ARTICLE IN PRESS

JGLR-01375; No. of pages: 8; 4C:

Journal of Great Lakes Research xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Journal of Great Lakes Research

journal homepage: www.elsevier.com/locate/jglr

Factors influencing microplastic abundances in nearshore, tributary and beach sediments along the Ontario shoreline of Lake Erie

Bethany Y. Dean [a], Patricia L. Corcoran [a,*], Paul A. Helm [b]

[a] Department of Earth Sciences, University of Western Ontario, 1151 Richmond St. N, London, ON N6A 5B7, Canada

[b] Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment, Conservation and Parks, 125 Resources Road, Toronto, ON M9P 3V6, Canada

ARTICLE INFO

Article history:
Received 27 December 2017
Accepted 17 July 2018
Available online xxxx

Communicated by Anett Trebitz

Keywords:
Microplastics
Lake Erie
Sediment
Nearshore
Tributary
Beach

ABSTRACT

Sediment samples were collected from nearshore, tributary and beach environments within and surrounding the northern part of Lake Erie, Ontario to determine the concentrations and distribution of microplastics. Following density separation and microscopic analysis of 29 samples, a total of 1178 microplastic particles were identified. Thirteen nearshore samples contained 0–391 microplastic particles per kg dry weight sediment (kg^{-1}), whereas 4 tributary samples contained 10–462 kg^{-1} and 12 beach samples contained 50–146 kg^{-1}. The highest concentrations of nearshore microplastics were from near the mouths of the Detroit River in the western basin and the Grand River in the eastern basin, reflecting an urban influence. The highest microplastic concentrations in beach samples were determined from Rondeau Beach in the central basin where geomorphology affects plastics concentration. The Welland Canal sample in the eastern basin contained the greatest concentration of microplastics of the tributary samples, which is consistent with high population density and shipping traffic. The overall abundance of microplastic in northern Lake Erie nearshore, tributary and beach samples is 6 times lower than in sediment sampled from northern Lake Ontario. The nearshore and beach sample results potentially reflect the transport patterns of floating plastics modeled for Lake Erie, which predict that the majority of plastic particles entering the lake are transported to southern shoreline regions rather than northern areas.

Introduction

Rivers, lakes, seas and oceans are polluted with plastics globally, as waste is either transferred from urban centers through natural and anthropogenic watercourses or is deposited directly from marine vessels. Plastic debris in aquatic environments has been shown to cause detrimental effects on various organisms (Gall and Thompson, 2015; Gregory, 2009; Kühn et al., 2015; Laist, 1997). These effects include entanglement in nets, ropes, packing loops, monofilament lines and other items (e.g. Innis et al., 2010; McIntosh et al., 2015; Yorio et al., 2014), ingestion by organisms such as birds, fish, and invertebrates (e.g. Pham et al., 2017; Possatto et al., 2011; Provencher et al., 2014), potential transfer of adsorbed pollutants from the surfaces of plastics to organisms (e.g. Colabuono et al., 2010; Endo et al., 2005; Koelmans et al., 2014), and encrustation of plastic objects leading to the transport of invasive species (Gregory, 2009; Tutman et al., 2017). Determining the inventory of plastic particles in benthic sediment enables identification of areas of increased risk for bottom-dwelling and -feeding organisms. Microplastic particles have been shown to adsorb pollutants, thereby exposing benthic invertebrates to chemicals during ingestion and possibly transferring them through the food web (van Cauwenberghe et al., 2015). Although investigations concerning plastic debris in surface water, shoreline, and land-based environments are extensive, comparably less information is available concerning benthic plastic debris, especially in lake basins. Buried plastic is not exposed to major degrading agents like UVB radiation and mechanical abrasion; and therefore, the negative effects of plastics may persist for 100s to 1000s of years (Barnes et al., 2009).

