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Young green turtles, *Chelonia mydas*, exposed to plastic in a frontal area of the SW Atlantic

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ABSTRACT

Ingestion of anthropogenic debris represents an important threat to marine turtle populations. Information has been limited to inventories of debris ingested and its consequences, but why ingestion occurs and the conditions that enable it are less understood. Here we report on the occurrence of plastic ingestion in young green turtles (*Chelonia mydas*) inhabiting the Río de la Plata (SW Atlantic). This estuarine area is characterized by a frontal system that accumulates anthropogenic debris. We explored exposure of green turtles to plastic and its ingestion via debris distribution, habitat use and digestive tract examination. Results indicated that there is considerable overlap of frontal accumulated plastic and core foraging areas of the animals. Exposure results in ingestion, as shown by the high frequency of plastic found in the digestive tracts. The Río de la Plata estuarine front is an area of conservation concern for young green turtles.

1. Introduction

Marine turtle populations have been reduced by exploitation and consumption of eggs and meat during the past centuries (IUCN, 2013; Meylan and Donnelly, 1999; Seminoff, 2004). Egg harvesting and consumption of turtles are now regulated in most places, but direct and indirect threats continue to threaten populations: bycatch in fishing gear kills thousands of turtles per year (Wallace et al., 2010), pollution with artificial lights on nesting beaches disrupts nest-site choice and orientation (Witherington and Martin, 2003), and oil spills affect marine turtles through direct contact or by fouling of their habitats. A pervasive, highly damaging and expanding problem is entanglement and ingestion of anthropogenic debris (Lutcavage et al., 1997). Some turtle populations are recovering after controlling direct exploitation (e.g. Bjorndal et al., 1999; Broderick et al., 2006; Chaloupka et al., 2008; Dutton et al., 2005; Marcovaldi and Chaloupka, 2007), but the cumulative impacts of other threats, including ingestion of anthropogenic debris, may hamper or reduce population recovery (Donlan et al., 2010; Coll et al., 2012; Maxwell et al., 2013).

Ingestion of anthropogenic debris has been reported in almost all marine turtle species. It occurs in all life stages and several geographic areas (see Schuyler et al., 2013 and references therein). Plastics are the most commonly ingested of all solid pollutants (Schuyler et al., 2013). The amount of debris found in the stomach of an animal is generally small, in terms of number of items and weight (Bjorndal, 1997; Schuyler et al., 2013), but even that may have lethal consequences through perforation or impaction of the digestive system (Bjorndal et al., 1994). Direct mortality due to debris ingestion seems to occur rarely, although it is difficult to prove. The most common health effects are exposure to chemicals leaching from the debris and dietary dilution that reduce somatic growth or reproductive output (Laist, 1987; McCauley and Bjorndal, 1999). Such sublethal effects are difficult to estimate for these long-lived and highly migratory animals (Bjorndal et al., 1994; McCauley and Bjorndal, 1999; NRC, 1990).

To date, research has focused on a valuable and exhaustive inventory of the debris ingested and its consequences, but why plastic ingestion occurs and the conditions that enable it are far from being understood. It has been suggested that leatherbacks mistake gelatinous plankton for floating plastic bags (Bjorndal, 1997; Mrosovsky et al., 2009); thus zooplanktivorous turtles would

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be particularly vulnerable to ingestion of plastic debris. Gelatinous plankton tends to be aggregated at physical discontinuities such as ocean fronts (Graham et al., 2001; Mianzan and Guerrero, 2000), and these same ocean features may concentrate floating debris (Barnes et al., 2009; Pruter, 1987). Therefore, during their oceanic developmental stage, marine turtles may be more exposed to debris ingestion when feeding in frontal areas (Carr, 1987; Schuyler et al., 2013; Witherington, 2002). Nevertheless, marine turtles with benthic and neritic feeding habits are also known to ingest plastic (e.g. Bjorndal et al., 1994; Bugoni et al., 2001; Schuyler et al., 2013; Tourinho et al., 2010). We report here on the occurrence of the problem in young green turtles in neritic habitats, linking the threat of plastic ingestion with a particular oceanographic feature in the distribution range of the species.

Juvenile green turtles reach the temperate waters of Argentina and Uruguay in their migration along foraging habitats of the eastern coast of South America (González Carman et al., 2011, 2012). From November to May, they intensively use the Río de la Plata estuarine area to feed on gelatinous plankton (González Carman et al., 2012, 2013; Fig. 1) that aggregates in the frontal system of the estuary (Mianzan et al., 2001). The system also accumulates anthropogenic debris (Acha et al., 2003). We explored exposure to plastics and its ingestion through the combination of information on plastic distribution, habitat use and examination of digestive tract contents of juvenile green turtles.

