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Abundant plankton-sized microplastic particles in shelf waters of the northern Gulf of Mexico☆

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ABSTRACT

Accumulation of marine debris is a global problem that affects the oceans on multiple scales. The majority of floating marine debris is composed of microplastics: plastic particles up to 5 mm in diameter. With similar sizes and appearances to natural food items, these small fragments pose potential risks to many marine organisms including zooplankton and zooplanktivores. Semi-enclosed seas are reported to have high concentrations of microplastics, however, the distribution and concentration of microplastics in one such system, the Gulf of Mexico, remains unknown. Our study documented and characterized microplastics in continental shelf waters off the Louisiana coast in the northern Gulf of Mexico, using bongo nets, neuston nets, and Niskin bottles. Additionally, we compared the size distributions of microplastics and zooplankton collected using the nets. Plastics were manually sorted from the samples, documented, and measured using digital microscopy. Confirmation of putative plastics was carried out by hydrofluoric acid digestion and a subsample was analyzed using FTIR microscopy. Estimated concentrations of microplastics collected on the inner continental shelf during this study are among the highest reported globally. Total microplastic concentrations ranged from 4.8 to 8.2 particles m^{-3} and 5.0 −18.4 particles m^{-3} for the bongo and neuston samples, respectively. Niskin bottles collected smaller plastic particles than the nets and indicated total microplastic concentrations (primarily fibers) from 6.0E4 − 15.7E4 particles m^{-3}. Microplastic concentrations were greater than the abundances of all but four of the five most abundant taxa from bongo nets and were not statistically different from the abundances of any of the most numerous taxa from neuston nets. Sizes of microplastics and zooplankton partially or completely overlapped, suggesting the potential for confusion with natural prey.

1. Introduction

Over the past decade, efforts to document the distribution of plastics in the marine environment have increased. Plastic debris has been documented in oceanic and littoral waters from the equator to the poles, both in surface waters and at depth (Ryan and Moloney, 1993; Barnes et al., 2009; Eriksen et al., 2014), and even on some of the world's most remote beaches (Benton, 1995; Gregory, 1999). The lightweight and durable nature of plastics, combined with massive global production (millions of tonnes annually), make these versatile compounds a persistent component of marine debris (Moore, 2008; Thompson et al., 2009; Andrady, 2011). Jambeck et al. (2015) estimated that 275 million tonnes of plastic waste was generated in 192 coastal countries in 2010, and of this total, an estimated 4.8–12.7 million tonnes entered the ocean, equivalent to 1.7–4.6% of the total plastic waste generated.

Ocean surveys around the world dedicated to assess the type and abundance of floating marine debris have indicated that the majority (60–90%) is composed of plastic (Lecke-Mitchell and Mullin, 1997; Barnes et al., 2009; Ryan et al., 2009; Ryan, 2013; Cozar et al., 2014; Eriksen et al., 2014; Bergman et al., 2015). The sources of marine plastic debris can be varied, originating from fishing, aquaculture, and shipping. However, the majority (approximately 80%) likely originates from terrigenous sources via wastewater effluent, run-off, and rivers (Andrady, 2011; Murphy et al., 2016). While most plastics in the literature on marine debris are macroscopic, it has been suggested that the most abundant size fractions of plastics in the oceans are smaller than 5 mm (Eriksen et al., 2014). Microplastics is the collective term to describe a heterogeneous mixture of plastic particles, of various

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shapes, with a maximum diameter of 5 mm (Moore, 2008; Arthur et al., 2009).

There are many sources of microplastics. These include: small pellets manufactured as commercial and industrial scrubbers, abrasives, or precursor resins for other plastic products (Hidalgo-Ruz et al., 2012); fibers and fragments derived from the deterioration of larger plastic products including laundering of synthetic fabrics; and microbeads added to cleansers and toothpastes as abrasives and colorants. Full degradation of plastic particles (mineralization) does not occur in the ocean on any appreciable scale; however, photo-degradation and mechanical stress tend to break plastics down into progressively smaller fragments over time (Derraik, 2002; Thompson et al., 2004; Ryan et al., 2009; Barnes et al., 2009). The size range of microplastics (0.1–5 mm) documented in sea surface and water column studies from a variety of ocean basins encompasses the size range of the majority of mesozooplankton (0.2–20 mm; Sieburth et al., 1978).

Although microplastics are ubiquitous components of micromarine debris (Carpenter and Smith, 1972; Moore et al., 2001; McDermid and McMullen, 2004; Thompson et al., 2004; Eriksen et al., 2013, 2014), there are regions where concentrations are particularly high. Accumulation and persistence of microplastics in convergent zones of oceanic subtropical gyres is well-documented (Moore et al., 2001; Goldstein et al., 2012; Eriksen et al., 2014; Cozar et al., 2014). However, generation and accumulation is also likely to occur in industrial coastal areas, gulfs, and bays surrounded by densely populated coastlines. Measurements of microplastics in a Swedish fjord and harbor area adjacent to a polyethylene production plant showed concentrations of approximately 100,000 plastic particles m^{-3} [A,B]. Measured concentrations of 243,853 particles km^{-2} in the Mediterranean Sea were comparable to the average concentrations measured in the inner accumulation zones of the subtropical ocean gyres and these high concentrations are believed to be a consequence of elevated plastic input and limited exchange with the Atlantic Ocean (Collignon et al., 2012; Cozar et al., 2014). Other studies have shown somewhat higher abundances in areas of semi-enclosed basins, with concentrations of 11.3 particles m^{-3} in the Baltic Sea (Setälä et al., 2016). The Black Sea, with extremely limited exchange into the Mediterranean Sea, through the Bosphorus and Dardanelles Straits, has been reported to have microplastic abundances as high as 3.3E3 particles m^{-3} (Aytan et al., 2016).