Microplastics have been reported from lake systems in many countries including, but not limited to Canada (e.g. Anderson et al., 2017; Ballent et al., 2016), China (e.g. Su et al., 2016; Zhang et al., 2016), India (e.g. Sruthy and Ramasamy, 2017), Italy (e.g. Sighicelli et al., 2018), Kenya/Uganda/Tanzania (Lake Victoria) (e.g. Khan et al., 2018), Switzerland (e.g. Faure et al., 2015), the UK (e.g. Vaughan et al., 2017), and the USA (e.g. Lasee et al., 2017). The only known published studies concerning benthic plastic debris in the Laurentian Great Lakes system were conducted in the St. Lawrence River (Castañeda et al., 2014) and Lake Ontario (Ballent et al., 2016; Corcoran et al., 2015). The main objective of this paper is to present the distribution and abundance of microplastics in benthic sediments of Lake Erie, and its tributaries. The results are compared with microplastic abundances on Lake Erie beaches, and with distribution models depicting the transport and depositional location of plastic debris throughout the lake. The work

* Corresponding author.
E-mail address: pcorcor@uwo.ca (P.L. Corcoran).

https://doi.org/10.1016/j.jglr.2018.07.014
0380-1330/

focuses on microplastics, which are defined as plastic particles <5 mm in size. Microplastics are derived from degradation of larger plastic products, or are manufactured as mm-size particles, such as pellets and microbeads.

Methods

Study area

Lake Erie is approximately 388 km long, has an average depth of 19 m, and has a breadth of 92 km (EPA, 2015). Water flows into Lake Erie through the Detroit River, which drains Lake St. Clair. There are three basins comprising Lake Erie; the western, eastern and central basins (Fig. 1). The amount of plastic debris surrounding and in Lake Erie could be influenced by: 1) its location downstream from Lakes Superior, Michigan, Huron, and St. Clair, 2) surface water circulation patterns, 3) sedimentation rates, 4) population density (a surrogate for plastics use), and 5) proximity to plastics use and manufacturing industries. Lake Erie is characterized by a two-gyre water circulation pattern (Fig. 1a, b). High winds during the winter season result in a strong circulation with anticyclonic movement in the northern part and cyclonic movement in the southern part of the lake. During the summer season, the dominant gyre is anticyclonic, with a minor cyclonic gyre in the western part of the lake (Beletsky et al., 1999). The complicated annual circulation patterns possibly contribute to varying sedimentation rates in the lake. Kemp et al. (1974) reported mean annual sediment accumulation of 1.1 to 13.4 mm/yr, with the greatest accumulation in the eastern basin. Similarly, Robbins et al. (1978) determined average annual sediment accumulation values of 10 mm/yr in eastern Lake Erie.

Approximately 12 million people live in the Lake Erie watershed, which represents one third of the population in the Great Lakes region (EPA, 2017). The quaternary watersheds closest to Lake Erie in Ontario, Canada are highly populated within 25–75 km of the lake. In addition to water circulation patterns, sedimentation rates, and population density, plastics accumulation may also be influenced by industries. Of the 50 U.S. states that have plastic industries, Ohio is ranked 3rd (The Plastics Industry Trade Association, 2015), and approximately 47% of the Canadian plastics industry is located in Ontario (Government of Canada, 2017). Plastic pellets from production plants are prone to spillage within factories as well as during transportation or off-loading, which can result in pellets moving down storm drains into rivers and lakes during rain events (Corcoran et al., 2015; Zbyszewski et al., 2014).

Sample collection and processing

Thirteen benthic sediment samples were collected in August 2014 by the Ontario Ministry of Environment and Climate Change (MOECC) using a Shipek sediment grab sampler (Wildco, Yulee, FL, USA). Ten samples were collected from Lake Erie nearshore locations, 1 from the mouth of the Grand River and 1 from the Detroit River (Fig. 2). At each station, the top 3 cm of three discrete grabs were homogenized in pre-cleaned stainless steel pans and transferred to a 500 mL polyethylene terephthalate (PET) jar. The samples were chilled and transported to the laboratory for analysis. One passive sediment trap sample was also collected from the same location as sample 5813 by the MOECC in 2014 (2060). The passive sediment trap consists of four acrylic cylinders set in 2 L plastic beakers in a deployment frame. The trap was deployed approximately 2 m above the lake bottom and captured material falling through the water column from May 26, 2014 to October 23, 2014. Upon retrieval of the sediment trap, the water was drained off and the settled material from each tube was transferred to a 500 mL PET jar.

