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Fisheries as a source of marine debris on beaches in the United Kingdom

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ABSTRACT

Marine debris from ships has persisted and remains a concern despite international agreements such as MARPOL. We report on an analysis of beach litter based on a data set established by the Marine Conservation Society (MSC) Beachwatch weekends. Debris collected around the UK was divided into three main types of debris: (1) plastic, (2) fishing, and (3) fishing related plastic and rubber. Correspondence analysis (CA) was used to examine patterns in the occurrence of debris types on a total of 1023 beaches and debris attributable to fishing was identified on clusters of beaches mainly located on the coasts of Scotland and along the English Channel. General Linear model (GLM) identified fishing as the highest explanatory factor when testing for relationships between litter and proximity to fishing ports and grounds. The results add to the growing body of evidence that the fishing industry is largely responsible for marine debris.

1. Introduction

Around 6.4 million tonnes of litter enter the sea each year (UNEP, 2009), most of which comprises extremely durable synthetic fishing gear, packaging materials, raw plastics and convenience items (Derraik, 2002; Pruter, 1987) which can persist in the environment for many years showing minimal biological or mechanical degradation (Alsopp et al., 2006). There are two principal types of marine debris: debris made from polymers denser than seawater which immediately sinks to the seafloor and debris that has high floating capacity, drifting on the ocean's surface over long distances, finally washing up on beaches driven by inshore currents and winds (Barnes and Millner, 2005; McIlgorm et al., 2011; Thiel et al., 2003). As the numbers of items of debris are increasing so does the magnitude of the resulting problems making it progressively harder to address or manage. MARPOL is the main international convention responsible for the prevention of marine environmental pollution by ships both operational and accidental and was adopted by the International Maritime Organisation (IMO) in 1973 (IMO, 2011a,b). The six MARPOL Annexes implement regulations aimed at preventing and minimising pollution from ships by oil, noxious liquid substances, packaged harmful substances, sewage, garbage and air pollution; Annex V, prevention of pollution by garbage from ships specifies the distances from land and disposal method (IMO, 2011a,b). It bans plastic disposal at sea and requires ports, marinas and terminals to provide waste disposal facilities for any garbage that is accumulated on ships at sea (IMO, 2011a,b). Since January 2013 the discharge of all garbage into the sea is prohibited except under specific circumstances (IMO, 2011a,b).

The aim of this study was to determine the origin of marine debris found on UK beaches including England, Wales, Scotland, Northern Ireland and the Channel Islands with particular emphasis on the relationship between debris and commercial fishing and shipping. The influence of tidal currents and winds is considered due to their impact on distribution and movements of marine debris (Slip and Burton, 1991) often leading to concentrations at oceanic convergence fronts in coastal waters around cities particularly industrialised harbours and ports (Ailliot et al., 2006; Carr, 1987; Derraik, 2002). We hypothesise that fishing is the major explanatory factor for marine debris pollution, including plastic, on UK beaches. Beach litter surveys provide valuable information on the amount and types of garbage that are currently disposed into the oceans (Benton, 1995). Because of the complexity of the data set with many items of debris of ambiguous origin, multivariate methods (correspondence analysis) is used to identify relationships between litter types and beach location. Multivariate analyses can be a suitable tool to determine the origin of marine debris particularly when looking at relations between distribution and environmental variables (Gauch, 1982; Randerson, 1993). However, because ordinations are only descriptive, general linear modelling (GLM) is used to test the subsequent predictions and to determine the biggest explanatory factor for pollution on British beaches.

2. Methods

The Marine Conservation Society (MCS) provided the raw data collected by volunteers for the MCS as part of the MCS Beachwatch

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Weekend on around 1000 UK beaches between 1999 and 2007 (MCS, 2014). MCS took environmental variables such as wind direction, tides and storm patterns into consideration restricting the survey to certain time frames. Beaches were classed as sand, shingle, rock or a combination of those and were either part of tourist resorts, rural coastal stretches or nature reserves. The 1–2 hour surveys were conducted along a stretch of coast a minimum of 100 m in length. Litter was observed between the current high water mark and the upper limit of the beach and recorded onto a prepared data sheet, classifying the items into suitable categories according to material and type i.e. plastic, metal, sanitary etc. as well as exact identity i.e. bottle, cigarette stub, gloves, etc.

2.1. Data analysis

The full data set included 1023 beaches, most of which were very similar to one another in regards to number of debris items. Using ordination allowed us to differentiate the central block of the data from those with more debris. The analysis then focused on 28 beaches for plastic debris, 29 beaches for fishing debris and 21 beaches for fishing related plastic and rubber debris. For most of the identified items the province and therefore its specific source is unknown, however, where the source was fisheries this was specified in the data analysis. If at least some part of the debris was identifiable it was also included into the analysis in order to be able to explore the potential for, as yet, unattributed debris to be from fishing grounds. The data were then summarised into different categories according to their type and most probable source: plastic, fishing and fishing related plastic and rubber, before being statistically analysed via correspondence analysis (CA) within the multivariate statistical package (MVSP) (Kovach, 1999). Based on the outcome of the CA further analyses focused on beaches identified as atypical, with a large volume and/or large diversity of debris including 32 beaches related to fishing, 30 beaches for plastic and 25 beaches for plastic and rubber analyses.

General linear modelling via IBM SPSS Statistics 20 (IBM, 2011) was used in order to determine if fishing activity is the principal explanatory factor at 95% confidence interval, focusing on the relationship of individual debris items to the presence of fishing ports or fishing grounds. Proximity to port was defined based on fisheries statistics maps (Fig. 1) (Radford, 2014) and information derived from relevant websites (MacIntosh, 2014).

