

Direct Wastewater Treatment Plant Inputs of Microplastics to the Laurentian Great Lakes

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Motivation & Objective

Effluent of wastewater treatment plants (WWTPs) are an important point source of pollutants to aquatic environments. Whilst not built for this purpose, WWTPs have high microplastics retention capacities (often >70%)¹. Thus, they can serve as important control points to reduce microplastics pollution to receiving water bodies.

The aim of this study is to constrain the flux of microplastics from WWTPs and determine the best next steps in terms of WWTP upgrades on both a lake-by-lake and country-by-country basis.

Methods

In order to constrain the total flux of microplastics from WWTPs (D_{MP}) to each of the Great Lakes, we assume a simple empirical relationship based on a previous nutrient WWTP study² (Eq.1)

$$D_{MP} = (P \times k_{PMP}) \times f_c \times (1 - f_r) \quad (1)$$

The inflow of microplastics to the WWTPs is calculated using the total mismanaged plastic waste flux³ of the prescribed watershed (P ; Figure 1), which is then converted to microplastic waste using a constant (k_{PMP}) derived from correlating WWTP plastic data and influent data⁴. Because of a lack of information, the connectedness of a watershed's population to WWTPs (f_c) is set equal to 1. Finally the percentage retention of microplastics within the WWTPs¹ is included based on the relative proportions of primary, secondary and tertiary WWTPs within each of the watersheds and their respective countries⁵.

