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Seasonal and spatial variations of marine litter on the south-eastern Black Sea coast

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ABSTRACT

The south-eastern Black Sea coast in Turkey was evaluated for marine litter composition and density covering nine beaches during four seasons. The marine litter (> 2 cm in size), was collected from the coast and categorized into material and usage categories. The data analysis showed that plastic was the most abundant litter (≥ 61.65%) by count and weight followed by styrofoam and fabric. The marine litter density ranged from 0.03 to 0.58 with a mean (± SD) of 0.16 ± 0.02 items/m^2 by count. Based on weight, it varied between 0.44 and 14.74 g/m^2 with 3.35 ± 1.63. The east side had a higher marine litter density than the west side with significant differences between beaches. The variations due to different seasons were not significant for any beach. The results of this study should provide baseline information about the coastal marine pollution and will assist the mitigation strategies.

1. Introduction

Marine litter is a significant environmental problem on global scale that harms not only aquatic resources but also imposes health and aesthetic problem (UNEP, 2009). According to Gall and Thompson (2015), 693 marine species are adversely affected by marine litter and the majority of them are reported to encounter plastic items. Several studies have reported plastic as the most abundant item in marine litter (Table 1) and according to Jambeck et al. (2015), every year up to eight million tonnes, 49% of which are produced by China, Indonesia, Philippines and Vietnam, enters the ocean. The majority of it comes from plastic bags, food and beverage containers (Thiel et al., 2013; Topçu et al., 2013).

The Black Sea is bounded by Turkey on the southern end with a coastal population of 23.7 million (TUIK, 2015). Several studies have reported plastic as the most dominant item, accounting for > 78% of total marine litter in the Turkish region (Aydın et al., 2016; Topçu et al., 2013). The composition of marine litter found on the beaches of the western Black Sea (in this paper, Black Sea refers to the Turkish Black Sea), indicates that half of the labelled litter is transported from other countries through the sea (Topçu et al., 2013). Furthermore, only 1.5% of the total plastic waste generated in Turkey is estimated to be mismanaged (Jambeck et al., 2015).

Though the south-western coast of the Black Sea has been exclusively examined for marine litter, no such study has been done on the south-eastern of the Black Sea. The aim of the present study was to evaluate the composition of marine litter and its density on the south-eastern Black Sea coast. This evaluation was carried out from the east to west coast of the south-eastern Black Sea during all four seasons. The results of this study will not only provide baseline information about the coastal litter pollution, but will also assist mitigation strategies for marine pollution.

2. Materials and methods

2.1. Study area

The study area is covering six provinces: Rize, Trabzon, Giresun, Ordu, Samsun and Sinop. Their total population is 3.7 million and ~ 80% of the regional population is settled and distributed along the coastal line (TUIK, 2015). The south-eastern Black Sea coasts receive a small number of tourists and are relatively crowded in summer. A total of nine stations (Fig. 1) with a fifty-meter-long transects (with widths varied between 5.6 m to 23 m) each were randomly selected through the following steps (Cheshire et al., 2009);

i. They were accessible during all four seasons.
ii. They were not located on a mouth of a river or near a dumping area.
iii. They have not been screened by any anthropogenic structures.

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Table 1
Marine litter densities (mean ± SD) in this study and other regions of the world.

Region	Density (items/m^2)	Plastic (%)	Reference
South-eastern Black Sea coast, Turkey	0.03–0.58 (0.16 ± 0.02)	61.65	This study
South-western Black Sea coast, Turkey	0.09–3.14 (0.88 ± 0.94)	91	Topçu et al. (2013)
Coastal Area of Cilician Basin, Turkey	0.02–5.15 (0.92 ± 0.36)	80	Aydın et al. (2016)
Monterey, USA	0.03–17.10 (1.00 ± 2.10)	68	Rosevelt et al. (2013)
Bootless Bay, Papua New Guinea	1.20–78.30 (15.30)	89	Smith (2012)
Kaohsiung, Taiwan	0.90–3.227	77	Liu et al. (2013)
Northwestern Adriatic beaches	0.16–0.57 (0.20)	81.10	Munari et al. (2016)
China	0.04	48	Zhou et al. (2016)
Rizhao City, China	0.08–0.45 (0.26)	20	Zhou et al. (2015)
Northern Taiwan	0.05–0.61 (0.19 ± 0.21)	46.75–94.05	Kuo and Huang (2014)
Australia	0.24	91.4	Smith and Markic (2013)
South China Sea	0.01	42	Zhou et al. (2011)
Santa Catarina, Brazil	0.12–4.98 (1.02 ± 1.52)	90	Widmer and Hennemann (2010)

2.2. Litter collection, categorization and assessment

A pre-survey was conducted in September 2012 to determine the stations and to make an initial beach clearance for the subsequent surveys. The surveys were conducted seasonally (on first days of December 2012, March 2013, June 2013 and September 2013) to determine marine litter density and composition.

