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Spatial and temporal analysis of litter in the Celtic Sea from Groundfish Survey data: Lessons for monitoring

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ABSTRACT

The Marine Strategy Framework Directive requires EU Member States to sample and monitor marine litter. Criteria for sampling and detecting spatial and/or temporal variation in the amount of litter present have been developed and initiated throughout Europe. These include implementing standardised sampling and recording methods to enable cross-comparison and consistency between neighbours. Parameters of interest include; litter occurrence, composition, distribution and source. This paper highlights the litter-related initiatives occurring in Irish waters; presents an offshore benthic litter sampling series; provides a power analysis to determine trend detection thresholds; identifies areas and sources of litter; and proposes improvements to meet reporting obligations. Litter was found to be distributed throughout Irish waters with highest occurrences in the Celtic Sea. Over 50% of litter encountered was attributed to fishing activities: however only a small proportion of the variability in litter occurrence could be explained by spatial patterns in fishing effort. Issues in implementing standardised protocol were observed and addressed.

1. Introduction

The Marine Strategy Framework Directive (MSFD, 2008) provides legally binding requirements for European member states to establish and subsequently monitor European marine waters for 'Good Environmental Status' (GES) by 2020. Based on 11 qualitative descriptors, GES is defined as "The environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive" (Article 3, MSFD, 2008). Successful implementation of a monitoring program for MSFD-Descriptor 10 (Marine Litter) is directly dependent upon the availability of reliable and affordable detection and monitoring techniques (TSG-ML, 2011, 2013). OSPAR is currently developing indicators for adoption throughout its contracting parties which are in line with both the MSFD and ongoing OSPAR monitoring (Intersessional Correspondence Group on Marine Litter (ICG-ML); TSG-ML, 2011). However, as a new reporting obligation, additional surveying and monitoring will be required, a process which can be extremely costly (e.g. staff and ship time) and results in trade-offs in survey flexibility (ICES, 2013a, 2013b; Galgani et al., 2013; TSG-ML, 2013).

In order to meet the challenges of increased sampling and reporting obligations in a resource limited environment, efforts thus far have largely required efficient integration of additional sampling into existing monitoring networks (TSG-ML, 2013). One such approach is the guidelines proposed and implemented by the International Bottom Trawl Survey (ICES, 2012), which provide standardised data entry forms to record the identification, weight, and size class categorisation of marine litter. This coordinated effort is essential in order to enable efforts between member states within regions to be complementary (e.g. common lists of items and categories), to allow cross-comparisons, and the examination of trans-boundary impacts and features (TSG-ML, 2013).

The abundance and distribution of marine litter vary greatly in both space and time, governed initially through human activities, and subsequently influenced by hydrodynamics, geomorphology, and biofouling accumulation rates (TSG-ML, 2011). Tidal influences can carry litter to shore, riverine flushing can result in a clearance zone along the shelf (Thompson et al., 2009; Galgani et al., 2000), and strong marine currents can accumulate litter into 'garbage patches' in oceanic gyres (Moore, 2003; Ebbesmeyer et al., 2007), and deep canyon systems near urban developments (Galgani et al., 2000). It has been estimated that about 70% of marine litter reaches the sea floor (OSPAR, 2014). How long litter endures in these environments is further related

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to the physical environment in which it ends up, for instance; high energy environments contribute to fracturing litter into smaller particles, increasing surface area for mechanical, microbial and/or chemical degradation (Thompson et al., 2009; Andrady, 2011). Plastics, the largest component of marine litter (CBD, 2012), are resistant to biodegradation (Thompson et al., 2004), enabling them to persist in the marine environment for centuries (Moore, 2003; Galgani et al., 2013). The incorporation of plastics into everyday life in their multiple guises has resulted in over 75% of marine litter being accounted for by plastics (TSG-ML, 2011). The primary route of plastic degradation on land is via photo-oxidative degradation from UVB radiation in sunlight; however, at sea, degradation can take several orders of magnitude longer than on land due to lower temperatures, lower available oxygen, and blocking of sunlight by fouling organisms (Andrady, 2011).

Fishing gear and related sectoral debris (e.g. ropes, cages, plastic boxes) are highlighted throughout the literature as being one of the most common forms of litter in the marine environment (Galgani et al., 2000). Fishing derived litter has also been found to cause economic repercussions on other coastal activities, such as tourism and shipping (Gregory, 2009; Moore, 2008; Takehama, 1990; Nash, 1992; McIlgorm et al., 2011).

