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Floating Marine Debris in waters of the Mexican Central Pacific

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ABSTRACT

The presence of marine debris has been reported recently in several oceans basins; there is very little information available for Mexican Pacific coasts, however. This research examined the composition, possible sources, distribution, and density of Floating Marine Debris (FMD) during nine research surveys conducted during 2010–2012 in the Mexican Central Pacific (MCP). Of 1820 floating objects recorded, 80% were plastic items. Sources of FMD were determined using key objects, which indicated that the most were related to the presence of the industrial harbor and of a growing fishing industry in the study area. Densities were relatively high, ranging from 40 to 2440 objects/km^2; the highest densities were recorded in autumn. FMD were distributed near coastal regions, mainly in Jalisco, influenced by river outflow and surface currents. Our results seem to follow worldwide trends and highlight the need for further studies on potential ecological impacts within coastal waters of the MCP.

1. Introduction

Marine debris is defined as any manufactured or processed solid waste material that enters the coastal or oceanic marine environment from any source (Coe et al., 1997; Galgani et al., 2015; Ryan, 2015). Its presence in the marine environment has created problems that include the aesthetic degradation of the environment, entanglements or ingestion by marine organisms, and human consumption of marine debris through seafood (Derraik, 2002; Sheavly and Register, 2007; Cole et al., 2011; Williams et al., 2011; Rochman et al., 2013; Schuyler et al., 2014;Van Cauwenberghe and Janssen, 2014; Lusher, 2015). For this reason, marine debris has been recognized as a problem of global importance, similarly to other issues such as climate change, ocean acidification, and biodiversity loss (Sutherland et al., 2010; SCBD and STAP, 2012).

Marine debris can be classified, taking into account its floatability, into two main categories: 1) debris that quickly sinks and deposits itself on the seafloor, and 2) floating debris that remains on the water surface. The composition, distribution, and density of Floating Marine Debris (FMD) in coastal and oceanic areas are primarily influenced by factors such as ocean current patterns, tides, and the proximity to urban, industrial and recreational areas, shipping lanes, and fishing grounds (Thiel et al., 2003; Galgani et al., 2015). Depending on its origin marine debris can be classified into either ocean-based debris (e.g. from ships) or land-based debris (e.g. direct dumping) (Williams et al., 2005; NOAA, 2014). To date, most studies indicate that a large portion of marine debris has land-based sources; nonetheless, in some regions of the world ocean-based activities such as fisheries and maritime traffic contribute significantly to marine debris abundance (Gregory, 2004; Hinojosa and Thiel, 2009).

Currently, FMD are found all over the world's oceans and consequently there have been a growing number of studies on the matter (e.g. Gregory and Ryan, 1997; Matsumura and Nasu, 1997; Barnes, 2002; Shiomoto and Kameda, 2005; Hinojosa and Thiel, 2009; Thiel et al., 2011, Ryan, 2013; Ryan, 2014, Suaria and Aliani, 2014; Suaria et al., 2015), but very few reports are available for the Mexican Pacific (Coe et al., 1997; Matsumura and Nasu, 1997; Ivar do Sul and Costa, 2007).

Most studies have been conducted in coastal waters through beach surveys (Silva-Iñiguez and Fischer, 2003; Turner and Holmes, 2011; Kordella et al., 2013), where high FMD abundances have coincided with urbanized regions, presence of shipping routes, or prevalence of ocean currents (Matsumura and Nasu, 1997; Thiel et al., 2003). These features also occur in the Mexican Pacific coast, where a number of important ports and cities are located. Therefore, a similar situation to the global marine debris problem could also occur in this region.

Coastal studies only portray a fraction of the problem that FMD can represent. For a better understanding of FMD occurrence, density, and potential effects on the environment, it is essential to increase FMD monitoring in coastal and open waters. Thus, the aim of this research was to establish the first evaluation of the composition, possible source,

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seasonal distribution, spatial distribution, and density of FMD within Mexican Central Pacific waters.

2. Materials and methods

The Mexican Central Pacific (MCP) is a region that comprises the waters extending from Cabo Corrientes, Jalisco, to Maruata, Michoacán. It has been subdivided into two zones: a coastal zone, defined by a stretch of continental shelf that extends from the coast to around 30 nm offshore; and an oceanic zone, which begins at 30 nm from shore and extends to 100 nm offshore. It was further subdivided according to the geopolitical divisions of the states of Jalisco, Colima and Michoacán; resulting in six quadrants (Fig. 1).

Systematic sighting surveys were conducted in MCP waters from 2010 to 2012 in order to record FMD. Surveys were conducted from two research vessels: the *BIP XII*, 24.4 m long with a 6.7 m high platform, and the *MaryChuy III*, 10.7 m long with a 4.3 m high platform. A team of six people was assembled in order to allow frequent (every 30–40 min) rotation of the positions: a port side observer, a starboard side observer, two independent observers, a data recorder, and one rest (break) position to avoid observer's fatigue. The following data were collected: time of record, rotation, GPS positions (using *Garmin GPSmap 76cs*), sea conditions (wind direction and speed, swell, visibility, and Beaufort scale), and sighting effort (1 = active sighting or 0 = inactive sighting). The sighting effort was determined by the weather and sea conditions. When sighting conditions were optimal (indicated by a Beaufort value of 0–3) observers remained active, scanning constantly to 90° on either side of the ship's bow with *Fujinon* 7 × 50 binoculars. When sighting conditions were not optimal (indicated by a Beaufort value ≥ 4 or by rain) observers remained at their position but did not use binoculars to search for debris.

