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Relationships among the abundances of plastic debris in different size classes on beaches in South Korea

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ABSTRACT

Plastic debris on six beaches near the Nakdong River Estuary, South Korea, was sampled in May and September 2012 and classified into three size classes, large microplastics (1–5 mm), mesoplastics (5–25 mm), and macroplastics (>25 mm). The relationships among the abundances of the size classes were then examined. The abundances of each size category in May (before rainy season) and in September (after rainy season) were 8205 and 27,606 particles/m^2 for large microplastics, 238 and 237 particles/m^2 for mesoplastics, and 0.97 and 1.03 particles/m^2 for macroplastics, respectively. Styrofoam was the most abundant item both in microplastic and mesoplastic debris, while intact plastics were most common in macroplastic debris. The abundances of meso- and micro-plastics were the most strongly correlated. There was a higher correlation between the abundances of macro- and meso-plastics than between macro- and micro-plastics.

1. Introduction

Plastics are widely used because of their lightweight nature, durability, potential for diverse applications, and low price (Thompson et al., 2009a). In recent years, annual plastics production has increased drastically, reaching 230 million tonnes in 2009 (PlasticsEurope, 2010). Large amounts of plastic are consigned to landfills, recycled, or are still in use. However, large amounts end up as marine debris as a result of insufficient treatment capacity, accidental inputs, littering, or illegal dumping (Barnes et al., 2009; Hopewell et al., 2009). Numerous studies in recent decades have reported that plastics are the main component of marine debris, regardless of time or location (e.g., Barnes et al., 2010; Ivar do Sul et al., 2009; Matsumura and Nasu, 1997; OSPAR, 2007; Storrier et al., 2007).

Plastic debris causes physical harm to marine life as a consequence of ingestion and entanglement (Good et al., 2009; Hong et al., 2013; Jacobsen et al., 2010; Laist, 1987). Moreover, the debris may be chemically harmful because plastics may contain chemicals added in the manufacturing process or adsorbed from the environment (Browne et al., 2009; Engler, 2012). Plastic debris eventually undergoes fragmentation on beaches or at sea, forming small-sized particles (Barnes et al., 2009; Cooper and Corcoran, 2010). These particles can be widely distributed and with decreasing size are more likely to be ingested by marine life (Andrady, 2011; Ng and Obbard, 2006). Recent studies have investigated the potential for microplastics debris to transport toxic chemicals to organisms including humans (Teuten et al., 2007; Thompson et al., 2009b).

Microplastics are manufactured as small plastic particles to produce resin pellets, scrubbers for cosmetics, or abrasives for blasting (primary microplastics) or they are generated by the fragmentation of larger plastic products (secondary microplastics) (Andrady, 2011; Cole et al., 2011; Gregory, 1996; Mato et al., 2001). Fragmented particles account for the majority of micro-plastics and have various origins (Gregory and Andrady, 2003), which make proper control difficult.

In order to develop management strategies, information about the abundance and spatiotemporal distribution of microplastics is essential. However, relevant data have not been well documented yet because microplastic surveys require much more time, labor, and technical support in comparison with surveys of larger debris (Cole et al., 2011).

If a reasonable correlation exists between microplastics and more easily surveyed larger plastics, this relationship could be

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useful for collecting information on the distribution and abundance of microplastics. A few studies have examined the size-dependent abundance of plastic debris (Claessens et al., 2011; Costa et al., 2010; Martins and Sobral, 2011). To the best of our knowledge, however, relationships among the abundances of beached debris in different size classes have not been reported. This study aimed to determine relationships among the abundances of macro-, meso-, and micro-plastic debris size classes to provide insights for the development of efficient microplastic survey methods.

2. Methods

The study was conducted on a sand bar in the Nakdong River estuary and on five beaches on Geoje Island (Fig. 1). Site Jinwoo (JW) was proximate to the river mouth and five sites were selected with increasing distance from JW.

The Nakdong River, the longest river in South Korea, flows south through highly developed and densely populated Busan metropolitan city. Debris from the Nakdong River watershed occasionally drifts ashore in the northeastern part of Geoje Island during the monsoon season in summer. Initial surveys at the six sites were conducted before rainy season in May 2012 and subsequent surveys at three of the six sites (HN, WH, and MS) took place after rainy season in September 2012 (Fig. 1).

