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Baseline

A baseline assessment of beach debris and tar contamination in Bonaire, Southeastern Caribbean

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ABSTRACT

Data on beach debris and tar contamination is provided for 21 natural beach sites in Bonaire, Southeastern Caribbean. Transects amounting to a combined length of 991 m were sampled March–May 2011 and a total of 8960 debris items were collected. Highest debris and tar contamination were found on the beaches of the windward east-coast of the island where geometric mean debris concentrations (± approx. 70% confidence limits) were 115 ± 58 items m^{-1} and 3408 ± 1704 g m^{-1} of beach front. These levels are high compared to data collected almost 20 years earlier on the nearby island of Curaçao. Tar contamination levels averaged 223 g m^{-1} on windward beaches. Contamination levels for leeward west-coast beaches were generally two orders of magnitude less than windward beaches.

1. Introduction

Marine debris and tar contamination affect ecosystems and the provision of ecosystem services in various ways, among which deleterious effects on wildlife and habitat quality, economy and aesthetics and even human health and safety (UNEP, 2006). Marine debris (litter) is a particularly wide-spread problem and is considered to be one of the most serious threats to sustainable use of the marine and coastal resources of the Caribbean (UNEP, 2006). Nevertheless, studies on beach debris, and general environmental pollution levels in the Caribbean remain sparse, which makes it difficult to provide conclusive arguments for policy and management action. A review by Ivar do Sul and Costa (2007) specifically emphasises the continuing paucity of recent studies on the debris problem for the Caribbean and the need for new data.

In this study we document beach debris and tar contamination at 21 natural beaches distributed around the island of Bonaire (Fig. 1). The first and only study on this topic for Bonaire dates from the mid-1980s and concerns a study of beach tar at four beach sites (Newton, 1987). To facilitate comparison to results obtained almost 20 years earlier on the nearby island of Curaçao, we closely followed the methods by Debrot et al. (1995, 1999). The data collected in this study provides base-line information on anthropogenic contaminants on the beaches of Bonaire which can be used to help direct both local and regional litter management efforts. Beach site selection followed the IOC manual for petroleum pollution monitoring (UNESCO, 1984; Ribic et al., 1992). Due to the predominant wind, wave and current direction, the beaches on the east side of the island are high-energy beaches (sites 12–21) while the beaches along the west side of the island (sites 1–11) are relatively sheltered. The beaches of the northern half of Bonaire further are basically small pocket beaches, ranging in width from just a few to more than 100 m, while the beaches of southern Bonaire are much longer and not forming distinct pocket beaches.

Sampling was conducted in the central part of each pocket beach in northern Bonaire and on an arbitrarily predetermined sampling point on the long stretches of beach in southern Bonaire. For the grossly contaminated windward sites, transect widths for debris collection was 5 m, whereas for the much less contaminated leeward beaches transect widths varied between 10 m (in the case of the pocket beach of Playa Benge) to 100 m or more in southern Bonaire to increase the debris sample size for comparison. Transect widths for tar collection were principally 2-m on windward beaches, and 5 m on leeward beaches. However, transect widths were extended in the case of extremely low soiling. Consequently, this approach maximized the chance of detecting tar on any given beach.

Sampling on all beaches was limited to the zone stretching from the low tide mark to the point where permanent beach vegetation first appeared (e.g. Santos et al., 2009). The upper few centimetres of the transects were raked and all debris and tar balls and oil found within the transect with a maximum diameter of 5 cm or greater was removed, identified, measured, cleaned where necessary and weighed. Data by Debrot et al. (1999) had indicated that

