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Microplastic in two South Carolina Estuaries: Occurrence, distribution, and composition

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ABSTRACT

Here we report on the distribution of microplastic contamination in two developed estuaries in the Southeastern United States. Average concentration in intertidal sediments of Charleston Harbor and Winyah Bay, both located in South Carolina, U.S.A., was 413.8 ± 76.7 and 221.0 ± 25.6 particles/m^2, respectively. Average concentration in the sea surface microlayer of Charleston Harbor and Winyah Bay was 6.6 ± 1.3 and 30.8 ± 12.1 particles/L, respectively. Concentration in intertidal sediments of the two estuaries was not significantly different ($p = 0.58$), however, Winyah Bay contained significantly more microplastics in the sea surface microlayer ($p = 0.02$). While microplastic concentration in these estuaries was comparable to that reported for other estuaries worldwide, Charleston Harbor contained a high abundance of black microplastic fragments believed to be tire wear particles. Our research is the first to survey microplastic contamination in Southeastern U.S. estuaries and to provide insight on the nature and extent of contamination in these habitats.

1. Introduction

Over the past few years, the occurrence of plastic debris in the environment has gained the attention of not just researchers, but also of policy makers, the general public, and various environmental groups. Much of this attention has focused on the presence, abundance, and fate of microplastics, as well as the potential toxic effects of microplastic exposure to organisms. Microplastics are defined as small plastic particles measuring < 5 mm in dimension (Van Cauwenberghe et al., 2013; Dris et al., 2015). These particles can be directly released into the environment, or can result from the degradation of large plastic debris. While the degradation of plastic in the environment is generally believed to be a slow process (Eerkes-Medrano et al., 2015), Weinstein et al. (2016) found that plastic debris in a salt marsh habitat can produce microplastics in as little as 8 weeks.

Coastal and marine ecosystems are particularly susceptible to plastic pollution. Microplastics have been found everywhere from populated urban beaches (Vianello et al., 2013) to deep-sea sediments (Van Cauwenberghe et al., 2013). While the ecological and public health effects of microplastics in the environment have yet to be fully elucidated, exposure to and ingestion of microplastics by aquatic organisms has been linked to decreased energy reserves (Wright et al., 2013), decreased growth (Wertz, 2015), and decreased reproductive output (Au et al., 2015). In addition, microplastic ingestion by aquatic organisms is suspected to serve as a route of human exposure through the consumption of seafood (Van Cauwenberghe and Janssen, 2014).

While a great deal of research investigating the occurrence and effects of microplastics in the oceans have been conducted (reviewed by Auta et al., 2017), fewer studies have investigated the presence and abundance of microplastics in estuarine systems that receive water from inland rivers and streams. Microplastic abundance in inland water was found to be positively correlated to population density and urban development (Eriksen et al., 2013; Yonkos et al., 2014). As the communities surrounding estuaries can be densely populated (Kennish, 2002), estuaries receiving water from inland rivers and streams may serve as a sink for microplastic debris, as often occurs with other contaminants such as metals, hydrocarbons, and pesticides.

Estuaries provide several valuable ecosystem services such as protecting the coastline from erosion and wave action, fixing carbon, and recycling nutrients (Schaafsma and Turner, 2015). Estuarine pollution is particularly problematic as estuaries also provide essential habitat for many commercially and recreationally important species such as crabs, fish, and shellfish. In a review by Van Cauwenberghe et al. (2015), researchers detailed the presence of microplastic particles in marine sediments and found that marine organisms residing in estuaries can ingest microplastic particles, mistaking them for a source of food. In

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addition, several recent studies have assessed the ingestion of microplastic particles by estuarine invertebrates such as grass shrimp, shore crabs, oysters, and clams (Van Cauwenberghe and Janssen, 2014; Watts et al., 2014; Davidson and Dudas, 2016; Gray and Weinstein, 2017). Results from these studies have indicated that commercially and recreationally important estuarine species can ingest microplastics and that this ingestion can result in mortality and uptake into gill appendages and soft tissues.

As top consumers of ocean-based food webs, humans likely accumulate contaminants, which may compromise fecundity, reproduction, and other somatic processes (Bergmann et al., 2015). Similarly, it has been suggested that seafood may serve as a route of microplastic exposure and accumulation in humans (Van Cauwenberghe and Janssen, 2014). While the consequences of microplastic ingestion by humans have not been fully elucidated, it is thought that microplastics may pose a variety of risks including oxidative stress, cell damage, inflammation, and leaching of chemical additives and adsorbed contaminants (Vethaak and Leslie, 2016). For these reasons, it is important to investigate the occurrence of microplastics in estuaries in order to better understand how they may affect the ecosystem services, economic value, and environmental and public health in these areas.

Charleston Harbor and Winyah Bay are two estuaries that are located on the coast of South Carolina, U.S.A. whose uses span from recreational to agricultural. The present study investigated the abundance, distribution, and composition of microplastics in intertidal sediments and in the sea surface microlayer at both locations. These estuaries are surrounded by coastal communities and may serve as sinks for microplastic pollution originating from a variety of point and nonpoint sources. Therefore, understanding the abundance of microplastics in these two locations can help identify contributing sources of microplastics as well as inform residents, researchers, and policy makers about their potential hazards.

