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Marine litter in submarine canyons of the Bay of Biscay

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ABSTRACT

Marine litter is a matter of increasing concern worldwide, from shallow seas to the open ocean and from beaches to the deep-seafloor. Indeed, the deep sea may be the ultimate repository of a large proportion of litter in the ocean.

We used footage acquired with a Remotely Operated Vehicle (ROV) and a towed camera to investigate the distribution and composition of litter in the submarine canyons of the Bay of Biscay. This bay contains many submarine canyons housing Vulnerable Marine Ecosystems (VMEs) such as scleractinian coral habitats. VMEs are considered to be important for fish and they increase the local biodiversity. The objectives of the study were to investigate and discuss: (i) litter density, (ii) the principal sources of litter, (iii) the influence of environmental factors on the distribution of litter, and (iv) the impact of litter on benthic communities.

Litter was found in all 15 canyons and at three sites on the edge of the continental shelf/canyon, in 25 of 29 dives. The Belle-île and Arcachon Canyons contained the largest amounts of litter, up to 12.6 and 9.5 items per 100 images respectively. Plastic items were the most abundant (42%), followed by fishing-related items (16%). The litter had both a maritime and a terrestrial origin. The main sources could be linked to fishing activities, major shipping lanes and river discharges. Litter appeared to accumulate at water depths of 801–1100 m and 1401–1700 m. In the deeper of these two depth ranges, litter accumulated on a geologically structured area, accounting for its high frequency at this depth. A larger number of images taken in areas of coral in the shallower of these two depth ranges may account for the high frequency of litter detection at this depth. A larger number of litter items, including plastic objects in particular, were observed on geological structures and in coral areas than on areas of bare substratum. The distribution of fishing-related items was similar for the various types of relief. Litter items were mostly colonised by scleractinian corals and hydroids. Several fish species and a lithodid crab seemed to associate with the accumulated litter.

This extensive study showed litter to be widely distributed in the submarine canyons of the Bay of Biscay. These findings increase our understanding of the distribution of litter, its composition and accumulation and its impact on benthic communities.

1. Introduction

The impact of human activities on the deep-sea environment has increased over recent decades, and this trend is predicted to continue in the near future (Ramirez-Llodra et al., 2011). The exploitation of living, mineral and energy resources are of particular concern, but there is also a growing body of evidence that litter is common and widespread, even in the deepest parts of the ocean (Miyake et al., 2011).

Litter on beaches and items floating on the surface of the ocean have been extensively studied (Galgani et al., 2015; Ryan, 2015). The interaction of this debris – especially plastics – with turtles, sea birds and marine mammals, through suffocation, ingestion and entanglement has been widely described in the literature (Kühn et al., 2015; Ryan, 2015). By contrast, little is known about the amount, distribution and composition of litter in the deep-sea environment, and its impact on deep-water habitats and benthic communities (Galgani et al., 2015; Miyake et al., 2011), although increasing numbers of studies are being undertaken to explore these issues (e.g. Galgani et al., 2015, Pham et al., 2014, Ramirez-Llodra et al., 2013). The studies carried out to date have indicated that plastic items predominate, at least in the Bay of Biscay

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(Galgani et al., 2000; Pham et al., 2014), four Portuguese canyons (Mordecai et al., 2011), several parts in the Mediterranean (Ramirez-Llodra et al., 2013; Tubau et al., 2015), the Gulf of Mexico (Wei et al., 2012), and along the shelf and slope of the west coast of the US (Keller et al., 2010), particularly in the Monterey Canyon (Schlining et al., 2013). Plastic longlines, originating from the fishing industry, were the main type of litter observed in the Azores (Pham et al., 2013) and off the coast of California (Watters et al., 2010), whereas ropes and gill nets were the most frequently observed items on the coral mounds off the Irish coast (Grehan et al., 2005). Fishing gear also dominated the litter found on the seamounts of Gorringe Bank (NE Atlantic; Vieira et al., 2015), the Tyrrhenian Sea in the Mediterranean (Angiolillo et al., 2015) and off the coast of South-East Africa (Woodall et al., 2015).

Submarine canyons along continental margins may act as a conduit for the transport of marine litter from shallower to deeper waters, or as a sink, retaining the litter in the deep sea (Mordecai et al., 2011; Pham et al., 2014; Schlining et al., 2013). Based on submersible video surveys in the Bay of Biscay, Galgani et al., (2000) reported higher densities of marine litter at bathyal depths in submarine canyons than on the continental shelf.