2. Problems

Beyond being unsightly, litter has very real consequences for our marine fauna. Up to 10% of all static fishing gear deployed annually is lost (Moore, 2008), these tangled masses of abandoned nets can continue to 'fish' for long periods of time ('ghost-fishing'), resulting in death for the majority of species and individuals encountered (Brown and Macfadyen, 2007; Gregory, 2009). Globally, over 370 marine species are known to have been directly affected by litter through ingestion or entanglement (CBD, 2012). The wide range of marine species affected by litter through ingestion include cetacean species (c. 50% of species affected), seabirds (>50%), marine turtles (100%) and many fish (114 species) (CBD, 2012) and invertebrate species (Katsanevakis et al., 2007; Murray and Cowie, 2011). On a global scale, approximately 88% of all litter damage to marine fauna is caused by plastics, 65% of which are linked to fishing activities (CBD, 2012). In the majority of cases, misidentification of litter items as prey is thought to be the primary cause of ingestion due to their bright colours (plastics) and/or behaviour (floating plastic simulate jellyfish) (Gregory, 2009; Moore, 2008), which result in impacts ranging from intestinal blockage and internal damage to impacted reproduction and toxin accumulation (Laist, 1987; Thompson et al., 2009; Teuten et al., 2009). Furthermore, a wide range of litter (plastic bags, six pack rings, and fishing debris such as ropes and nets) present an entanglement risk for many marine species (Brown and Macfadyen, 2007; Gregory, 2009).

Benthic fauna and habitats are also threatened by litter (particularly fishing gear and plastic bags), through smothering and abrasion (Brown and Macfadyen, 2007; Gregory, 2009). Floating debris can also aid in alien species invasions, providing hard substrates for colonisation and acting as rafts for transportation (Winston, 1982; Barnes, 2002; Derraik, 2002; Gregory, 2009; Katsanevakis et al., 2007; Gall and Thompson, 2015). Plastics attract and concentrate a range of potentially toxic chemicals (Thompson et al., 2009; Andrady, 2011; Rochman et al., 2013), which may then enter the food chain via ingestion (e.g. as microplastics). This has led to the call by some for plastics to be classified as hazardous materials (Rochman et al., 2013).

Microplastics (fragmented plastics <5 mm) have thus far been detected in sand, sediment and biota (Depledge et al., 2013). Microplastics generally result from the mechanical breakdown of larger plastic items, but they can also enter the marine environment directly, via spills of industrial raw materials such as plastic pellets (Gregory, 2009; Andrady, 2011), or via sewerage systems due to microbeads present in personal care products such as shampoos, body washes and cosmetics (UNEP, 2015), or even microfibers that are released when we wash our clothes (Browne et al., 2011). Even so-called 'biodegradable' plastics are composites held together with biodegradable materials such as starch but that leave behind non-degradable plastic fragments (Thompson et al., 2004; Andrady, 2011). Because of their small size, they are readily ingested passively, and available to smaller and more numerous organisms than larger litter (Laist, 1987; Moore, 2008; Thompson et al., 2004; Browne et al., 2007).

Despite a multitude of known negative impacts, we currently know very little about the location, movement, behaviour and sources of litter in Irish marine waters. This study sets out to provide data on the extent and abundance of marine litter in Irish waters, particularly based on trawl surveys. We identify hotspot areas, investigate types and sources of marine litter, and predict timelines for detection of trends under current sampling protocols. Data and advice is also provided in relation to Irish current monitoring methods, and recommendations upon which continued and extended monitoring can be built in order to gain a better understanding of the marine litter issue, such as sources, accumulation rates and patterns.

Table 1
Litter categories from IBTS for the North East Atlantic Region (TSG-ML, 2013). Categories related to fishing are highlighted in italics.

A: Plastic	B: Metals	C: Rubber	D: Glass/ceramics	E: Natural products/clothes	F: Miscellaneous
A1: Bottle	B1: Cans (food)	C1: Boots	D1: Jar	E1: Clothing/Rags	F1: Wood (processed)
A2: Sheet	B2: Cans (beverage)	C2: Balloons	D2: Bottle	E2: Shoes	F2: Rope
A3: Bag	*B3: Fishing related*	C3: *Bobbins (fishing)*	D3: Piece	E3: Other	F3: Paper/cardboard
A4: Caps/lids	B4: Drums	C4: Tyre	D4: Other		F4: Pallets
A5: Fishing line (monofilament)	B5: Appliances	C5: Other			F5: Other
A6: Fishing line (entangled)	B6: Car parts				Related size categories
A7: Synthetic rope	B7: Cables				
A8: Fishing net	B8: Other				Size categories
A9: Cable ties					A: $<5 * 5$ cm $= 25$ cm^2
A10: Strapping bands					B: $<10 * 10$ cm $= 100$ cm^2
A11: Crates and Containers					C: $<20 * 20$ cm $= 400$ cm^2
A12: Plastic diapers					D: $<50 * 50$ cm $= 2500$ cm^2
A13: Sanitary towel/tampon					E: $<100 * 100$ cm $= 1$ m^2
A14: Other					F: $>100 * 100$ cm $= 1$ m^2

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