Trends in Sediment Contaminant Concentrations in the Huron-Erie Corridor

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The legacy of anthropogenic pollution in the Laurentian Great Lakes manifests in impaired water quality, degraded habitat, and decreasing wildlife populations. While pollutants can take years or decades to move thorough the water and biota of the lakes (Hites, 2006; Carlson et al., 2010), they can persist even longer in the form of contaminated sediments. The primary classes of contaminants in Great Lakes sediments are organic chemicals produced through industrial activities or heavy metals from both industrial activities and combustion of fossil fuels. Organic contaminants of concern the Laurentian Great Lakes include long-known examples such as DDT (dichlorodiphenyltrichloroethane) and PCBs (polychlorinated biphenyl), but also emerging contaminants such as PFAS (poly- and perfluorinated compounds). Heavy metals of widespread concern in sediments include mercury, lead, and cadmium. Both heavy metals and organic contaminants in sediments can be incorporated into the food web, including fish and birds. In response to this legacy of pollution, both the United States and Canada instituted pollution control measures beginning in the 1970s.

Assessing the effectiveness of pollution control measures for reducing contaminants in Great Lakes sediments is a difficult task: contaminants exhibit both strong spatial variation and slow rates of change. Extensive spatial surveys have been performed in each of the Laurentian Great Lakes and interconnecting channels (Marvin et al., 2002; Mitchell et al., 2018). These surveys are critical for understanding spatial distribution of contaminants, but do not necessarily tell us whether levels of contaminants are increasing or decreasing in response to management actions (see Forsythe et al., 2004; Szalinska et al., 2006; Forsythe and Marvin, 2009). As a result, we lack historical measurements of many contaminants found in surface sediments. In some cases, archived sediment material can be analyzed using modern techniques (Painter et al., 2001; Sverko et al., 2007), but this approach is limited by the availability of that material. A different approach is to examine the concentration of contaminants across the depth of a sediment core. By pairing measurements of contaminant concentration with radiometric estimates of the year in which the sediments were deposited, researchers can reconstruct the history of contaminant concentrations (Soonthornnonda et al., 2011; Yuan et al., 2014; Codling et al., 2018). This approach is technically difficult and has known drawbacks (Codling et al., 2018), but can be useful when archival samples are missing.

Despite reductions in the contaminant discharge and deposition to the basin (Painter et al., 2001; Mohapatra et al., 2007; Li et al., 2018) and local remediation of contaminated sediments (Richman et al., 2017), many contaminants remain elevated (Burniston et al., 2011). This report summarizes the trends in sediment contaminants over time in order to determine whether basin-wide management actions are achieving the desired outcomes. Data summarized herein come from seventeen peer-reviewed publications that measured sediment contaminants at the same locations during multiple years (either through repeated sampling or within a single core). Together, these data comprise 160 different records of contaminant concentrations through time. The complete dataset is from the author upon request.

Figure 1 summarizes the trends in contaminant concentrations over time, separated by waterbodies within the corridor. Overall, 126 out of 160 records (79%) showed a decrease in contaminant concentration between the first and final years of available data. Compared to the first year for each record, the concentration of contaminants decreased by a median of 45% by the time of the most recent measurement. The number of records varies dramatically throughout the corridor, but in each case the majority show a reduction in contaminant concentrations from past to present. Some of most dramatic improvements in contaminant concentrations come from the Saint Clair River (Richman et al., 2017), where remediation of sediments in the Cole Drain and Dow waterfront areas decreased organic contaminants in suspended sediments by more than 99% between 1995 and 2008.