There are about 135 submarine canyons along the continental margin of the Bay of Biscay (Bourillet et al., 2006). These canyons host many Vulnerable Marine Ecosystems (VMEs) constructed by corals, sponges and oysters (De Mol et al., 2011; Huvenne et al., 2011; Reveillaud et al., 2008; Van Rooij et al., 2010). VMEs are considered to be functional and biodiversity ‘hotspots’, providing structural complex habitats that locally enhance the diversity and biomass of benthic communities (Buhl-Mortensen et al., 2010). Cold-water coral reefs, in particular, are thought to be important for many fish species (Costello et al., 2005; Roberts et al., 2006), as they provide shelter, feeding sites, spawning grounds (Auster, 2007; Sulak et al., 2007), and nursery areas (Baillon et al., 2012). However, the species responsible for the construction of these VMEs may, like geological structures (e.g. boulders and rocky outcrops; Schlining et al., 2013; Watters et al., 2010), trap litter (Bergmann and Klages, 2012; Galgani et al., 2000).

The principal human activities in the Bay of Biscay are fishing and shipping. The French and Spanish fishing fleets operate in this area, with the French (deep-sea) fleet targeting grenadiers (Macrouridae spp., especially *Coryphaenoides rupestris*), black scabbard fish (*Aphanopus carbo*), monkfish (*Lophius* spp.) and langoustines (*Nephrops norvegicus*) in particular (ICES, 2015). This part of the Atlantic Ocean also hosts a number of commercial and recreational shipping lanes. Human activities can have major detrimental effects on VMEs, which are fragile and easily disturbed, and recover only slowly, if at all (Althaus et al., 2009; Williams et al., 2010).

There is a need to determine what types of litter are present and their distribution, if we are to understand their impact on VMEs. We used footage acquired with an ROV and a towed camera system between 2009 and 2011 to estimate the amount of litter, its composition and distribution within the canyon systems of the French part of the Bay of Biscay in the North-East Atlantic Ocean. The objectives of this study were: (i) to determine the density of litter, (ii) to establish the principal sources of litter, (iii) to consider the influence of environmental factors on the distribution of litter within and between canyons, and (iv) to investigate the impact of litter on benthic communities.

2. Material and methods

2.1. Study site

The Bay of Biscay is part of the North-East Atlantic Ocean located to the west of France and the north of Spain. It includes the Armorican and Aquitaine margins, which we studied here, and it is bounded by the Celtic margin in the north, and the North Iberian margin in the south. The Armorican margin extends from the Berthois Spur to the Conti Spur, with a broad continental shelf (up to 200 km) and a steep, canyon-dominated slope. By contrast, the Aquitaine margin extends from the Conti Spur to the Capbreton Canyon, and has a narrow shelf (70 km) and a smooth slope (Bourillet et al., 2006).

2.2. Data collection

Data were collected during two cruises on the R/V *Pourquoi Pas?* (Ifremer, France) — BobGeo in 2009 (Bourillet, 2009) and BobEco in 2011 (Arnaud-Haond, 2011) — and one cruise on the R/V *Le Suroît* (Ifremer, France) — BobGeo 2 in 2010 (Bourillet, 2010). The main objectives of these cruises were to study VMEs and/or geological features in canyons of the Bay of Biscay. Fifteen canyons were included in this study, mainly along the Armorican margin with the exception of the Arcachon Canyon located on the Aquitaine margin. In total, 29 dives were undertaken, 26 of which took place within canyons. The remaining three dives took place on the edge of the continental shelf/canyon (Table 1).

The Scampi towed camera system was used to collect data during 17 dives, and the Victor 6000 ROV during 12 dives (Table 1). The Scampi is equipped with a Nikon D700 photo camera directed vertically downwards. The system was towed at a mean speed of 0.9 knots, about 2–3 m above the seafloor. Photographs were taken at intervals of 10 to 90 seconds.

The Victor 6000 has multiple cameras. For the purpose of this study, we used the downward-facing video camera (Sony FCB-H11). For comparison of the footage obtained with the ROV and the images taken by the towed camera, frame-grabs were taken from the video footage at one-minute intervals, with ADELIE annotation software. These frame-grabs were analysed in the same way as the photographs obtained with the towed camera system. Hereafter, we use the term ‘images’ to refer to both frame-grabs from the ROV and photographs from the Scampi. We obtained a mean of 5.8 images 100 m^{-1} with the ROV (after averaging over all dives), and 5.3 images 100 m^{-1} with Scampi.

Metadata (image name, time code and latitude/longitude) were recorded with ADELIE software, for both the towed camera and the ROV.

A depth value was extracted for each image from Digital Terrain Models, with grid sizes of 15, 25 or 125 m (Bourillet et al., 2012). These depth values were used to calculate the mean, minimum and maximum water depth of each dive. The mean depth of the dives was between 228 and 1598 m (Table 1), with a minimum water depth of 223 m and a maximum water depth of 2359 m.

2.3. Data analysis

Images were subjected to quality control to ensure that litter items were reliably identified and counted. Two criteria were used for quality control: (i) altitude; images were excluded if they were taken less than 1 m or more than 5 m above the seafloor, and (ii) image quality; images were excluded if poorly focused, taken in low-light conditions or with a high particle load.

Each image was annotated for three sets of criteria: (i) marine litter, (ii) the fauna colonising the marine litter, and (iii) seafloor structures. Litter items were identified and allocated to one of six

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