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Spatial distribution of marine debris on the seafloor of Moroccan waters

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ABSTRACT

Marine debris pollution is considered as a worldwide problem and a direct threat to the environment, economy and human health. In this paper, we provide the first quantitative assessment of debris on the seafloor of the southern part of the economic exclusive waters of Morocco. The data were collected in a scientific trawl survey carried out from 5 to 25 October 2014 between (26N) to (21N) covering different stratums of depths (from 10 to 266 m) and following a sampling network of 100 stations distributed randomly in the study area. A total of 603 kg of debris was collected and sorted into five main categories: plastic, metal, rubber, textiles and glass. Over 50% of collected items was made by plastic, 94% of them are the plastic fishing gear used to capture the *Octopus vulgaris*. The analysis of the distribution shows that anthropogenic debris is present in the majority of the prospected area (~ 47,541 km^2) with different densities ranging from 0 to 1768 (± 298,15) kg/km^2. The spatial autocorrelation approach using GIS shows that the concentration of this debris is correlated very well with a set of factors such as the proximity to fishing activity sites. Moreover, the mechanism of transportation and dispersion was influenced by the hydrodynamic properties of the region.

1. Introduction

Marine debris is considered as a pervasive worldwide pollution problem and a direct threat to wildlife, from smallest species of the marine trophic chain to human health and safety (UNEP, 2005, 2009, 2015; Sheavly and Register, 2007; Pham et al., 2014).

The United Nations Environment Program (UNEP) defines the marine debris as any persistent, manufactured or processed solid material discarded, disposed or abandoned into the marine and coastal environment. This includes five main categories; plastic, metal, textile, glass and rubber, where plastic materials represent the major constituents of this debris due to resistance of plastic to degradation (Corbin and Singh, 1993; Galgani and Andral, 1998; Ferentinos et al., 1999; Galgani et al., 2000; Derraik, 2002; UNEP, 2005; Barnes et al., 2009; Ryan et al., 2009; Browne et al., 2011; Cole et al., 2011).

The threat of anthropogenic debris to the marine environment has been neglected for a long time, until 1960, when the international literature highlighted the problems, and discussed their impacts and implications (Ryan, 2015; Bergmann et al., 2015). Several surveys were launched to ensure complete coverage of oceans and seas. The UNEP (2009) evaluated globally the amount of debris entering the oceans every year at 6.4 million tons [5.8 million metric tons (MT)].

Depending on winds, currents and marine hydrodynamic (Barnes et al., 2009), the debris composition and density changes greatly between locations. From the pole to the equator, all the sites are affected by this kind of pollution that has no borders (Thompson et al., 2009; Browne et al., 2011; Bergmann et al., 2015). They can be floating on the sea surface, on the seafloor or on the shorelines (Barnes et al., 2009; Ryan et al., 2009; Goldstein et al., 2013; Pham et al., 2014; Bergmann et al., 2015).

Most of the studies of marine debris were conducted on beaches using item counts along transects due to the easy accessibility of the data. The sea surface was surveyed using the ship-based observation technique to quantify and locate the floating debris. However, the deep-sea floor is much less widely investigated, due to some sampling difficulties, us inaccessibility, and the high cost of sampling in deeper waters. Until now, The results of deep sea monitoring show that marine litter is widely spread in deep waters, their abundance know strong spatial variations between areas (Pham et al., 2014), and their mean densities were ranging from 0 to more than 100,000 items/km^2(Galgani et al., 2000; Barnes et al., 2009; Keller et al., 2010; Miyake et al., 2011; Ramirez-Llodra et al., 2013; Schlining et al., 2013; Pham and Gomes-Pereira, 2013; Fabri et al., 2014; Debrot et al., 2014; Fischer et al., 2015; Bergmann et al., 2015; Zhou et al., 2016).

The impacts of marine debris have been described extensively and the consequences are alarming and occur in various forms. The marine

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debris can cause serious ecological, aesthetic and human health damage (Corbin and Singh, 1993; MaLiTT, 2002; Islam and Tanaka, 2004; Sheavly and Register, 2007; Gregory, 2009; GESAMP, 2010; Vegter et al., 2014; Di Beneditto and Awabdi, 2014; Gall and Thompson, 2015).

Even though this phenomenon is a worldwide problem, it has not been studied extensively in the Eastern Atlantic Ocean, and particularly in Moroccan waters. Knowing that Morocco has a coastline that stretches more than 3000 km with double maritime frontages; the Atlantic Ocean and the Mediterranean Sea, and fishing potential close to 1.5 million tons "renewable every year" (FAO, 2001). However, in the end, the marine environment is the main receptacle of pollutants. It receives directly 98% of liquid discharges from industrial and agricultural sectors and 52% of urban domestic wastes from coastal towns (Nakhli, 2010).

The present paper details the results of the first assessment of sea floor marine debris in Southern Atlantic Ocean of Morocco using data collected during a scientific trawling survey. Our objectives were to examine the abundance and composition of these marine debris, study their spatial distribution and concentration, define the relationship with the socio-economic activities and environmental characteristics, identify the potential geographic origins of this debris, and finally study the mechanism of transportation of marine debris in this area.