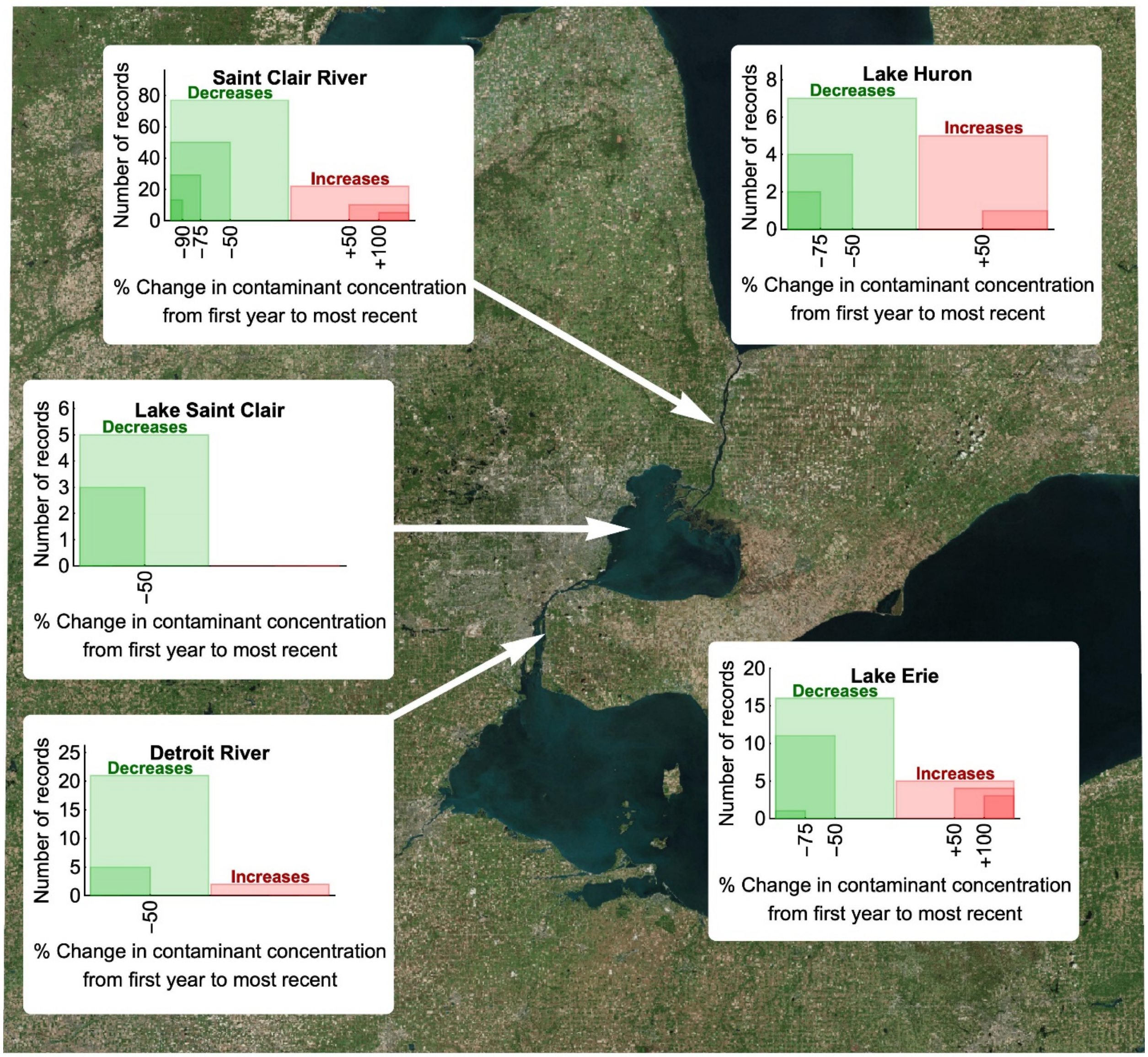
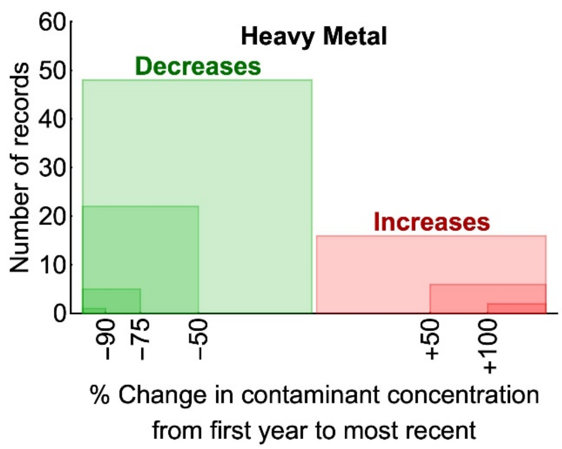


Figure 1. Summary of changes in contaminant concentrations over time within the Huron-Erie corridor. In each panel, the height of the bars represents the number of individual records

showing a decrease (green) or increase (red) in contaminant concentration between the first and final years of the study. The darker inset bars depict the number of those records showing an increase or decrease of at least the magnitude displayed on the horizontal axis.

Although Figure 1 indicates that the problem of sediment contamination is improving, there are a substantial number of records where contaminant concentrations have actually increased over time, in some cases by 100% or more (Codling et al., 2018). One particularly concerning example is PFAS in Lake Erie, where concentrations have increased by more than 1000% since the 1970s. This dramatic change is due, in part, the absence of background PFAS prior to industrial production of the chemicals.