All human-induced litter items in the transects greater than 2 cm diameter were collected by hand from shoreline to shore edge line. Natural items (i.e. sea weeds, animal bones, natural wood) were not assessed. After the collection of litter items, they were categorized according to material and usage categories. Litter items were classified into six material categories (plastic, styrofoam, fabric, paper, metal and glass) and nine usage categories (beverage, general packaging, food packaging, clothing, medical waste, fishing equipment, household goods and undefined). Because of very low proportion of medical waste, fishing equipment and household goods, they were grouped in "other" category.

The categorized litter items were counted and weighed in order to estimate the litter density by number and weight. The litter density was calculated by using the following formula;

$$D = N/(w*l)$$

where D is the density of litter items, N is the total number or total weight of the litter items collected from the transect, w is the width (vertical distance between the shoreline and shore edge line) of the transect in meters, l is the length (50 m) of the transect in meters. The potential sources of litter items (land-based and sea-based sources) were determined by the method provided by Ribic et al. (2011). After categorization and estimations, the litter items were thrown to the nearest garbage container.

The clean-coast index (CCI) presented by Alkalay et al. (2007) was used for evaluating the coast cleanliness. CCI was estimated for all stations in every season by using the following formula;

$$CCI = \frac{Total\ \ litter\ count\ \ on\ \ transect}{Total\ \ area\ of\ \ transect} * K$$

where K is a coefficient equal to 20 and was used for convenience to make the results clearer for the public. The CCI scale ranged 0 to > 20, with very clean as 0–2, clean as 2–5, moderately clean as 5–10, dirty as 10–20 and extremely dirty as > 20.

2.3. Data analysis

Shapiro-Wilk test (Shapiro and Wilk, 1965) was used to test the normal distribution. Because the data were not normally distributed log transformation [log(x+1)] was used to normalize distribution (Zar, 2010). One-way ANOVA was used to test for significant differences in marine litter density between seasons and stations. Significant differences were evaluated with Tukey's HSD. All statistical analyses were performed by using SPSS 23.0 for Windows (SPSS, Chicago, Illinois, USA).

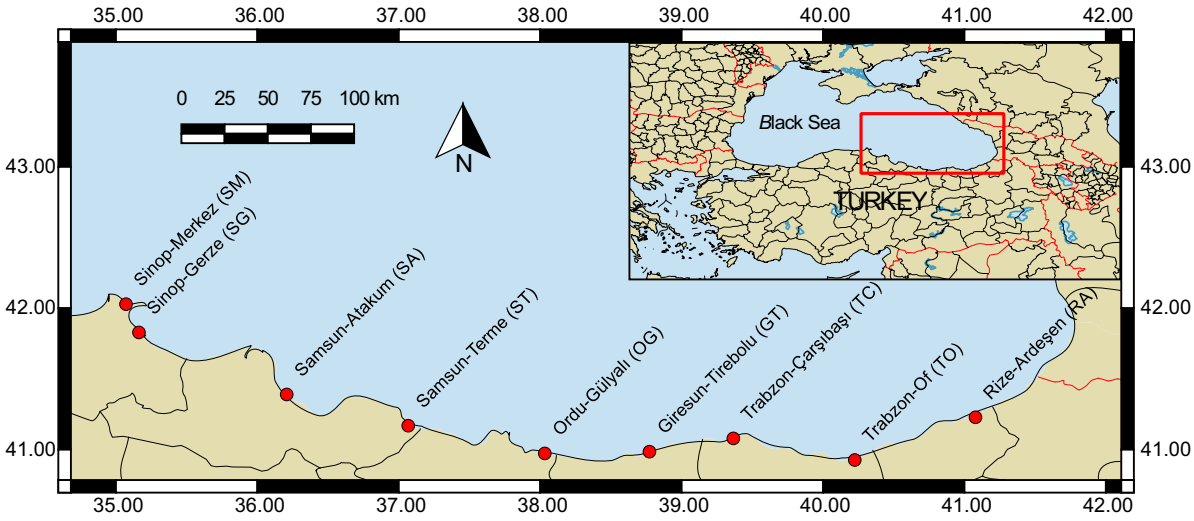

Fig. 1. Map of the study area.