Twelve sediment samples were collected from six Lake Erie beaches in November 2015, using a split spoon sampler, which recovered sand from the foreshore (between low- and high-water marks) and backshore (high-water mark to inland beach limit) to a depth of 30 cm. Polyvinyl chloride (PVC) liners containing each increment were capped, placed in a cooler and transported to the lab. Sediment samples were also collected from 2 northwestern Lake Erie tributaries

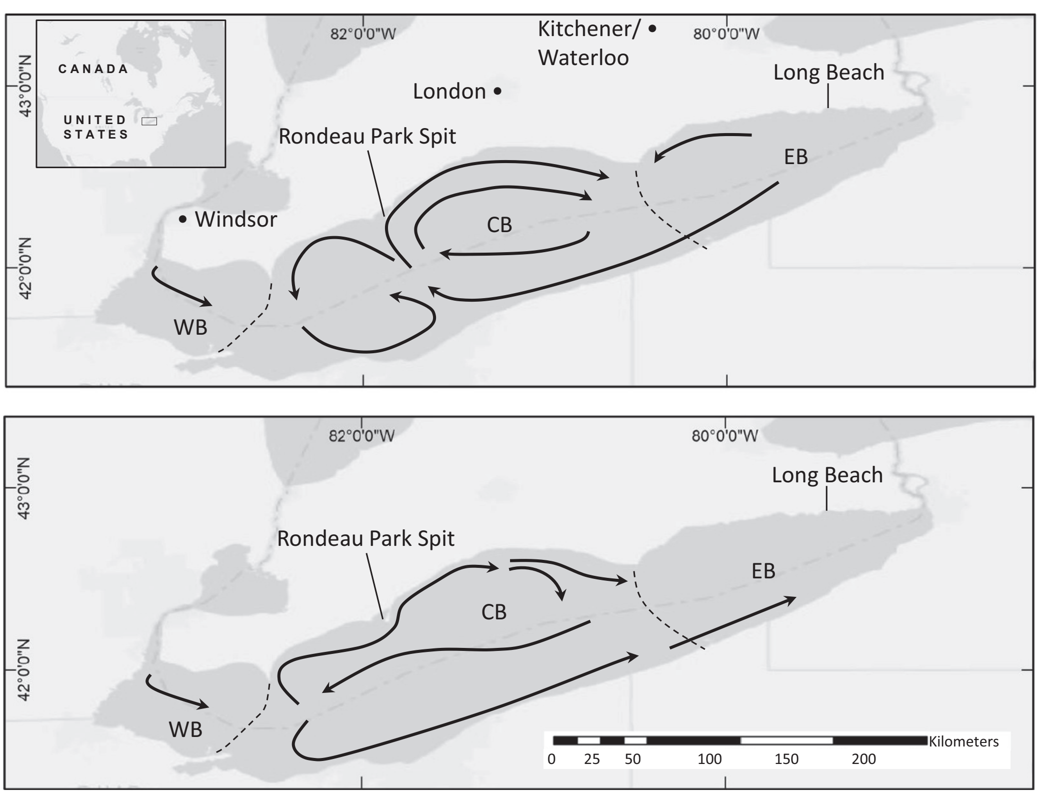

Fig. 1. Maps of Lake Erie displaying surface water circulation patterns from May–October (upper) and November–April (lower). Inset shows location of Lake Erie in North America; WB – western basin, CB – central basin, EB – eastern basin. Surface water circulation patterns from Beletsky et al. (1999).

Please cite this article as: Dean, B.Y., et al., Factors influencing microplastic abundances in nearshore, tributary and beach sediments along the Ontario shoreline of Lake Erie, J. Great Lakes Res. (2018), https://doi.org/10.1016/j.jglr.2018.07.014