A total of nine surveys were conducted during the study period. Three surveys were completed during 2010, covering the winter, spring/summer and autumn seasons; two surveys were conducted in 2011, covering the winter and autumn seasons (due to logistical reasons the survey covering the spring/summer period could not be completed); and four surveys were conducted during 2012, two of which were conducted during autumn, the first at the beginning of the season in the coastal region only, and the second at the end of the season in the coastal and oceanic regions (Table 1).

Survey effort ranged from 991.1 km to 1398.9 km, and totaled 11,079.0 km. Variations in survey effort are attributed to a number of factors such as the use of different vessels. *BIP XII* has the capacity to navigate long distances and was used to conduct the oceanic surveys of 2010 and 2011, but was unavailable for the remaining surveys, whereas *MaryChuy III* is more limited in its capacity to undertake oceanic surveys and was used only for coastal surveys. The second factor that contributed to differences in effort is associated to climatic conditions. The presence of storms limited the distance surveyed away from the coast as well as the hours and days worked at sea. Nonetheless, once effort per season was taken into account it was determined that the survey area was satisfactorily covered. Bearing in mind that this is the first effort to analyze FMD within MCP waters, we consider that the results gathered here are pioneer and significant.

When FMD was sighted the following data were collected: time, GPS position, type of FMD, radial distance and angle (data taken with binoculars), as well as any other observation of interest (such as FMD patches).

Floating Marine Debris was categorized according to type or composition and possible use. Key objects are objects used exclusively for a particular activity, and are therefore considered as unequivocal indicators of either land- or ocean-based sources; for example, a buoy or a fishing line are objects used in ocean activities, whereas a ball or a carpet are commonly used on land. Key objects were identified according to Silva-Iñiguez and Fischer (2003) and Sheavly (2005) to establish possible sources of FMD.

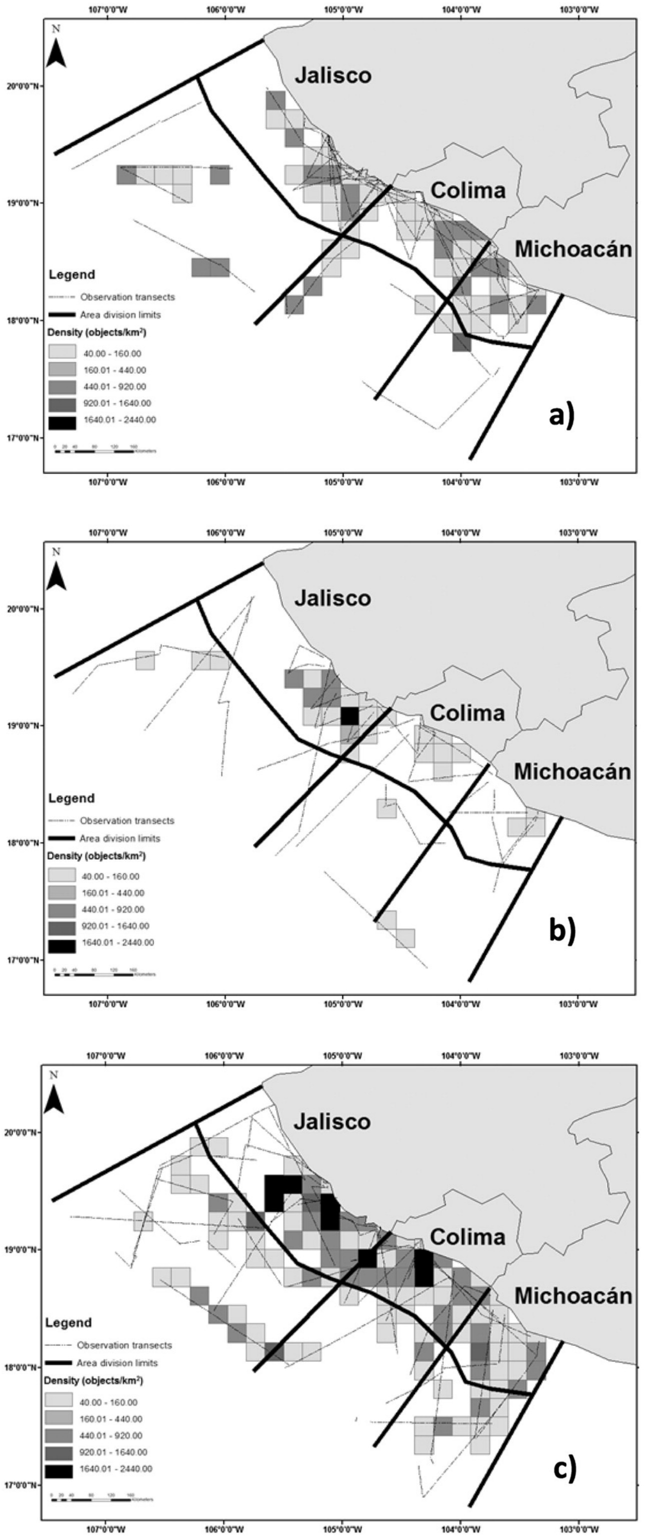

Fig. 1. Density of Floating Marine Debris (FMD) during: a) winters, b) springs/summers, and c) autumns during 2010–2012. The coastal and oceanic regions are indicated with thick lines. Observation effort is shown as thin lines representing transects conducted.

The density of FMD ($D = \text{objects/km}^2$) was estimated using the line transect method (Seber, 1982), which is based on the number of objects recorded during a transect, using the following equation:

$$D = \frac{n}{\left(2 * \frac{w}{1000}\right) * L}$$

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