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Date-prints on stranded macroplastics: Inferring the timing and extent of overwash deposition on the Skallingen peninsula, Denmark

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ABSTRACT

The presented study shows that the delivery of marine macrodebris to a high-energy coastal environment has been abundant enough over the last three decades as to allow a spatial reconstruction of morphological change based on production-date prints. A dataset of > 110 spatially discrete samples has been collected in an area affected by overwashing on the Skallingen peninsula, SW Denmark. A conceptual model for the chronological interpretation of the date prints is proposed and cross-compared with a dense time-series of satellite images and orthophotos. It appears that the litter-derived ages are capable of reproducing information on both the timing and the extent of overwash occurrence. Despite the usefulness of the method as a tool for rapidly assessing the approximate age of recent coastal deposits, the study shows the alarming degree and long-standing of marine-litter pollution on the eastern board of the southern North Sea.

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1. Introduction

Over the last four decades the accumulation of plastic objects and fragments has been documented for a wide range of marine, coastal and estuarine environments worldwide (Carpenter and Smith, 1972; Colton et al., 1974; Garrity and Levings, 1993; Thompson et al., 2004; Barnes et al., 2009; Browne et al., 2010; Eriksson et al., 2013; Cózar et al., 2014; Ivar do Sul and Costa, 2014). Plastic is a collective term describing synthetic organic polymers with diverse properties, chemical compositions and applications (Thompson et al., 2009). Since the 1950s, the global production volume has experienced an average annual growth of c. 9% and will have reached 300 megatons per year before the end of the decade (PlasticsEurope, 2013). Plastics have become highly competitive alternatives to conventional solids and fibers in industrial production, primarily due to their low cost and weight, as well as due to the versatility and the durability of the materials (Andrady and Neal, 2009). While the latter may be a desirable property of an item in use, durability can become an issue at the end of the product lifecycle. Considerable amounts of solid wastes end up in natural environments, due to insufficient waste-disposal practices or careless handling (UNEP, 2009; STAP, 2011; Eriksen et al., 2014). Currently, between 40 and 80% of marine debris are plastic items (Derraik, 2002; Barnes et al., 2009), amounting to an estimated number of more than five trillion pieces with a weight of over 250.000 t worldwide (Eriksen et al., 2014). Along beaches of the southern North Sea c. 200–600 items of marine litter are on average found per 100 m of shoreline and plastics constitute roughly ¾ of the amount of marine litter surveyed (UNEP, 2009). Most plastics do neither deteriorate easily nor decompose entirely in natural environments, leading to a gradual accumulation of plastic objects or fragments in the world's oceans (Barnes et al., 2009; STAP, 2011). It has been proposed that plastics will constitute a characteristic and lasting deposit transferred as a human legacy into the Earth's geological record (Barnes et al., 2009; Zalasiewicz et al., 2011; Corcoran et al., 2014). The striking ubiquity, abundance, and diversity of plastic objects in marine and coastal environments suggest a potential for systematic analysis. In this article, a spatial record of date-prints retrieved from macroplastic objects, collected in a dynamic barrier-setting in SW Denmark, is presented and a couple of conceptual considerations and principles for their interpretation are discussed. The plastic record facilitates insights into the chronology of overwash fan activation and foredune recovery at the chosen field site.

2. Materials and methods

2.1. Study area

The Skallingen peninsula is a young and low lying barrier spit located in the northern part of the Danish Wadden Sea (Fruergaard et al., 2013; Fig. 1). The peninsula is c. 10 km long and c. 2 km wide and is characterized by a flat topography with sandy beaches and dune ridges on its exposed SW side and a protected back-barrier environment of salt marshes on its eastern side. The area is microtidal (spring tidal range: c. 1.7 m) and entirely composed of unconsolidated sediments

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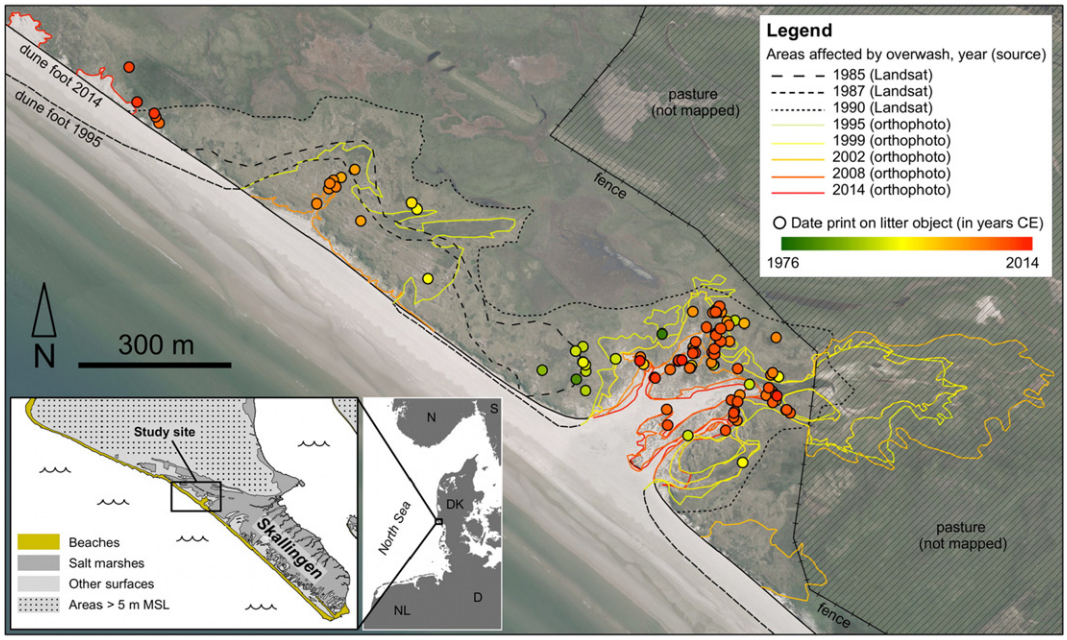

