 26,2016	0918	3	3	Nov. 23 2016	1147	6.5	3	July 26
	Inshore	42 54.3062	82 27.5252	5.5	May 10,2016	1320	3	5.7	July 25,2016	1530	3	3	Nov. 23 2016	1242	5.9	3	
272	Middle	42 54.3065	82 27.5285	7.0	May 10,2016	1320	3	6.8	July 25,2016	1530	3	3	Nov. 23 2016	1242	7.0	3	
	Offshore	42 54.3073	82 27.5310	8.0	May 10,2016	1320	3	8.1	July 25,2016	1530	3	3	Nov. 23 2016	1242	8.3	3	
	Inshore	42 54.1948	82 27.5449	4.3	May 10,2016	1200	3	4.5	July 25,2016	1505	3	3	Nov. 23 2016	1306	4.7	3	Covered in Macrophytes
374	Middle	42 54.1949	82 27.5489	5.8	May 10,2016	1200	3	6.1	July 25,2016	1505	0	3	Nov. 23 2016	1306	6.3	3	Rebar bent flat
	Offshore	42 54.1965	82 27.5516	7.1	May 10,2016	1200	3	7.0	July 25,2016	1505	0	3	Nov. 23 2016	1306	7.2	3	Tubes gone - July 25
	Inshore	42 53.8706	82 27.4750	4.8	May 10,2016	1045	3	4.8	July 25,2016	1437	3	3	Nov. 23 2016	1338	5.0	3	
270	Middle	42 53.8691	82 27.4791	6.0	May 10,2016	1045	3	6.2	July 25,2016	1437	3	3	Nov. 23 2016	1338	6.4	3	Lots of macrophytes at all
	Offshore	42 53.8693	82 27.4833	6.9	May 10,2016	1045	3	7.0	July 25,2016	1437	3	3	Nov. 23 2016	1338	7.2	3	three sites - Nov. 23
	Inshore	42 53.7837	82 27.4299	4.5	May 10,2016	0925	3	4.4	July 25,2016	1415	3	3	Nov. 23 2016	1347	4.6	3	
100	Middle	42 53.7829	82 27.4338	5.7	May 10,2016	0925	3	5.9	July 25,2016	1415	3	3	Nov. 23 2016	1347	6.1	3	Lots of macrophytes at all
	Offshore	42 53.7824	82 27.4368	6.8	May 10,2016	0925	3	6.9	July 25,2016	1415	3	3	Nov. 23 2016	1347	7.1	3	three sites - Nov. 23
	Inshore	42 53.2871	82 27.3428	4.2	May 9, 2016	1530	3	4.3	July 25,2016	1355	3	3	Nov. 23 2016	1417	4.5	3	
266	Middle	42 53.2882	82 27.3463	5.1	May 9, 2016	1530	3	4.9	July 25,2016	1355	3	3	Nov. 23 2016	1417	5.1	3	
	Offshore	42.53.2881	82 27.3500	6.4	May 9, 2016	1530	3	6.8	July 25,2016	1355	3	3	Nov. 23 2016	1417	7.0	3	

