OSPAR standard method and software for statistical analysis of beach litter data

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ABSTRACT

The aim of this study is to develop standard statistical methods and software for the analysis of beach litter data. The optimal ensemble of statistical methods comprises the Mann-Kendall trend test, the Theil-Sen slope estimation, the Wilcoxon step trend test and basic descriptive statistics. The application of Litter Analyst, a tailor-made software for analysing the results of beach litter surveys, to OSPAR beach litter data from seven beaches bordering on the south-eastern North Sea, revealed 23 significant trends in the abundances of beach litter types for the period 2009–2014. Litter Analyst revealed a large variation in the abundance of litter types between beaches. To reduce the effects of spatial variation, trend analysis of beach litter data can most effectively be performed at the beach or national level. Spatial aggregation of beach litter data within a region is possible, but resulted in a considerable reduction in the number of significant trends.

1. Introduction

Marine litter, here defined as anthropogenic waste dispersed in the marine environment, has become a global threat to marine ecosystems. Depending on its density, it occurs floating on the surface and in the water column or settled on the seafloor and on beaches (Browne et al., 2010). Litter can be washed onto a beach by the sea or directly deposited there by humans. Once on the beach, marine litter can, in part, be moved away again by wave action and wind. It generally accumulates as beach litter and a steady state between input and erosion is reached within at least four weeks (Ribic et al., 2010, 2012; Schulz et al., 2015). Most of the beach litter consists of plastic polymers, which break down over a time span of several hundred years (Barnes et al., 2009). Marine litter embodies a clear risk of harm to marine animals via ingestion of mesolitter (size range 0.5–2.5 cm) and microlitter (< 0.5 cm, van Franeker et al., 2011), and by entanglement in plastic items, especially filamentous macrolitter (> 2.5 cm, OSPAR, 2010; Derraik, 2002).

In 2008, the Marine Strategy Framework Directive (MSFD) of the European Union (EU) was implemented (EU, 2008, 2010). According to descriptor 10 'Marine Litter' of the MSFD, the properties and quantities of marine litter should not cause harm to the coastal and marine environment. In order to evaluate marine litter pollution for the MSFD, indicators have to be defined. In the North East Atlantic, at the OSPAR and national levels, the amount of litter on beaches, "beach litter", is one of the indicators developed for this purpose. The level of litter pollution and trends in abundance of litter items are monitored on beaches by applying a standard OSPAR monitoring protocol (OSPAR, 2010) and are analysed using the statistical methods defined in this study.

Worldwide, a number of different monitoring methods have been used to assess beach litter, such as those by Alkalay et al. (2007), Bravo et al. (2009), Cheshire et al. (2009), Opfer et al. (2012) and OSPAR (2010). Alkalay et al. (2007) only recorded plastic items and monitored transects perpendicular to the strandline. Abundances of plastic particles larger than 2 cm were chosen as basis for a simple beach litter index. Bravo et al. (2009) randomly selected beaches along the Chilean coast. These authors used densities per square meter as a litter indicator and found plastic items and cigarette butts to be the most abundant types of beach litter. Similar to the OSPAR method (2010), Cheshire et al. (2009) selected survey beaches according to criteria, such as their accessibility, a lack of beach cleaning activities and their neighbourhood to potential sources. Cheshire et al. (2009) recommend using flux rates of 77 individual litter types as a measure of pollution, rather than
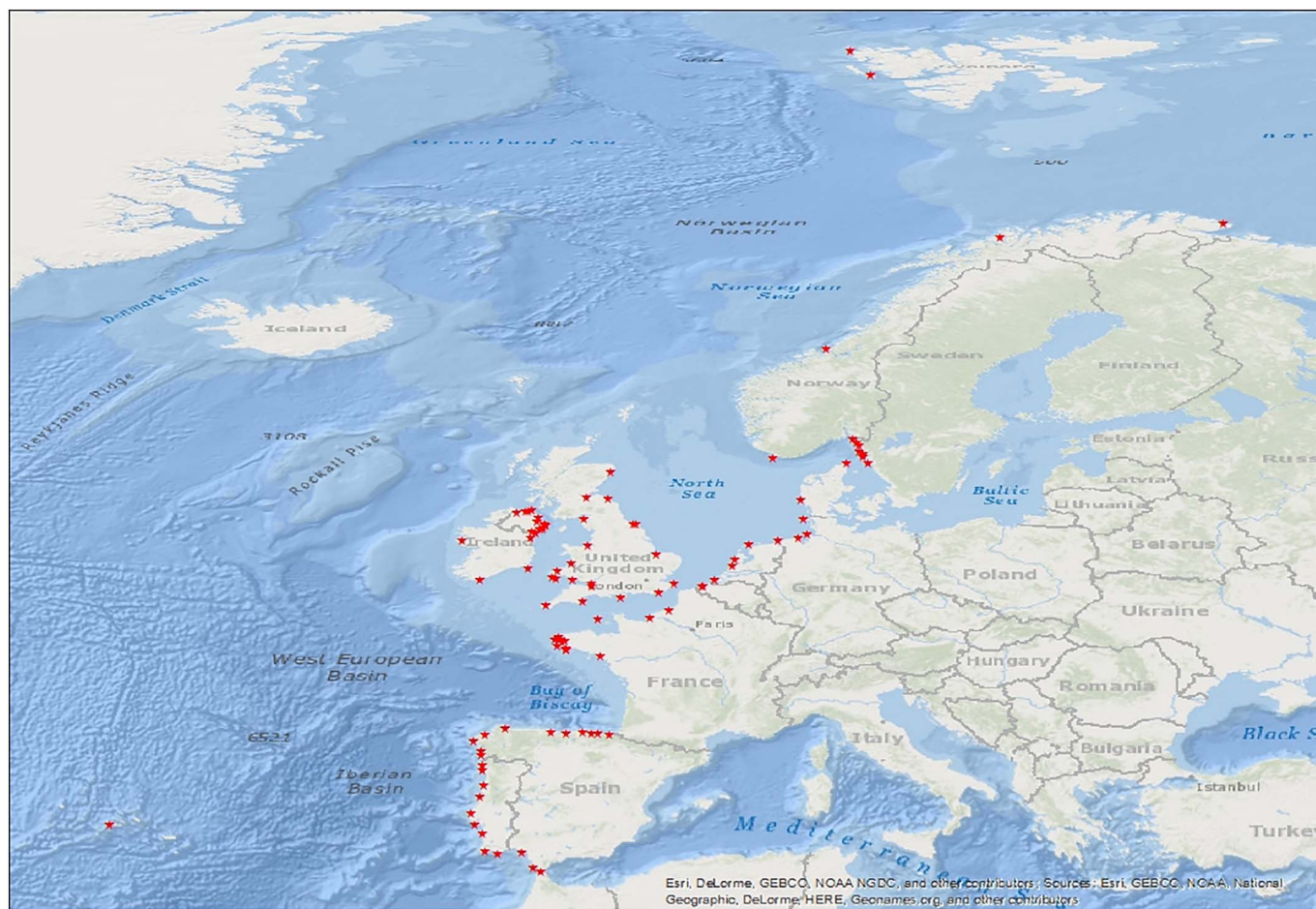
Fig. 1. Map of the OSPAR region. Blue lines confine sub-regions. Red dots mark position of beaches monitored for beach litter. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