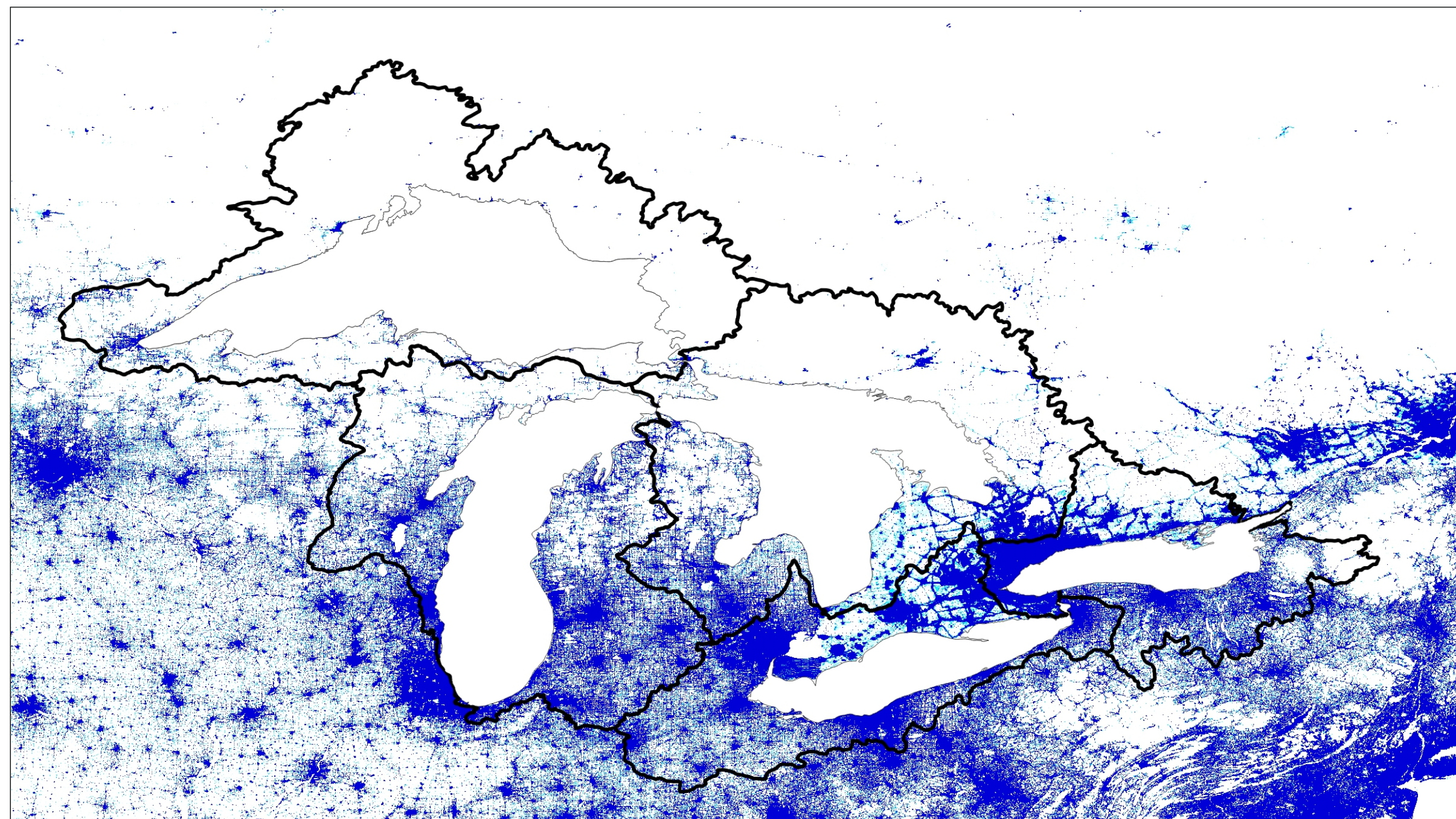


Figure 1. Mismanaged plastic waste generation defined within the Great Lakes watersheds. Based on data from Lebreton and Andrady, 2019³

The calculated input fluxes are then utilized within a simple Great Lakes box model in order to track WWTP derived microplastics along the Great Lakes continuum (Figure 2).