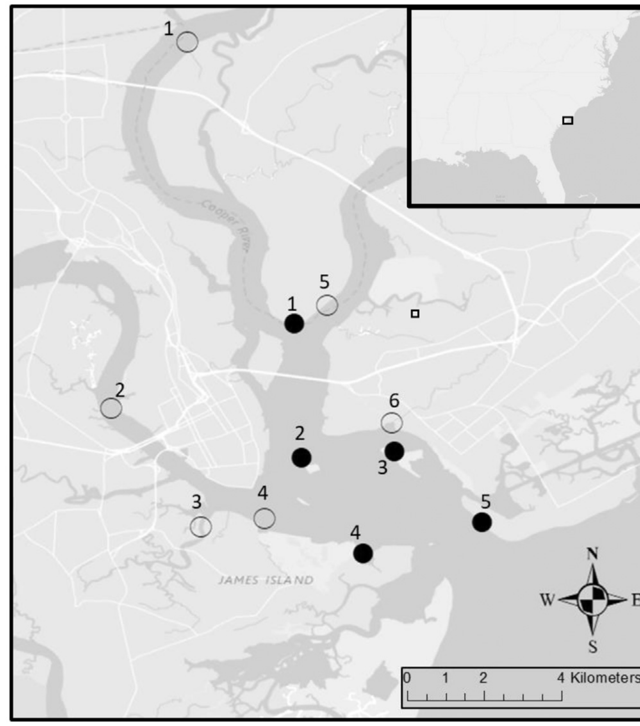

Fig. 1. Sampling sites in Charleston Harbor. Open circles represent sites where sea surface microlayer samples were collected (1-Cooper River, 2-Ashley River, 3-James Island Creek, 4-Middle of Harbor, 5-Wando River, 6-Shem Creek). Closed circles represent sites where intertidal sediments were collected (1-Daniel Island, 2-Shute's Folly, 3-Crab Bank, 4-Grice Cove, 5- Sullivan's Island). Map made with ArcGIS Map 10.4.1.

2. Materials and methods

2.1. Study sites

Charleston Harbor (32° 49′ 7.1″ N, 79° 55′ 40.41″ W) is an inlet of the Atlantic Ocean and is formed by the confluence of the Ashley River, the Cooper River, and the Wando River in Charleston County, SC (population 396,484) (United States Census Bureau, 2016a). It is a partially mixed estuary that serves as part of the intercoastal waterway and has an estuarine drainage area of 3113 km^2. The population surrounding the entire watershed of Charleston Harbor is 664,607 people (Charleston Waterkeeper, 2014). The harbor has several competing uses including industrial, tourism, commercial, and recreational activities. Along the rivers that drain into the harbor, there are several industrial facilities that include petrochemical, ink and pigment, and paper and packaging manufacturers. Inside the harbor, there are several shipyards that receive contents from cargo ships. In addition, Charleston Harbor is home to the fastest growing U.S. port (South Carolina Ports Authority, 2015).

Winyah Bay (33° 17′ 28.32″N, 79° 16′ 32.16″W) is the fourth largest estuary on the Eastern coast of the U.S. in terms of discharge rate, with an estuarine drainage area of 24,633 km^2 (Voulgaris et al., 2002) and is the state's largest tidal freshwater wetlands (The Nature Conservancy in South Carolina Winyah Bay, 2015). Winyah Bay is also an inlet of the Atlantic Ocean and is formed by the confluence of the Waccamaw River, Pee Dee River, Black River, and Sampit River in Georgetown County, SC (population 60,804) (United States Census Bureau, 2016b). The population surrounding the entire watershed of Winyah Bay is 227,200 people (SC DNR, 2009). Winyah Bay has several competing uses including industrial, recreational, and agricultural activities. The five lakes that drain into the watershed are used for industrial and recreational purposes, supplying power, and supplying irrigation (SC DNR, 2009). A majority of the water that drains into Winyah Bay is used for thermoelectric power (83.5%), industry (10.0%) and water supply (6.0%) (SC DNR, 2009).

Sampling for the present study occurred in both Charleston Harbor and Winyah Bay. Intertidal sediment was collected from five sites within Charleston Harbor (Fig.1; Table 1) and five sites within Winyah Bay (Fig. 2; Table 2). Sea surface microlayer samples (n = 1) were collected from six sites in Charleston Harbor (Fig. 1; Table 1) and six sites in Winyah Bay (Fig. 2; Table 2). Sample sites were selected to be upstream of the estuary, below the confluence of the rivers feeding the estuary, in the middle of the estuary, and near the mouth of the estuary emptying into the Atlantic Ocean. Sampling in Charleston Harbor and Winyah Bay occurred June through August 2014. The average tidal range of Charleston Harbor and Winyah Bay is 1.5 m and 1.4 m, respectively.

Table 1
Sample locations in Charleston Harbor. Intertidal sediments (n = 9–12 per site) are designated as IS and sea surface microlayer samples (n = 1 per site) are designated as SML. GPS is recorded in degree decimal (DD). *designates sample sites with (n = 9 per site).

Sample site	Sample type	GPS (DD)
Daniel Island	IS	32.81913, −79.91614
Grice Cove	IS	32.74948, −79.89529
Sullivan's Island	IS	32.75902, −79.85950
Crab Bank*	IS	32.78048, −79.88591
Shute's Folly*	IS	32.77855, −79.91403
Ashley River	SML	32.79338, −79.97152
Cooper River	SML	32.90416, −79.948753
Wando River	SML	32.82446, −79.90645
James Island Creek	SML	32.75748, −79.94451
Middle of Harbor	SML	32.75973, −79.92520
Shem Creek	SML	32.78890, −79.88670