Fig. 1. The Skallingen peninsula is located on the eastern seaboard of the southern North Sea and forms the northernmost barrier of the European Wadden Sea. The spatial distribution of date prints retrieved from macrolitter items (circles), collected in an area repeatedly affected by deposition during storm events, shows a clear correlation with the timing and extent of overwash occurrence as reconstructed from remotely sensed data (lines).

(Aagaard et al., 1998; Fruergaard et al., 2015). The shoreline of Skallingen is retreating at an average rate of c. 3 m/year (Aagaard et al., 1995; Nielsen and Nielsen, 2006a). Overwashing is considered an important process of sediment transport in transgressive barrier (island) settings and has a strong influence on the geomorphology and development of the Skallingen peninsula (Nielsen and Nielsen, 2006b).

2.2. Background data

In this study, the spatial development of overwash deposits was reconstructed using a time-series of Landsat satellite images (1982, 1985, 1987, 1990) at a resolution of 30 × 30 m (exception: 1982 image, 60 × 60 m) and digital orthophotos (1995, 1999, 2002, 2004, 2006, 2008, 2010, 2012, 2014) with resolutions of 0.8 × 0.8 m or higher. Areas affected by overwashing were mapped at a scale of 1:2000 in relation to the 2014 position of the dune foot, defining the most landward location of the highest water-levels during extreme events. The interpretation of the surface morphology of the site was supported by a digital elevation model (DEM), based on airborne laser-scanning recorded in 2007–2008 and released at a resolution of 1.6 × 1.6 m with a vertical accuracy of ±0.1 m (Rosenkranz and Frederiksen, 2011). Maximum overwash extents and dune foot positions were digitized using the ArcMap 10 Geographical Information System (GIS) software. The compilation and GIS-based analysis of densely-stacked image time-series is a well-established approach for the assessment of the magnitude and timing of morphological changes in dynamic environments over annual to decadal timescales (e.g. Mathew et al., 2010; Rogers et al., 2015).

2.3. Collection of litter data

For the purpose of this study, all areas affected by overwashing over the time period documented in the available geodata were surveyed in May 2015 for deposited marine litter. The spatial distribution of visible litter objects was mapped using a handheld GPS device (Garmin GPSmap 62) with a horizontal precision of ±3 m. Only stabilized items with an unambiguous relation to either overwash morphology or event wracklines were sampled, to avoid errors resulting from redeposition of light or easily entrained items by e.g. wind. The date prints were recovered as production (i.e. mold) dates of plastic containers or as the expiration dates of their contents, based on date code inserts. Items lacking any (decipherable) age indication were omitted and no coordinates were recorded. The expiration dates were corrected using estimated typical timespans between the production date and the expiration date for similar products. No samples were surveyed in the distal parts of the research area, due to pasturing and the supposed clean-up of these areas.

2.4. Conceptual considerations for the interpretation of date prints from storm deposits

At a given field site, the amount and composition of marine litter depends on the original intensity of the respective litter sources, as well as on the rates of delivery, decay, burial, and exhumation (Santos et al., 2009). At the event of overwashing, an amount of floating debris is separated from the pool of marine litter contained in coastal waters and washed ashore in sand sheets or wracklines. The stranded debris thus is a random subsample of the marine debris contained in the nearshore coastal waters at the point in time when overwashing occurs. The major part of marine debris floats and large amounts of litter are transferred to beaches during storm events (Garrity and Levings, 1993; Bowman et al., 1998; Taffs and Cullen, 2005; Kataoka et al., 2013). Larger objects are usually found in the upper beach zone at elevations of the main wave run-up height and they thus have a greater chance of remaining visible and in place over extended periods of time (Bowman et al., 1998; Williams and Tudor, 2001; Martins and Sobral, 2011; Kataoka et al., 2013). Given their size, these objects can be surveyed for age indications in the field as spatially-discrete objects (Fig. 2).

The interpretation of the age indication retrieved from the collected litter items follows a simple logic: A date print is an absolute indication for the production date of an item or the expiration date of its former contents. When encountered in an overwash deposit, the date print merely allows establishing a lower limit for the point in time when overwash deposition occurred. In other words, an item of plastic

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