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Statistical analyses of the results of 25 years of beach litter surveys on the south-eastern North Sea coast

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ABSTRACT

In the North Sea, the amount of litter present in the marine environment represents a severe environmental problem. In order to assess the magnitude of the problem and measure changes in abundance, the results of two beach litter monitoring programmes were compared and analysed for long-term trends applying multivariate techniques. Total beach litter pollution was persistently high. Spatial differences in litter abundance made it difficult to identify long-term trends: Partly more than 8000 litter items year^{-1} were recorded on a 100 m long survey site on the island of Scharhörn, while the survey site on the beach on the island of Amrum revealed abundances lower by two orders of magnitude. Beach litter was dominated by plastic with mean proportions of 52%–91% of total beach litter. Non-parametric time series analyses detected many significant trends, which, however, did not show any systematic spatial patterns. Cluster analyses partly led to groupings of beaches according to their expositions to sources of litter, wind and currents. Surveys in short intervals of one to two weeks were found to give higher annual sums of beach litter than the quarterly surveys of the OSPAR method. Surveys at regular intervals of four weeks to five months would make monitoring results more reliable.

1. Introduction

During the last decades, marine litter has been a focus of interest of environmental marine science because of drastically increasing amounts of litter in all compartments of the marine environment (Barnes et al., 2009; Eriksen et al., 2014). It has potential adverse effects on biota via entanglement in nets, ropes and ribbons (Gregory, 2009; Vegter et al., 2014; Votier et al., 2011) as well as through ingestion of micro- and mesoplastics (Browne et al., 2008; van Franeker et al., 2011). In addition, drifting litter can be a vector of invasive species (Barnes, 2002; Barnes and Fraser, 2003; Barnes and Milner, 2005; Majer et al., 2012).

During the last decades, increasing numbers of scientific publications have dealt with marine litter. Most of them have been descriptive in terms of quantifying its abundance and composition or have highlighted the incidence of adverse effects on specific animal species (Brandão et al., 2011; Corcoran et al., 2009; Widmer and Hennemann, 2010). Few have dealt with the identification of trends in abundance in the marine environment (Barnes et al., 2009; Ribic et al., 2010, 2012). Nevertheless it is evident that in the North-East Atlantic and the North Sea (i.e. the OSPAR region), plastic debris comprises the major part of marine litter with a proportion of between 50% and 70% of total litter load, while the major fraction recorded on beaches is packaging material (OSPAR, 2009).

The sources of marine litter are well known, but there is still a considerable lack of knowledge concerning the importance of the different sources and the identification of items that could function as indicators for a given source (Nilsen et al., 2014). Regular long-term monitoring of marine litter is necessary to fulfil the requirements of the European Union's Marine Strategy Framework Directive (MSFD, EU, 2008) and can be used to provide trends in

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litter pollution and identify litter sources and pathways.

On the German North Sea coast, beach litter monitoring has been carried out as part of two different monitoring schemes using slightly different methods. Since 2002, the standardized monitoring protocol of OSPAR (2010) has been applied at four beaches with counts at intervals of three months. The second method has been performed by three non-governmental environmental organizations (NGOs), namely Der Mellumrat e.V., Verein Jordsand e.V., and Schutzstation Wattenmeer e.V., at 15 beaches with counts at intervals of three days to two weeks (Clemens et al., 2002; Fleet, 2003). The two methods have used different categorizations of beach litter. Data from the NGO surveys comprise a long and scientifically valuable time series starting in 1989, which until present have only been investigated by descriptive statistics and simple non-parametric time series analyses (Clemens et al., 2002; Fleet, 2003). Schulz et al. (2013) analysed the entire OSPAR data applying non-parametric time series analyses and cluster analyses. These authors found various significant trends, which showed high spatial heterogeneity, but a comparison of the OSPAR method with other survey programmes is still missing.

Results of this study shall help to improve the efficiency and effectiveness of beach litter monitoring on the German North Sea coast. The subordinate aims of this study were to examine long-term trends for significant patterns in the beach litter data of the three NGOs and the comparison of both survey methods.

2. Methods

2.1. Study site

The study site is part of the coast of the North Sea, a semi-enclosed shelf sea adjacent to the Northern Atlantic Ocean (Fig. 1). The North Sea is connected to the Atlantic in the south via the English Channel between England and France/Belgium and in the north by the Norwegian Sea, which is located between Scotland and Norway. Westerly winds and predominantly anticlockwise currents mainly transport floating and submerged objects from the Channel along the southern coast eastward to the German Bight (Vauk and Schrey, 1987).