Like the Mediterranean Sea, the Gulf of Mexico (GOM) is a semi-enclosed sea that is largely surrounded by continental landmasses and receives discharge from the Mississippi, Atchafalaya, Mobile, and other large river systems. The Mississippi River drains most of the large, urban, population centers in the central United States. The average discharge of the Mississippi is 16,990 $m^3\ s^{-1}$. Consequently, it has the potential to introduce massive quantities of plastic originating from its drainage basin into the GOM. Floating macroscopic plastic debris is abundant and widely distributed in the northern GOM (Lecke-Mitchell and Mullin, 1992, 1997). However, despite an initiative coordinated by NOAA and its partners to improve monitoring and assessment methods to quantify the amounts, sizes, and composition of marine litter (Kershaw et al., 2011), there do not appear to have been any measurements of the distribution of pelagic microplastics anywhere in the GOM.

Therefore, goals of this preliminary and exploratory pilot study in the GOM were as follows: (1) to determine if microplastics were present in coastal shelf waters of the northern GOM; (2) if microplastics were present, to estimate their concentrations; (3) to determine the size ranges of microplastics; and (4) to document the sizes and types of zooplankton that co-occurred with microplastics.

2. Materials and methods

2.1. Sample collection

Samples were collected in September 2015 during part of a 24 h cruise on the *R/V Pelican* at four stations off the Louisiana coast in the GOM (Fig. 1). Conditions were moderately rough throughout the cruise with wave heights estimated at 1.2–1.5 m. Water column samples were collected using a 60 cm diameter bongo net fitted with 335 μm mesh nets deployed in an oblique tow from a depth of approximately 15 m to the surface (Table 1). Tow durations lasted an average time of 3.6 (±1.5) min. The volume of water filtered was determined using a General Oceanics flowmeter (Model No, 2030R) with a high-velocity rotor placed slightly off-center in the mouth of each net. Neuston tows used a 60 cm ring net with 335 μm mesh equipped with floats and weight that enabled it to sample the surface water with approximately 70% of the frontal area of the ring submerged. This enabled collection of zooplankton and microplastics from the upper 40 cm of the ocean. The distance that the neuston net sampled was estimated from shipboard GPS data using a Matlab script. This was multiplied by the frontal area of the net and adjusted to reflect 70% submergence to estimate the volume sampled (Table 1). The ends of both the bongo nets and neuston nets were folded and tied shut to avoid using a plastic (PVC) cod end.

Upon retrieval, the nets were rinsed down from the outside of the net using the onboard freshwater source to limit potential microplastic contamination. The samples were washed from the nets into a stainless steel sieve (50 μm mesh) from which they were transferred into glass jars with metal lids containing chilled 95% non-denatured ethanol.

Bulk seawater samples were collected using 5 L Niskin bottles attached to the ship's CTD-rosette. Bottles were triggered individually to close at approximately 1 m, 5 m, and 10 m from the surface, except at Station 1 (ST1), where bottles were accidently triggered at distances of approximately 1 m, 5 m, and 10 m from the seafloor due to a communications error (Table 1). Duplicate 250 ml aliquots were collected from each Niskin bottle and stored at 4 °C.

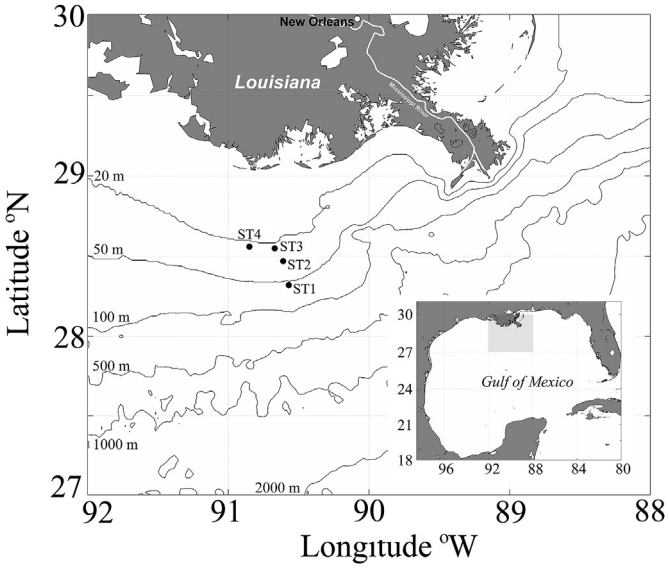

Fig. 1. Sampling locations off the Louisiana Coast in the northern Gulf of Mexico. The shaded area on the inset map indicates the area depicted on the main map.