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Macrodebris and microplastics from beaches in Slovenia

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ABSTRACT

The amount of marine debris in the environment is increasing worldwide, which results in an array of negative effects to biota. This study provides the first account of macrodebris on the beach and microplastics in the sediment (shoreline and infralittoral) in relation to tourism activities in Slovenia. The study assessed the quality and quantity of macrodebris and the quality, size and quantity of microplastics at six beaches, contrasting those under the influences of tourism and those that were not. Beach cleanliness was estimated using the Clean Coast Index. Tourism did not seem to have an effect on macrodebris or microplastic quantity at beaches. Over 64% of macrodebris was plastic, and microplastics were ubiquitous, which calls for classification of plastics as hazardous materials. Standard measures for marine debris assessment are needed, especially in the form of an all-encompassing debris index. Recommendations for future assessments are provided for the Adriatic region.

1. Introduction

Global population is expected to reach 9.5 billion people by 2050, with the highest growth registered in developing nations (UN/DESA, 2014). It is likely that there will also be an increase in the demand for disposable consumables – the annual plastic production in 2011, for example, was 280 million tons, more than 186 times the amount produced in the 1950s (Depledge et al., 2013). An estimated ten percent of this accumulates as persistent plastic debris in the ocean (Barnes, 2002; Derraik, 2002; Thompson et al., 2009b), converging to mid-ocean sub-tropical gyres (Kaiser, 2010; Kershaw et al., 2011). In 2010, the North Pacific gyre contained more than double the amount of marine debris (750.000 pieces km^{-2}) detected nine years earlier (330.000 pieces km^{-2}) (Moore et al., 2001; Boerger et al., 2010). Microplastic (plastic particles < 5 mm) convergence zones have also been observed in the South Pacific and in the North Atlantic (Law et al., 2010; Eriksen et al., 2013). In the North Pacific and in the South Atlantic, larger plastic debris accumulate to form giant 'garbage patches' (Pichel et al., 2007; Ryan, 2013), reinforcing the idea that marine debris is a global issue that needs to be addressed urgently (Barnes et al., 2009; Kershaw et al., 2011; Depledge et al., 2013).

Ocean currents spread large amounts of debris from industrialized and densely populated areas to even the most remote and unpopulated coastal regions (McDermid and McMullen, 2004; Barnes et al., 2009; Santos et al., 2009; Hirai et al., 2011). Yet, only a few of the main sources and sinks of marine debris have been identified worldwide (Ryan et al., 2009; Browne et al., 2011). In an effort to counter this issue, current studies aim to assess the global (coastal and offshore) distribution of the two main categories: macrodebris (size > 5 cm) and microplastics (Thompson et al., 2004; UNEP, 2005; Claessens et al., 2011; Collignon et al., 2012; Van Cauwenberghe et al., 2013). In Europe, this knowledge will help countries to conform to the Marine Strategy Framework Directive and achieve 'good environmental status' by 2020 (Galgani et al., 2010).

Marine debris is defined as any persistent, man-made solid waste discarded into the marine environment (Galgani et al., 2010; CBD, 2012). Most of it is made of plastic (Barnes et al., 2009) that originates from both land- and ocean-based sources, and which interacts with at least 663 species worldwide (CBD, 2012). Plastics foster a myriad of negative effects on marine organisms, such as entanglement, intestinal blockage, suffocating,

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smothering, and ghost fishing (Gregory, 2009). These further cause negative physiological effects, lower fitness, reproductive failure, changes in community structure, and death (Spear et al., 1995; Barnes, 2002; Derraik, 2002). Approximately 370 species have been found entangled in or having ingested marine debris worldwide (CBD, 2012; Galgani et al., 2013). For example, all seven species of marine turtles, at least 14 cetacean species, 20 pinniped species, and 56 marine or coastal bird species have been found entangled in plastics worldwide (Katsanevakis, 2008). Additionally, marine birds are known to ingest considerable amounts of plastic and accumulate plastic-derived chemicals in their tissues (Tanaka et al., 2013; Acampora et al., 2014).

Microplastics were first detected in the North Atlantic four decades ago (Carpenter and Smith, 1972). They are minute fragments of plastic debris, which are divided into small (<1 mm in diameter) and large (1–5 mm in diameter) particles (Gregory and Andrady, 2003; Betts, 2008; Moore, 2008; Fendall and Sewell, 2009; Imhof et al., 2012). Microplastics consist of nylon, polyester, acrylic, polypropylene, polyethylene, poly(ethylene–propylene), polyvinyl chloride, polyvinyl alcohol, polystyrene, polyester, polyurethane, polyacrylonitrile, alkyd, alkyd resin, and polyamide fibers, though their main component is usually synthetic polymer(s) (Barnes et al., 2009; Leslie et al., 2011; Vianello et al., 2013). Degradation processes of plastics are extremely slow, such that particles persist for very long periods of time in the marine environment (Hidalgo-Ruz et al., 2012) and become readily available to biota. Microplastic ingestion has been observed in a wide range of marine taxa, including crustaceans, molluscs, fish, birds, and mammals (Thompson et al., 2009a; Fossi et al., 2012; Lusher et al., 2013; Wright et al., 2013; Watts et al., 2014), and can result in a wide range of negative effects, such as blockage of the intestinal tract and abrasion in small organisms (similarly to the effects of macroplastics in large biota) (Wright et al., 2013). Microplastic ingestion could also disrupt the endocrine and reproductive systems, diminish energy rates, and increase toxic load in smaller organisms (Galgani et al., 2010). Moreover, these particles are incorporated into marine food webs (Farrell and Nelson, 2013; Setälä et al., 2014) and provide a substrate for leached contaminants, which could also bioaccumulate (Teuten et al., 2009).