2015

Site #	Subsite	Latitude	Longitude	Depth In (m)	Date In	Time In	Tubes In	Depth Out&In	Date Out & In	Time Out & In	Tubes Out	Tubes In	Date Out	Time Out	Depth Out	Tubes Out	Comments
	Inshore	42 57.197	82 25.438	4.8	May 13,2015	1040	3	2.8	Sept.1,2015	1110	3	3	Nov.17,2015	1200	2.8	3	
365	Middle	42 57.198	82 25.444	5.5	May 13,2015	1040	3	5.7	Sept.1,2015	1110	3	3	Nov.17,2015	1200	5.7	3	
	Offshore	42 57.199	82 25.444	6.9	May 13,2015	1040	3	6.5	Sept.1,2015	1110	3	3	Nov.17,2015	1200	6.5	3	
	Inshore	42 56.221	82 26.647	5.1	May 13,2015	0930	3	4.8	Sept.1,2015	1050	3	3	Nov.17,2015	1135	4.8	3	
75	Middle	42 56.222	82 26.654	5.9	May 13,2015	0930	3	5.6	Sept.1,2015	1050	3	3	Nov.17,2015	1135	5.6	3	
	Offshore	42 56.224	82 26.656	6.5	May 13,2015	0930	3	6.2	Sept.1,2015	1050	3	3	Nov.17,2015	1135	6.2	3	
	Inshore	42 55.986	82.26.863	5.8	May 12,2015	1615	3	4.8	Sept.1,2015	1030	3	3	Nov.17,2015	1112	4.8	3	
310	Middle	42 55.988	82 26.862	6.9	May 12,2015	1615	3	6.4	Sept.1,2015	1030	3	3	Nov.17,2015	1112	6.4	3	
	Offshore	42.55.992	82 26.863	7.7	May 12,2015	1615	3	7.4	Sept.1,2015	1030	3	3	Nov.17,2015	1112	7.4	3	
	Inshore	42 55.623	82 27.060	4.5	May 12,2015	1435	3	4.4	Sept.1,2015	1015	3	3	Nov.17,2015	1050	4.4	3	
139	Middle	42 55.623	82 27.064	5.4	May 12,2015	1435	3	5.2	Sept.1,2015	1015	3	3	Nov.17,2015	1050	5.2	3	
	Offshore	42 55.625	82 27.068	6.4	May 12,2015	1435	3	6.0	Sept.1,2015	1015	3	3	Nov.17,2015	1050	6.0	3	
	Inshore	42 54.744	82 27.382	3.8	May 12,2015	1140	3	3.9	Sept.1,2015	0950	3	3	Nov.17,2015	1025	3.9	3	
371	Middle	42 54.746	82 27.385	5.0	May 12,2015	1140	3	4.5	Sept.1,2015	0950	3	3	Nov.17,2015	1025	4.4	3	
	Offshore	42 54.745	82 27.388	6.1	May 12,2015	1140	3	5.8	Sept.1,2015	0950	3	3	Nov.17,2015	1025	5.8	3	
	Inshore	42 54.305	82 27.522	5.5	May 12,2015	1035	3	4.8	Aug.31,2015	1515	3	3	Nov.17,2015	0935	4.8	3	
272	Middle	42 54.305	82 27.526	7.0	May 12,2015	1035	3	6.2	Aug.31,2015	1515	3	3	Nov.17,2015	0935	6.2	3	
	Offshore	42 54.305	82 27.529	7.8	May 12,2015	1035	3	7.5	Aug.31,2015	1515	3	3	Nov.17,2015	0935	7.5	3	
	Inshore	42 54.042	82 27.531	4.4	May 12,2015	1245	3	3.6	Aug.31,2015	1545	3	0	Nov.16,2015	1520	3.6	3	
372	Middle	42 54.042	82 27.536	6.1	May 12,2015	1245	3	5.5	Aug.31,2015	1545	3	0	Nov.16,2015	1520	5.5	3	
	Offshore	42 54.042	82 27.536	6.9	May 12,2015	1245	3	6.5	Aug.31,2015	1545	3	3	Nov.16,2015	1520	6.5	3	
	Inshore	42 53.940	82 27.502	4.5	May 12,2015	1335	3	3.7	Aug.31,2015	1615	3	3	Nov.16,2015	1500	3.7	3	
373	Middle	42 53.940	82 27.509	6.1	May 12,2015	1335	3	5.5	Aug.31,2015	1615	3	3	Nov.16,2015	1500	5.5	3	
	Offshore	42 53.939	82 27.510	7.4	May 12,2015	1335	3	6.8	Aug.31,2015	1615	3	3	Nov.16,2015	1500	6.8	3	
	Inshore	42 53.781	82 27.431	4.3	May 12,2015	0945	3	3.5	Aug.31,2015	1455	3	3	Nov.16,2015	1440	3.5	3	
100	Middle	42 53.782	82 27.432	5.4	May 12,2015	0945	3	4.5	Aug.31,2015	1455	3	3	Nov.16,2015	1440	4.5	3	
	Offshore	42 53.782	82 27.437	6.5	May 12,2015	0945	3	5.4	Aug.31,2015	1455	3	3	Nov.16,2015	1440	6.4	3	
	Inshore	42 53.285	82 27.343	4.0	May 11,2015	1630	3	3.5	Aug.31,2015	1435	3	3	Nov.16,2015	1410	3.5	3	
266	Middle	42 53.284	82 27.346	5.1	May 11,2015	1630	3	5.0	Aug.31,2015	1435	3	3	Nov.16,2015	1410	5.4	3	
	Offshore	42 53.284	82 27.350	6.4	May 11,2015	1630	3	5.9	Aug.31,2015	1435	3	3	Nov.16,2015	1410	5.9	3	
	Inshore	42 52.293	82 27.700	4.3	May 11,2015	1505	3	3.9	Aug.31,2015	1410	3	3	Nov.16,2015	1340	3.9	3	
148	Middle	42 52.295	82 27.708	5.2	May 11,2015	1505	3	5.0	Aug.31,2015	1410	3	3	Nov.16,2015	1340	5.0	3	
	Offshore	42 52.296	82 27.707	5.9	May 11,2015	1505	3	5.9	Aug.31,2015	1410	3	3	Nov.16,2015	1340	5.9	3	