2. Methods

2.1. Study area: the Río de la Plata frontal system

The Río de la Plata (Argentina–Uruguay) is a two-layered estuarine system where freshwater flows seaward on the surface, and denser, saline shelf water intrudes along the bottom (Mianzan et al., 2001; Fig. 1). This dynamic generates two salinity fronts separated by *ca.* 150 km and connected by a salt-wedge: a bottom and a surface front at the inner and outer part of the estuary, respectively. The bottom front can be approximated at the surface by the presence of an estuarine turbidity maximum. The turbidity maximum is due to the suspended matter flocculation near the tip of the salt wedge, and re-suspension of sediment due to tidal stirring (Framiñan and Brown, 1996). The turbidity front can be easily identified in satellite images; its modal position is located near the limit of the marine water intrusion. (Acha et al., 2008; Framiñan and Brown, 1996; Mianzan et al., 2001). The surface front has lower salinity gradients than those of the bottom front, and its location is more variable. This frontal system favors the retention and concentration of gelatinous plankton (Alvarez Colombo et al., 2003; Cabreira et al., 2006; Mianzan and Guerrero, 2000; Mianzan et al., 2001), which constitutes the main food for green turtles in the area (González Carman et al., 2013). Along with gelatinous plankton, the bottom front also accumulates anthropogenic debris that drifts down the river and is generated by highly populated cities in the region (i.e. Buenos Aires, Montevideo) and by intensive vessel traffic (Acha et al., 2003).

2.2. Exposure to plastic pollution

Data on the distribution and concentration of anthropogenic debris in the Río de la Plata are from Acha et al. (2003). Anthropogenic debris (plastic bags, cans, bottles and hard plastic pieces) were collected from 1996 to 2001 using a bottom trawl net operated at 269 stations arranged in a random sampling design that covered most part of the estuary (Acha et al., 2003). For our analysis, we used information only on plastic debris (plastic bags and hard plastic pieces) since it is most frequently consumed by marine turtles (Bjorndal et al., 1994; Bugoni et al., 2001; Tomás et al., 2002; Tourinho et al., 2010). Plastic debris was counted and expressed as number of items per km^2. For further details on the sampling method see Acha et al. (2003).

We overlapped data on plastic debris distribution with green turtle foraging areas obtained through satellite telemetry from 9 turtles during the period 2008–2011 (González Carman et al., 2012; Fig. 2). Animal positions were analyzed with state-space models to identify locations where the animals were likely engaged in foraging activities (Breed et al., 2009; Maxwell et al., 2011; see modeling details in González Carman et al., 2012). Fixed kernel density estimation was used to construct a map showing foraging areas, created from the 'foraging' locations from the state-space model results. This method

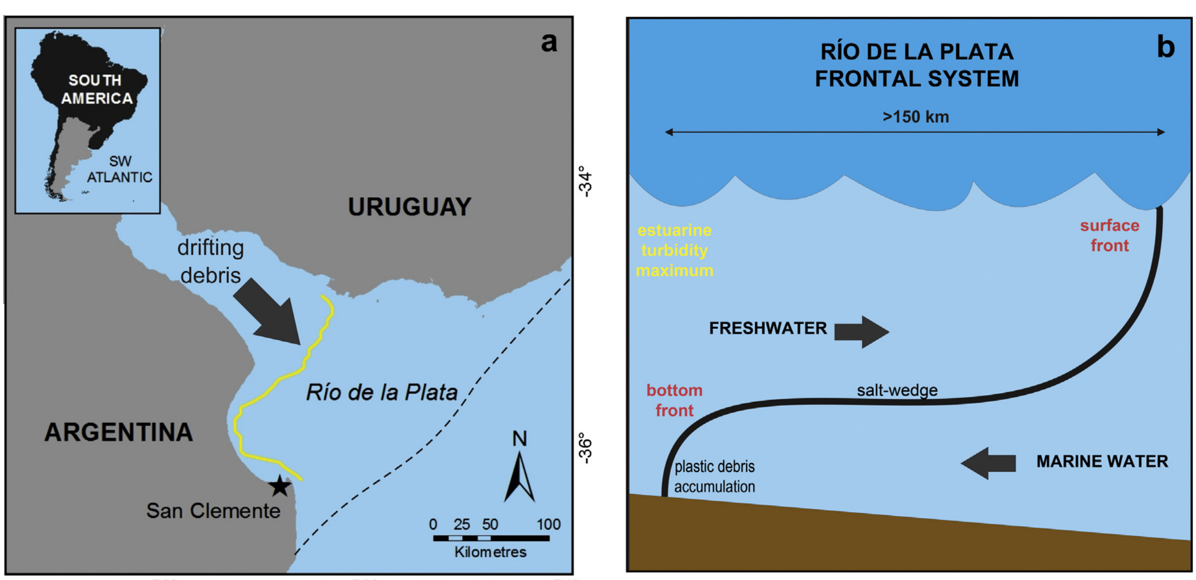

Fig. 1. (a) Río de la Plata estuarine area (Argentina–Uruguay). The yellow line represents the modal position of the turbidity front (from Framiñan and Brown, 1996) which is a proxy of the bottom salinity front position. The black dashed line indicates an approximate position of the surface salinity front (Mianzan et al., 2001; Cabreira et al., 2006). Black star indicates the location where green turtles were caught as bycatch in a gillnet fishery, providing material for the digestive tracts sampling. (b) Conceptual diagram of the Río de la Plata frontal system modified from Acha et al. (1999) and Mianzan et al. (2001) (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).