



Below the surface: Twenty-five years of seafloor litter monitoring in coastal seas of North West Europe (1992–2017)



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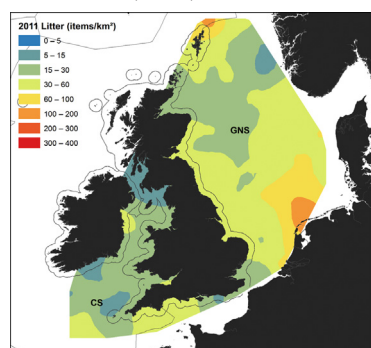
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HIGHLIGHTS

- Widespread distribution of litter items on the seabed, up to 1835 pieces km⁻²
- Over the 25-year period, 63% of the trawls contained at least one plastic litter item.
- No significant temporal trend in total number of litter items km⁻²
- Significant trends in plastic bags (down) and fishing debris (up)
- Potential influence of behavioural changes on litter abundance?

GRAPHICAL ABSTRACT

Marine litter abundance (litter items km⁻²) on the seafloor in North West European Seas, all data from 2011 interpolated using R, Shiny and PostGIS. The black line surrounding the UK represents the 12 nm boundary. The black line in the Western Channel and starting near the tip of Shetland symbolizes the MSFD boundary for the Celtic Sea (CS) and Greater North Sea (GNS). Key to regional divisions: GNS-off, Greater North Sea offshore stations outside 12 nm; GNS-in, Greater North Sea inshore stations within 12 nm; CS-off, Celtic Sea offshore stations outside 12 nm; CS-in, Celtic Sea inshore stations within 12 nm.



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ABSTRACT

Marine litter presents a global problem, with increasing quantities documented in recent decades. The distribution and abundance of marine litter on the seafloor off the United Kingdom's (UK) coasts were quantified during 39 independent scientific surveys conducted between 1992 and 2017. Widespread distribution of litter items, especially plastics, were found on the seabed of the North Sea, English Channel, Celtic Sea and Irish Sea. High variation in abundance of litter items, ranging from 0 to 1835 pieces km⁻² of seafloor, was observed. Plastic items such as bags, bottles and fishing related debris were commonly observed across all areas. Over the entire 25-year period (1992–2017), 63% of the 2461 trawls contained at least one plastic litter item. There was no significant temporal trend in the percentage of trawls containing any or total plastic litter items across the long-term datasets. Statistically significant trends, however, were observed in specific plastic litter categories

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1. Introduction

Globally, marine litter has become a pollution problem, originating from a variety of land and sea-based sources. Ongoing surveys have demonstrated that man-made litter has now been documented to occur in almost every marine environment studied to date (Barnes et al., 2009; Browne et al., 2011; Derraik, 2002; Jambeck et al., 2015; Ryan et al., 2009). Marine litter consists mainly of plastic materials, both in numbers and by weight, with minor amounts of metal and glass contributing to the overall litter load. Typical plastic items such as bags, bottles and fishing related litter are omnipresent and indicative of a variety of anthropogenic pressures (UNEP, 2009). According to Jambeck et al. (Jambeck et al., 2015), population size and the quality of waste management systems largely determine where the greatest mass of uncaptured waste becomes plastic marine litter.

An ongoing challenge is in relation to reducing the amount of litter in the marine environment. This problem has been at the forefront of several international initiatives. In June 2012 at Rio + 20, the Global Partnership on Marine Litter (GPML) was launched. More recently, the Leader's Declaration of the 2015 G7 Summit acknowledged the global risks posed by marine litter, particularly plastics, to marine and coastal ecosystems and potentially human health. As such, marine litter generation and prevention are linked to a variety of human activities and policy areas operating at both national and international levels. Therefore, to address both the sources and impacts of marine litter, legislation and agreements need to relate to waste and wastewater management, product design, shipping, fisheries policies, consumption and behavioural patterns (Gold et al., 2013; Newman et al., 2013; Trouwborst, 2011). In Europe, specific legislation was introduced to deal with marine litter and its impact on the coastal and marine environment: the Marine Strategy Framework Directive (MSFD) (European Parliament and Council of the European Union, 2008). The MSFD incorporates an indicator specifically in relation to litter and requires evidence that member states are moving towards Good Environmental Status (GES). More specifically, the MSFD operates by monitoring, amongst others, trends in the amount of litter deposited on the sea floor, including analysis of its composition, spatial distribution and, where possible, sources (European Parliament and Council of the European Union, 2008).