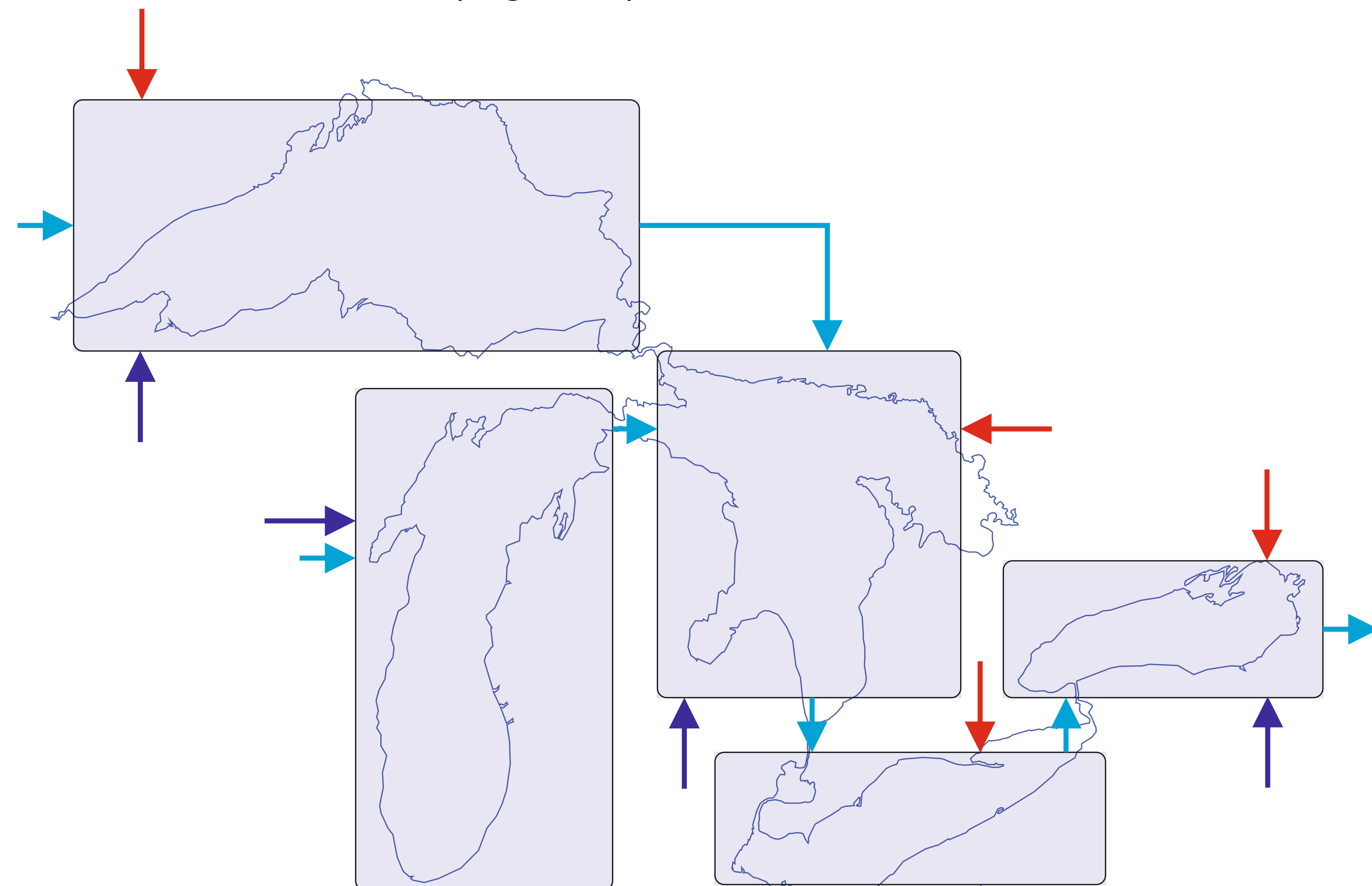


Figure 2. Laurentian Great Lakes model schematic. Cyan - Water mass fluxes, Red - Canadian microplastic WWTP flux, Blue - USA microplastic

Results

Using the empirical relationship, the daily fluxes of mismanaged plastic waste in each of the lakes' watersheds and the corresponding microplastics inputs from Canadian and USA WWTPs are then calculated and compared to the countries overall plastic generation.

Country	Lake	Microplastic count flux per day	Percentage of total country flux
Canada	Superior	3.42×10^{13}	0.5%
Canada	Huron	1.88×10^{15}	22.8%
Canada	Erie	3.80×10^{15}	4.5%
Canada	Ontario	1.84×10^{16}	7.1%
Canada	Great Lakes Total	2.41×10^{16}	34.8%
USA	Superior	4.54×10^{14}	0.1%
USA	Michigan	2.12×10^{17}	0.8%
USA	Huron	5.00×10^{15}	2.6%
USA	Erie	2.55×10^{17}	0.5%
USA	Ontario	1.51×10^{16}	3.5%
USA	Great Lakes Total	4.88×10^{17}	7.5%

These microplastic fluxes are then included within the box model and ran to steady state to determine the relative contributions to each lake from each country, as well as where the microplastic is being retained across the entire continuum (Figure 3).