3. Results

3.1. Patterns of marine debris on beaches

Axis 1 of the CA explains that 63.5% of variance apparently related primarily to fishing activity. Outlier beaches were identified and correlated to proximity to fishing ports and fishing grounds. Most of these beaches were found in area IVa, northern North Sea, VIId/e, English Channel (East/West) and VIa, West of Scotland, with a few on the Irish Sea, Wales, NE England (Lancashire) and within the Bristol Channel (Wales) coasts. Fig. 2 shows distinct litter groupings of plastic net (size 1/2), polystyrene fish boxes and heavy-duty rubber gloves. Fig. 3 shows groups of coherent clusters of plastic items including plastic fish boxes, plastic bottles (foreign) and plastic rope as well as plastic net (size 1/2). The CA did not produce coherent grouping for plastic debris other than that related to fishing. Fig. 4 shows several groups including plastic fish boxes, heavy-duty rubber gloves, plastic rope and plastic pieces (size 1/2).

3.2. Fisheries as a source of marine debris on beaches

GLM analysis was conducted but indicated no significant relationship between plastic marine debris and proximity to fishing ports. However, within the analyses fishing related materials, several plastic items, including fish boxes (GLM: $F_{5,24} = 3.763$, $P = 0.012$), floats (GLM: $F_{5,24} = 3.840$, $P = 0.011$), net (size 2) (GLM: $F_{5,19} = 2.833$, $P = 0.045$), rope (GLM: $F_{5,19} = 2.904$, $P = 0.041$) and plastic pieces (size 3) (GLM: $F_{5,19} = 2.753$, $P = 0.049$), indicate a strong relationship between fishing grounds and beached marine debris (Table 1–2). Plastic industrial packaging crates were the only items significant in both analyses (GLM: $F_{5,24} = 4.713$, $P = 0.004$; GLM: $F_{5,19} = 4.192$, $P = 0.01$). Furthermore, fishing weights (GLM: $F_{1,30} = 3.822$, $P = 0.06$; GLM: $F_{4,27} = 2.469$, $P = 0.069$), plastic cleaning product bottles (GLM: $F_{5,24} = 2.152$, $P = 0.058$), plastic pieces (size 3) (GLM: $F_{5,24} = 2.608$, $P = 0.051$) and plastic floats (GLM: $F_{5,19} = 2.516$, $P = 0.066$) show a near significant trend within the different analyses.

4. Discussion

4.1. The fishing industry as a source of marine debris on beaches in the UK

These results suggest that fishing industry is responsible for a large proportion of the marine debris on UK beaches, particularly in areas with adjacent fishing grounds (Gregory, 1999; Jones, 1995; Slip and Burton, 1991). Few studies have focused on the composition and distribution of marine debris on UK beaches, mainly on areas along the coast of Wales and the Bristol Channel (Balas et al., 2006; Tudor and Williams, 2003, 2004, 2006; Williams and Simmons, 1997; Williams and Tudor, 2001; Williams et al., 2003). Debris collected from other North Sea coastlines such as Germany, the Netherlands, Belgium, France, Norway and Denmark, has been largely attributed to shipping and fishing activity (Galgani et al., 2000; van Franecker, 2005; Vauck and Schrey, 1987). Furthermore, fishing gear, operational as well as floating fragments, has been shown to cause entangling and mortality of marine animals (Derraik, 2002) including seabirds (Bugoni et al., 2008; Simeone et al., 1999; Stemoniewicz, 1994; Votier et al., 2011; Zador et al., 2008), cetaceans (Johnson et al., 2005; Neilson et al., 2009; Ramos et al., 2011; Robbins and Mattila, 2004), turtles (Carr, 1987), sharks (Sazima et al., 2002) and seals (Hanni and Pyle, 2000; Hofmeyr et al., 2006; Page et al., 2004).

Items identified as significant by GLM analyses can be related to fishing activity. Plastic fish boxes as well as industrial packaging crates are most likely being used for packaging purposes on fishing vessels for transportation and distribution of fish and other seafood. Plastic net and plastic ropes are part of fishing gear and items frequently used on fishing vessels (Henderson, 2001). As for plastic floats and plastic pieces the identification of their source is somewhat more difficult. However, plastic floats are often used in pelagic longline fishing gear to support the gear (Watson and Kerstetter, 2006). Metal represents a threat to marine organisms due to risk of poisoning when ingested (Borowski, 1997; Zabka et al., 2006). It is often found on windward beaches (Debrot et al., 1999) since it does not float or can get blown away by wind. Items such as metal fishing weights that have low or no buoyancy cannot have been adrift for a very long time and must have been deposited in local coastal areas. This might explain why metal fishing weights showed a near significant trend. They most likely stem from local sources within close proximity to the coasts of the UK. Plastic bottles (cleaner) and plastic pieces (size 3) also showed a near significant trend. Plastic bottles in particular contribute most to marine debris and are often the most dominant item of debris found on beaches (Dixon and Dixon, 1983). However, due to the lightweight and high buoyancy these bottles might not only be of local source but from sources further away either being carried by currents or blown around by winds (Astudillo et al., 2009; Garrity and Levings, 1993). Characteristics of plastic pieces are not further described making it hard to identify their origin. This illustrates the difficulty in determining the true trends of ocean sourced debris since often they are obscured by unknown sources because debris material is often found in small fragments due to degradation and weathering (Andrady, 2011). When plastics are exposed to UVB radiation by sunlight and hydrolytic

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