Globally, waste management legislation is seen in the broader context of enhanced resource efficiency, now a key cross-cutting policy goal (UNEP, 2016). As an example, the first jurisdictions where plastic bag reduction policies emerged and regulatory action was taken were in South Asia in the late 1990s and early 2000s, primarily based on concerns regarding human health and livelihoods (Clapp and Swanston, 2009). Most northern industrialised countries have also seen attitudes shift in recent years (Clapp and Swanston, 2009). In Europe, the first legislation against plastic bag use was introduced by Ireland and Denmark in 2002 and 2003 respectively. In Ireland, the effect of the tax on the use of plastic bags in retail outlets has been dramatic—a reduction in use of the order of 90%, and an associated gain in the form of reduced littering and negative landscape effects (Convery et al., 2007). This tax on plastic shopping bags, previously provided free of charge to customers at points of sale, was adopted by other European member states in the following years (Convery et al., 2007). Since the plastic bag tax policy came into force in England in October 2015, the total number of carrier bags used at the UK's biggest retailers has fallen by an estimated 85% ("Single-use plastic carrier bags charge: data in England for 2015 to

2016 - GOV.UK," n.d.). In the context of a European Circular Economy, a directive to reduce the use of thin plastic bags, many of which end up as waste in the marine environment was finally agreed on the 28th of April 2015 (EEA, 2015).

In relation to marine litter from sea-based sources such as the fishing industry, legal and technical measures to ensure that littering from lost or abandoned fishing gear is minimised are provided by the Food and Agriculture Organization of the United Nations (FAO): Recommendations for the Marking of Fishing Gear (FAO, 2016) and Code of Conduct (FAO, 1995). The abandonment of fishing gear is specifically prohibited by the International Maritime Organisation in its Convention for the Prevention of Pollution from Ships (Convention, 1973). From a European perspective, the Common Fisheries Policy (CFP) states that measures should be taken to conserve resources and limit the environmental impact of fishing (Council of the European Union, 2002). The European Commission also recognised the importance of the marking of fishing gear in 1994 and, more recently, in 2004 (Brown and Macfadyen, 2007). Furthermore, the European Maritime and Fisheries Fund supports measures to remove lost fishing gears from the seafloor.

This surge in marine litter related legislation has identified a requirement for long-term monitoring programmes, capable of assessing the effectiveness of newly implemented measures. To date, the majority of marine litter studies have focused on visible and easily accessible litter contamination, such as that along shorelines or floating on the surface of the water (Ryan et al., 2009). However, some litter sinks and almost all floating litter is expected to be cast onto a beach or to sink to deeper waters, eventually landing on the seafloor. This may be due to a variety of repeating processes such as degradation, fouling by marine organisms (e.g. bacteria, algae and sessile organisms), or ingestion and excretion by marine animals (Cole et al., 2013, 2011; Graham and Thompson, 2009; Gregory, 2009; Harms, 1990; Webb et al., 2009). On continental shelves, fishing trawl surveys provide a practical way in which to monitor seafloor litter because they cover a wide area and collect a suitable quantity of litter for analysis (Spengler and Costa, 2008). Nevertheless, long-term datasets on marine litter on the seafloor are sparse (Galgani et al., 2010, 2014). Where studies are available they cover relatively short time series and have catalogued seabed litter using a variety of techniques such as snorkeling, SCUBA diving, trawl surveys, sonar and the use of submersibles and ROVs (Bergmann and Klages, 2012; Galgani et al., 2014; Miyake et al., 2011; Schlining et al., 2013; Spengler and Costa, 2008; Watters et al., 2010). For example, the presence of large amounts of plastic litter has been reported in European continental shelf seas (Galgani et al., 2000; Pham et al., 2014), including in the Baltic, North (Kammann et al., 2017) and Celtic Sea, the Bay of Biscay (Galgani et al., 1995a), the Barents Sea and Norwegian Sea (Buhl-Mortensen and Buhl-Mortensen, 2017), and the Mediterranean (Galgani et al., 1996, 1995b; Galil et al., 1995; Pasternak et al., 2017; Stefatos et al., 1999), Adriatic (Bingel et al., 1987) and Black Sea (Ioakeimidis et al., 2014). Plastic litter items have been found in deep sea canyons of the French Mediterranean coast (Galgani et al., 1996), the west coast of Portugal (Mordecai et al., 2011) and nearby to seamounts close to the Azores (Pham et al., 2014, 2013).

Since 1992, the Centre for Environment, Fisheries and Aquaculture Science (Cefas), a UK Government organisation, has been collecting seafloor litter data on environmental and fisheries stock assessment surveys. Such research provides spatial and temporal trend assessments of the abundance of seafloor litter within North West European seas and acts as a baseline against which litter reduction mitigation

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