Both classes of contaminants (organics and heavy metals) investigated by these studies are more likely to exhibit decreases than increases over time (Figure 2). For heavy metals, these decreases



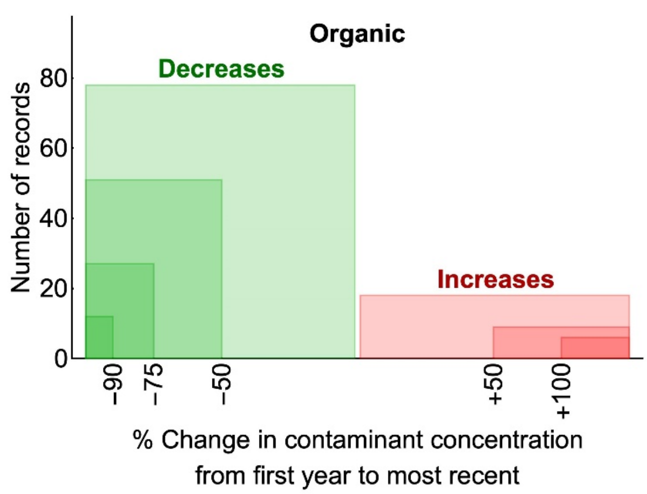


Figure 2. Layout is the same as for Figure 1, but the records are binned by class of contaminant (organic versus heavy metal).

are mostly attributable to reductions in loading (Drevnick et al., 2012; Yuan et al., 2018), resulting in deeper distribution of contaminants in sediments over time. For organic chemicals, the decreases in sediment contaminant concentrations over time are attributable to both decreased loading (Guo et al., 2018) and degradation and advection within the sediments and water (Codling et al., 2018).

While the overall trends are encouraging, there are two important cautions for interpreting the findings from this synthesis. The first is that trends in sediment concentrations are not always linear through time. Indeed, many records show dramatic intra- and interannual variation, particularly when analyzing the strata from a single core (Yuan et al., 2014; Codling et al., 2018). The implication of this caveat is that short-term records or those with few timepoints may show patterns that are not representative. The second caution for interpreting these trends is that some contaminants may show dramatic changes over time but remain at levels that are not considered hazardous to human or wildlife. Some of the studies summarized here directly compare their findings to contaminant standards and regulations (Painter et al., 2001), a necessary step to link these trends to management actions.

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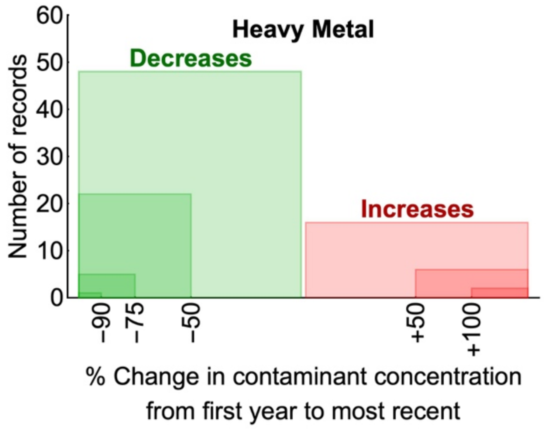
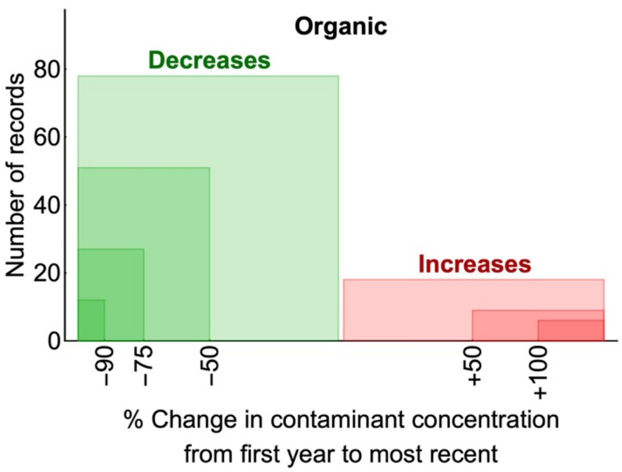


Heavy Metal
Decreases
Increases
Number of records
60
50
40
30
20
10
0
−90
−75
−50
+50
+100
% Change in contaminant concentration
from first year to most recent



Organic
Decreases
Increases
Number of records
80
60
40
20
0
−90
−75
−50
+50
+100
% Change in contaminant concentration
from first year to most recent