Tangible damages to humans caused by marine debris are difficult to estimate. The tourism industry, for example, faces monetary loss due to both a decrease in activity on polluted beaches and the costs of beach cleaning (Sheavly and Register, 2007; Jang et al., 2014). Beachgoer safety issues arise from broken glass, medical waste, fishing lines, discarded syringes, and possibly from bacterial contamination of discarded hygiene waste (Sheavly and Register, 2007). On the other hand, fishermen face propeller entanglement, damage to fishing gear, and time losses due to gear cleaning as a result of macroplastic pollution (Nash, 1992; van Franeker et al., 2005). It is still uncertain, though, whether marine debris can reduce fish quality through debris ingestion or tainting (van Franeker et al., 2005). Moreover, indirect economic impacts result from the degradation of the marine environment. An increase in tourism may enhance debris accumulation in the Adriatic Sea, which already faces a dense concentration of debris in the seafloor (Galgani et al., 2000). In the case of Slovenia, the amounts and types of debris found along the 46.7 km appear to be different (Palatinus, pers. comm.), suggesting that human populations may have distinct impacts in each beach location.

The present study assessed (1) the quality and quantity of macrodebris, and (2) the quality, size and quantity of microplastics on beaches in Slovenia, contrasting those which were under the influences of tourism (touristic, T) and those that were not (non-touristic, NT). Finally, it assessed the cleanliness of Slovenian beaches using the Clean Coast Index (Alkalay et al., 2007). The results provide the first assessment of macrodebris at the beach and microplastics in the sediment in relation to tourism activities along the coast of Slovenia.

2. Methods

2.1. Study area

Slovenian tourism has increased by 160% in the last fifteen years, and the country welcomed approximately three million tourists in 2011 (Maja Pak, Director of Slovenian Tourist Board, pers. comm.). The present study took place during the peak of the tourist season, in July 2012. Point samples were collected at six beaches along the Slovenian coast (Fig. 1A), Debeli Rtič (T1), Jadranska (NT1), Simonov Zaliv (T2*), Bele Skale (NT2), Portorož (T3*), and Seča (NT3). Sampling sites were chosen based on the level of urbanisation and human presence, such that areas of high urbanisation and flux were considered as touristic (T1, T2*, and T3*) and those with limited (or absence of) urbanisation and visit as non-touristic (NT1, NT2, and NT3).

The Slovenian coast is part of the Gulf of Trieste, which is a shallow (20 m depth), semi-enclosed basin with horizontal bathymetry on its southern part (Malačič et al., 2012). Four rivers contribute to fresh water input to the Gulf, two in Italy (Isonzo and Timavo), one in the proximity of Koper (Rižana), and the other further south, in Seča (Dragonja), shown in Fig. 1B.

2.2. Macrodebris

2.2.1. Sampling

Beaches are cleaned on a monthly basis in Slovenia, though two of the three touristic ones, Portorož (T2*) and Simonov Zaliv (T3*), were cleaned daily (represented by the symbol "*") throughout the summer at 6 a.m. In order to account for this and to estimate the macroplastics accumulated in the last 24 h, sampling was performed before the beach cleanup (5 a.m.). One 50-m transect was placed randomly along the beach, parallel to the shoreline. All debris ⩾2 cm was collected in the area ranging from the shoreline to the upper beach limit (determined by the presence of vegetation, dunes, or rocks) within the 50-m transect, as shown in Fig. 2. Sampling was performed according to the operational guidelines for rapid beach debris assessment described by Cheshire et al. (2009).

2.2.2. Analysis

Particles were classified in relation to 59 categories and 8 major groups (according to a combination of the approaches used by Cheshire et al., 2009 and Palatinus, pers. comm.), counted, and weighed (only major groups). Cigarette filters were analysed separately from other plastic items due to the high relevance of this category to infer the land-based origin of the debris (Oigman-Pszczol and Creed, 2007). Macrodebris quantity (count and weight) was extrapolated for six of the debris categories (Table 1) for the two beaches with daily cleaning (Portorož – T2* and Simonov Zaliv – T3*), in order to compare with that of beaches cleaned monthly. The extrapolation was possible because the date of last monthly cleaning event of all beaches was known (June 26th, 2012) and because the Slovenian local authorities recorded the quality and estimated quantity (count and weight) of macrodebris collected daily at Portorož (T2*) and Simonov Zaliv (T3*) during weekdays and weekends in July 2012. Extrapolation values were obtained with the equation:

$$\begin{aligned}&\text{Extrapolated macrodebris quantity}\\&\quad= \text{sampled quantity} + (\text{estimated quantity per weekday} * \text{Tw})\\&\qquad + (\text{estimated quantity per weekend day} * \text{Tw-e})\end{aligned}$$