their abundances. According to their monitoring protocol, beaches are surveyed every three months, while there is no clear definition of the length of the beach, which is surveyed. The method of Opfer et al. (2012) is based on a random selection of beach transects and the abundances of 43 individual litter types. This method defines several criteria for beach selection, such as substrate, accessibility, minimum length and cleaning activities.

The most detailed protocol for monitoring beach litter is used by OSPAR (2010). Since 2001, beach litter surveys have been carried out on 100 m stretches of coastline in a total of 129 beach survey sites bordering on the North Sea and the North-East Atlantic (Fig. 1). Surveys are carried out at regular intervals of three months and abundances of 112 different litter types are recorded. All data are entered into a central beach litter database. A selection of data from this database was analysed by Schulz et al. (2013). These authors made a first proposal for an evaluation system based on abundances and trends of individual litter types and of general categories, such as total plastic litter. However, the necessity of establishing a standard method for the analysis and assessment of beach litter data for the whole of the OSPAR region and for the MSFD, required further development. An assessment system for OSPAR beach litter data has to be robust against outliers, it must be applicable to time series of data, which are partly non-normally distributed and it has to use an objective and unbiased selection of litter types as input data. In addition, the length of the time series to be analysed and descriptive statistical parameters, need to be defined. Standard data analysis and assessment methods were proposed by the OSPAR Intersessional Correspondence Group Marine Litter (ICG-ML). OSPAR has agreed to use the proposed methods, which are described here, as the standard for the analysis of the OSPAR beach litter dataset.

Software has been developed, which fulfills the requirements mentioned above, and which can be applied easily to the OSPAR beach litter data format. The overall aims of this study were:

- To develop a transparent, effective, practical and efficient beach litter assessment method for state and trend analysis of total abundance of beach litter and the abundance of individual litter types, for OSPAR and MSFD application,
- to use the OSPAR dataset for the further development of analytic methods for beach litter data,
- to present a case study using German and Dutch beach litter data,
- to test different spatial aggregation levels for trend analysis,
- to select an optimized set of state and trend analysis methods and to implement these statistical methods in the tailor-made beach litter software, Litter Analyst.

The method was also developed to fulfil the requirements of the MSFD. Information on trends in abundance of individual litter types enables the effectiveness of measures targeted to reduce litter pollution to be evaluated. In this study, a novel standard data analysis and assessment method for OSPAR beach litter data and the software tool, Litter Analyst, used to apply this method are presented. Litter Analyst can be used to analyse the OSPAR beach litter data and any other data relying on the same or a comparable monitoring protocol, which can produce a suitable data input format. Beach litter data have been analysed statistically on a number of occasions, partly for marine regions as large as the OSPAR region (Ribic et al., 2010, 2012). However, to the knowledge of the authors, Litter Analyst is the first statistical assessment software dedicated to the analysis of beach litter data.