Fifteen beaches, located at the southeastern coast of the North Sea have been surveyed since 1992 and partly since 1989. In this study, beach litter survey data from eight of these 15 beaches were investigated, namely of the beaches Minsener Oog, Mellum Nord, Mellum Süd, Scharhörn, Büsum, Amrum, Föhr and Sylt (Fig. 1, large subfigure). Data of seven of the 15 NGO beaches were not considered for statistical analyses, because these beaches border on the Wadden Sea and therefore reveal quite different nearshore hydrodynamics than the remaining eight beaches. Survey sites varied between a 100 m and a 2000 m stretch of beach. In addition, four survey sites of 100 m length each, located on beaches on the southeastern coast of the North Sea (Fig. 1, large subfigure), were selected from the OSPAR beach litter monitoring database, namely Juist, Minsener Oog, Scharhörn and Sylt.

2.2. Beach litter surveys

The NGO surveys were carried out at intervals of three days to two weeks. Survey sites covered the area from the tideline to any natural border at the top of the beach i.e. foot of the dunes. The stretch of beach surveyed varied from 100 m on the island of Mellum to 2000 m on the island of Amrum. During surveys, all litter was counted and removed from the beach when pieces were not too heavy for removal. However in subsequent surveys, double counting of the same heavy pieces was avoided. The amount of

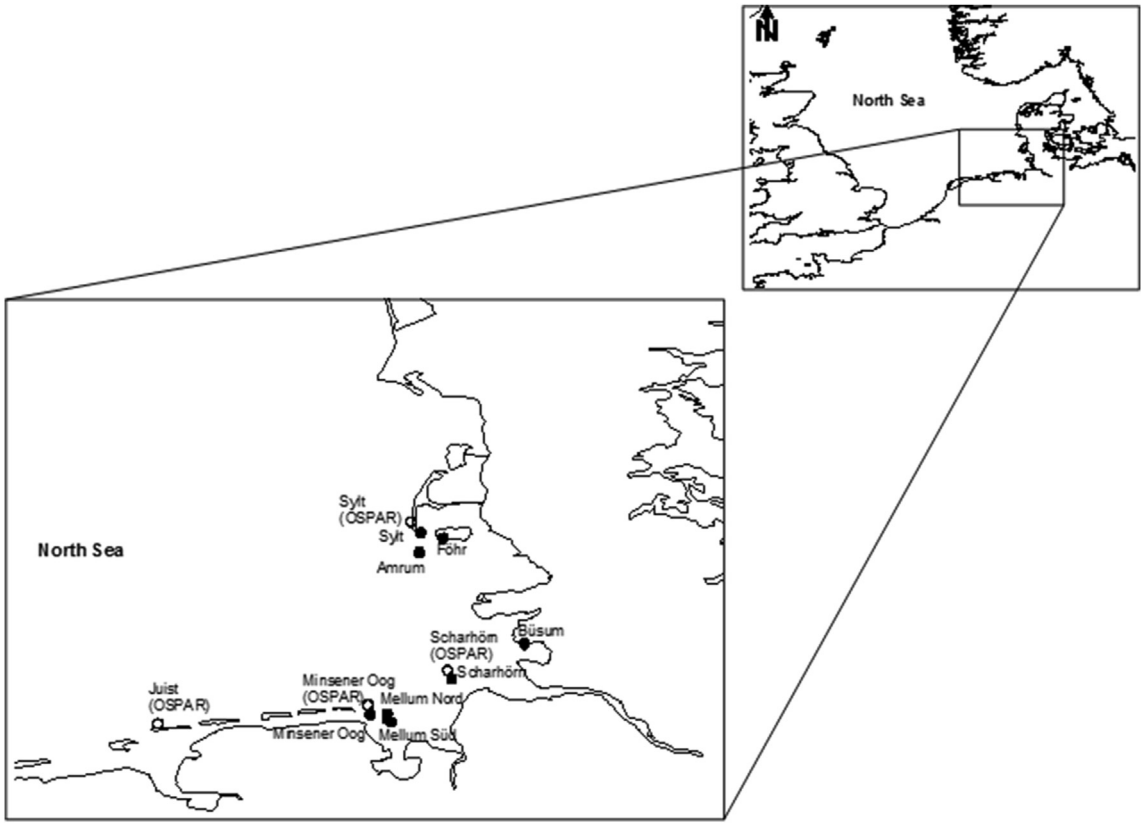

Fig. 1. Maps of the study site (small map: North Sea, large map: German coast of the North Sea). Lines give coastlines of the North Sea. Bold dots indicate positions of eight selected beaches regularly surveyed for beach litter by NGOs. Empty dots indicate positions of four beaches surveyed within the framework of the OSPAR convention (OSPAR, 1992).