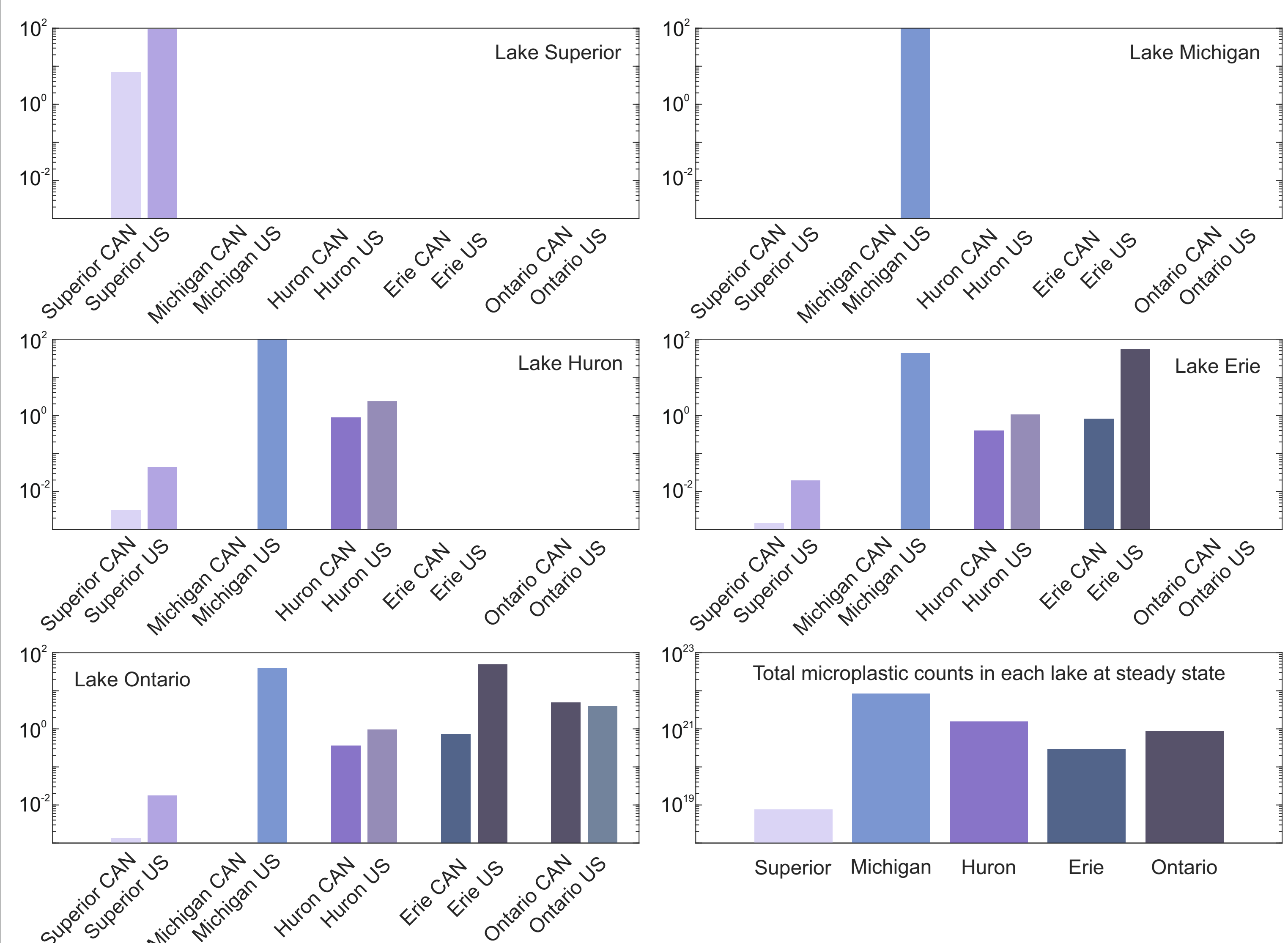


Figure 3. Model results showing the percentage contributions of inputs to each lake to the microplastic counts in each lake plus downstream lakes.

From the water mass fluxes, we estimate a total daily exported microplastic flux of 3.43×10^{17} counts from Lake Ontario into the St. Lawrence river.

Conclusions

We present first estimates of WWTP inputs of microplastics to the Great Lakes and the potential downstream transfers along the lake continuum. The results identify WWTP inputs to Lake Michigan as a major source impacting the lake's microplastics budget but also those of the downstream lakes. Nearly 40% of the total WWTP-derived microplastics count entering the St. Lawrence River are estimated to originate from Lake Michigan. The proportion of microplastics from WWTP effluents in the Great Lakes basin that reach the North Atlantic remains to be determined.

References: ¹Iyare et al. (2020) *Environmental Science: Water Research & Technology*. ²Powley et al. (2016) *Environ. Sci. Technol.* ³Lebreton and Andrady (2019) *Palgrave Communications*. ⁴Gies et al., (2018) *Marine Pollution Bulletin*. ⁵Arvai et al. (2014) *Water Quality Research Journal of Canada*.