2. Materials and methods

2.1. Study area

Southern Atlantic Ocean of Morocco extends from Cap Boujdor 26N to Cap Blanc 21N. It is considered as a transition zone between northern subtropical Atlantic water (temperate) and tropical Atlantic southern water (Fig. 1).

Geomorphologically, the continental shelf is large and heterogeneous; the underwater formations are more extended to the north than the south. In the forefront Level (24N), the extent of the continental shelf is at the maximum and reaches about 100 nautical miles, while it is minimal (20 miles) at Cap Barbas in the south (22N), and at Cap Boujdor in the north (26N). A 94% of the total surfaces are adapted to the trawling activities (INRH, 1990).

The area climate is affected by the wind from the north and northeast, which is likely to generate when combined with a canary current. The winds run essentially parallel to the coast and limit terrigenous contributions to the offshore. The intensities are relatively large with significant occurrences conditions of strong winds, sometimes exceeding 12 m/s (INRH, 2013).

Hydrodynamically, the Moroccan Atlantic coast is directly under the influence of the anticyclone of the Azores and the zone of the intertropical convergence (ITCZ). The combination of the Canaries current and drift effects the surface water by the trade winds that cause a coastal continuous deep cold water rich in nutrients (nitrates and phosphates) called upwelling (Barton, 1998; Pelegr et al., 2005; Benazzouz et al., 2014b). It leads to the high productivity of the zone and affects the abundance and availability of fishery resources (INRH, 2015).

The fisheries activities in the studied area are organized into three segments of fishing (deep-sea fishing, coastal fishing and artisanal fishing) (INRH, 2014). It reaches up 60% of all of the activity of the national fishing. A wide variety of species with a high demand in foreign markets exists in this area. The pelagic fishery is very important with a strong dominance of sardines (*Sardina pilchardus*) and Cephalopods are the main exploited demersal species (FAO, 2001; INRH, 2002).

Several fishing techniques were then used to catch this species. The trawl bottoms and the nets are the most used by deep sea and coastal segments of fishing, while the "jig" and the *Octopus vulgaris* pots, were used by the artisanal segment in this Area (INRH, 2014).

2.2. Methods

2.2.1. Sampling methods

Relating to the marine monitoring program and the control of fisheries Resources, the National Institute of Fisheries Research of Morocco (INRH) conducts every year a prospection scientific survey to cover the Moroccan exclusive economic zone EEZ. A scientific trawling survey by Charif AL IDRISSI vessel research sampled the continental shelf from 8 to 27 October 2014. It covered an area that extends between cap Boujdor (26N) and Cap Blanc (21N) from 10 to 266 m depth (~ 47,541 km^2). The aim was to assess the stock of cephalopods in the region and specifically that of *Octopus vulgaris*, and provide all information about every phenomenon affecting the Southern Moroccan marine ecosystem. In parallel, we collected marine debris, following the same sampling network of this prospecting survey. A number of 100 stations were chosen randomly in the total surface of prospected area, according to the search time available and the distance traveled by the vessel to explore all of the potential geographical coverage. The area surveyed was subdivided into four depth strata (Strate1: less than 50 m deep, Strate2: between 50 and 100 m, Strate3: between 100 and 150 m and Strate4: greater than 150 m), while the majority of prospected station was chosen between 0 to 100 m depth (Table 1).

The trawling fishing gear used was a Spanish trawl net with an opening diameter of 21 m and Morger Steel Panels weighs 450 kg, the trawling time was fixed in 30 min and the trawling speed was 3 knots on average.

At every station, multitude parameters have been identified: the geographical position, the time of trawling, the depth, the distance to the coast, the seabed nature (which varies between sandy and muddy), the total quantity and nature of each type of marine debris.

2.2.2. Classification of debris

For each sampling event, a detailed analysis was carried out on the contents of the trawl to separate debris from marine species; knowing that some species use marine debris as artificial shelter. A wide diversity of anthropogenic debris were found (gloves, fabric, plastic shoes and bottles, aluminum cans of soda, glass bottle, plastic chip bag, metal paint and fishing equipment). They were counted, sorted and weighed to define their total quantity. Then they were classified according to the methodology of separation defined by (Keller et al., 2010), where they are divided into five main categories: plastic, glass, metal, textiles (fabric or fiber), and rubber.

2.2.3. Statistical analysis

According to Zhou et al. (2016) the density of debris lying on the seafloor for the trawl net sampling method, was calculated using the equation:

$$D = \frac{n}{A}$$

where density (D) is the amount of marine debris (kg/km^2) per station. n is the number of debris collected per haul for a given category and A is area swept per (km^2). Then swept area in each station by a fishing gear during a unit of effort is calculated by:

$$A = t.\ s.\ h.\ x^2$$

where s = the speed of trawling, h = length of the trawl rope, t = trawl time, x^2 = fraction expressing the width of the surface trawled divided by the length of the back rope (FAO, 1985).

Then the relative abundance of marine debris was calculated by:

$$Relative\quad Abundance = \frac{D}{\sum D}.\ 100$$

2.2.4. Spatial analysis

In analyzing the data, we followed a process consisting of three