Appendix Table 2: **Results from the Mann-Kendall test and the magnitude of the trend with the Sen's method in MAKESENS for suspended sediment Hg data for transects with long-term data (2001-2022).** For time series with less than 10 data points the S test is used, and for time series with 10 or more data points the normal approximation is used for the Mann-Kendall test.

+: a trend is detected but it is not significant; * p<0.05; ** p <0.01; *** p<0.001

TREND STATISTICS

Sed Traps Hg data 2001-2022

				Mann-Kendall trend			Sen's slope estimate									
Time series	**First year**	**Last Year**	**n**	**Test S**	**Test Z**	**Signific.**	**Q**	**Qmin99**	**Qmax99**	**Qmin95**	**Qmax95**	**B**	**Bmin99**	**Bmax99**	**Bmin95**	**Bmax95**
T-75	*2001*	*2022*	*12*		-1.71	+	-0.038	-0.133	0.019	-0.094	0.007	1.05	1.93	0.33	1.80	0.47
T-139	*2001*	*2022*	*10*		-2.96	**	-0.020	-0.059	-0.010	-0.048	-0.011	0.50	1.05	0.34	0.89	0.36
T-143	*2001*	*2022*	*11*		-2.49	*	-0.027	-0.044	0.000	-0.034	-0.004	0.62	0.79	0.19	0.68	0.24
T-100	*2001*	*2022*	*12*		-2.40	*	-0.015	-0.028	0.001	-0.024	-0.003	0.52	0.64	0.35	0.59	0.40
T-266	*2001*	*2022*	*12*		-3.50	***	-0.021	-0.038	-0.009	-0.035	-0.013	0.53	0.73	0.36	0.71	0.40

Appendix Table 3: **Results from the Mann-Kendall test and the magnitude of the trend with the Sen's method in MAKESENS for suspended sediment Hg data from 2015 - 2022.** For time series with less than 10 data points the S test is used, and for time series with 10 or more data points the normal approximation is used for the Mann-Kendall test.

+: a trend is detected but it is not significant; * p<0.05; ** p <0.01; *** p<0.001

TREND STATISTICS

Sed Traps Hg data 2015-2022

				Mann-Kendall trend			Sen's slope estimate									
Time series	**First year**	**Last Year**	**n**	**Test S**	**Test Z**	**Signific.**	**Q**	**Qmin99**	**Qmax99**	**Qmin95**	**Qmax95**	**B**	**Bmin99**	**Bmax99**	**Bmin95**	**Bmax95**
T-75	*2015*	*2022*	*5*	*-2*			-0.032					0.57				
T-370	*2015*	*2022*	*4*	*4*			0.009					0.22				
T-139	*2015*	*2022*	*5*	*-4*			-0.004					0.19				
T-371	*2015*	*2022*	*5*	*-10*		*	-0.022					0.23				
T-272	*2015*	*2022*	*5*	*-4*			-0.006					0.18				

TREND STATISTICS

Sed Traps Hg data 2015-2022

				Mann-Kendall trend			Sen's slope estimate									
Time series	**First year**	**Last Year**	**n**	**Test S**	**Test Z**	**Signific.**	**Q**	**Qmin99**	**Qmax99**	**Qmin95**	**Qmax95**	**B**	**Bmin99**	**Bmax99**	**Bmin95**	**Bmax95**
T-374	*2015*	*2022*	*4*	*2*			0.025					-0.23				
T-270	*2015*	*2022*	*4*	*6*		+	0.043					-0.54				
T-100	*2015*	*2022*	*5*	*-2*			-0.002					0.27				
T-266	*2015*	*2022*	*5*	*-8*		+	-0.005					0.26				