This study classified three size classes of 'large microplastics' (1 to <5 mm) (hereafter microplastics mean large microplastics), 'mesoplastics' (5 to <25 mm), and 'macroplastics' ($\geqslant$25 mm). The United Nations Environment Programme/Intergovernmental Oceanographic Commission (UNEP/IOC) recommends a lower limit of 25 mm for macrodebris in their guidelines (Cheshire et al., 2009). Many researchers have also operationally defined microplastics as particles of up to 5 mm, which are readily ingested by organisms (Kershaw and Leslie, 2012). Particles of which size are smaller than 1 mm cannot be identified and counted without microscopic observation and subsequent spectroscopic confirmation. Thus, the targeted microplastic size range was confined to 1–5 mm in this study.

At each sampling site, we selected two 10 $\times$ 10 m large quadrats (placed in locations that visually appeared to have the maximum and minimum amounts of beached debris) along the strandline (Fig. 2) and collected all macroplastic items (>25 mm) within large quadrats. Within each 10 $\times$ 10 m large quadrat, five small quadrats (0.5 $\times$ 0.5 m) were randomly selected for microplastic and mesoplastic sampling. All natural and artificial debris within a depth of 5 cm in the quadrats was sieved sequentially with 5- and 1-mm Tyler sieves (CISA, Spain) onshore; debris on the sieves was stored in zipper bags and brought to the laboratory. In the case of wet sand samples, sieving was conducted after air drying in the laboratory to avoid contamination of the mesh screen cover.

After removing natural debris, the remnants in each size class were classified into five categories: intact plastics (which have original production form), fragments, Styrofoam (expanded polystyrene), other foamed plastics, and pellets. Styrofoam and other foamed plastics were not counted separately as intact items or fragments because intact samples were rare.

Every count in each size class was recorded. The abundances and relative proportions of the plastic categories were calculated for each size class in a total of 18 large quadrats (six sites $\times$ two large quadrats in May and three sites $\times$ two large quadrats in September). Relationships among the abundances of micro-, meso-, and macro-plastic groups were identified using Spearman's rank correlation (rho). The relationship between the abundances of micro- and meso-plastics was determined using general linear regression analysis.

3. Results

3.1. Abundance and composition of plastic debris

Overall abundances of plastic debris were increased by two or three orders of magnitude with decreasing size class in May and September (Fig. 3). The average abundances of microplastic debris were 8205 particles/m^2 in May and 27,606 particles/m^2 in September (Fig. 3a and Table S1). The highest microplastic abundance (92,217 particles/m^2) among the large quadrats was found in

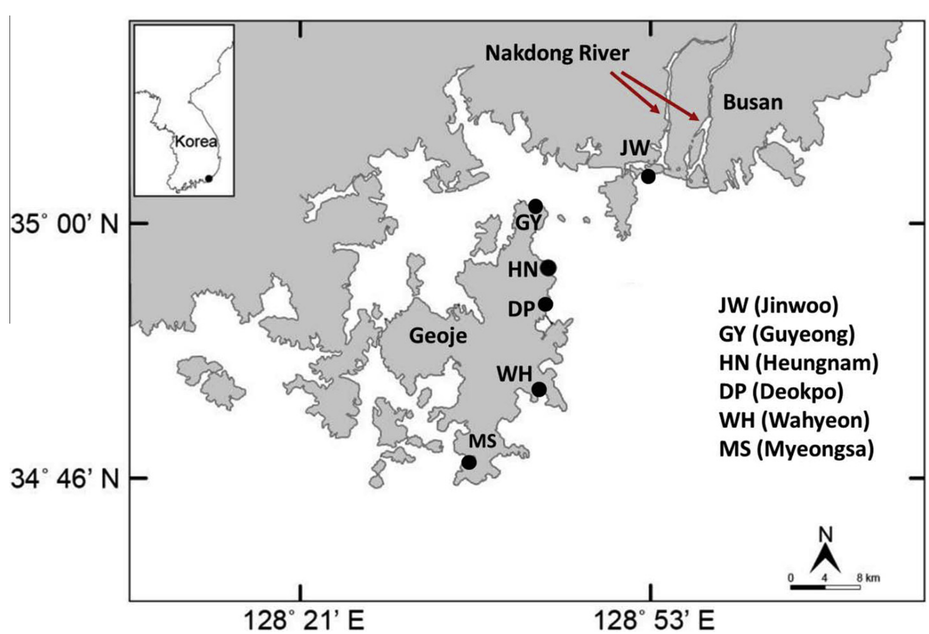

Fig. 1. Sampling locations for beached plastic debris: First sampling campaign was conducted at all sites before rainy season in May 2012, and second sampling was conducted at HN, WH, and MS after rainy season in September 2012.