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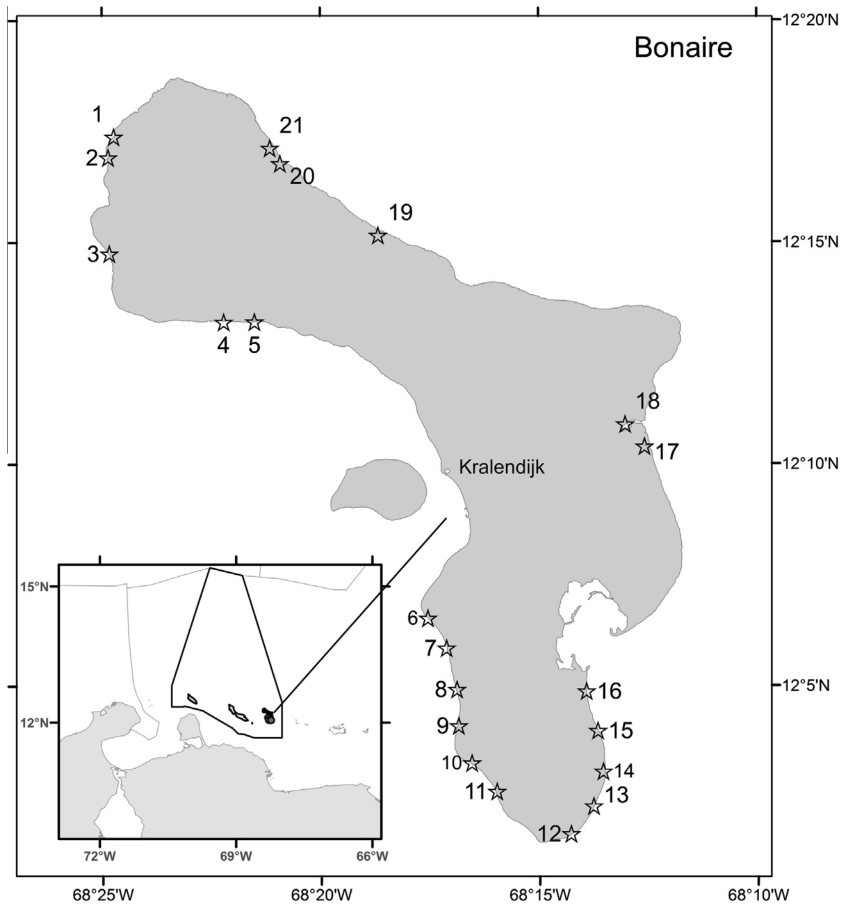

Fig. 1. Map of Bonaire showing the location of the 21 beach sites selected for debris and tar contamination assessment.

collection of fragments smaller than 5 cm by hand picking was incomplete. Plastic bottle caps (2 cm diameter) were an exception and were efficiently sampled at such small sizes and therefore were included in this analysis.

Whereas lighter items were taken back to the lab for more accurate weighing pooled by category of material, heavy items, such as boards and beams were weighed in the field to the nearest kg. Materials were identified as either plastic, wood, glass, polystyrene foam (styrofoam), metal, cloth, paper, rubber or masonry. Debris items were also identified according to use.

Debris concentrations were expressed as numbers and weights of items m^{-1} of beach front and tar only as weight m^{-1} of beach front. As beach debris concentrations are typically highly variable and appear to be generally log-normally distributed (e.g., Butler et al., 1998), the geometric mean is a statistically more robust measure of central tendency than the arithmetic mean. Therefore, we expressed debris densities in terms of geometric means with approximate 70% confidence limits based on the log-normal distribution. Statistical comparison of debris concentrations between coastal categories was done using the distribution-free Mann-Whitney U-test. The differences in relative frequency of debris type, and size were tested for by Chi-square Goodness-of-Fit tests. For comparison of size-distributions between coasts, comparison was only considered if the number of objects of a particular material collected exceeded 30 items. All statistical tests were conducted using IBM SPSS vers. 19.

On windward beaches, a total of 7988 items were collected for a combined weight of 246.3 kg from a total of 46 m of beach front. Contamination levels on windward beach sites ranged from an average of 9–1640 items m^{-1} of beach front (Table 1), for a geometric mean of 115 ± 59 items m^{-1}. In terms of debris weight, corresponding contamination levels ranged from 545 to 35,306 g m^{-1} (Table 2), for a geometric mean value of 3408 ± 1704 g m^{-1}. The leeward beaches had much lower levels of debris contamination. In this, the leeward beaches of the extreme northern and southern promontories of the island, directly under the windward coast of the island, were an exception. However, as these were atypical leeward beaches, they were not included in our study. On leeward beaches, a total of 972 items were collected for a combined weight of 43.1 kg from a total of 945 m of beach front. Debris densities on leeward beach sites ranged from 0.1 to 5 items m^{-1} and from 5 to 716 g m^{-1} of beach front. Corresponding geometric mean levels were 1 ± 0.4 items m^{-1} and 38 ± 19 g m^{-1}. The differences in debris contamination between windward and leeward beaches were statistically significant in terms of both numbers and weight ($p = 0.000$). Tar was only encountered on two of the eleven leeward beaches studied for an average of 4 g m^{-1}. On the windward coast, tar was collected at 5 of the 10 beach sites (range: 7.5–1424 g m^{-1}) for an average of 223 g m^{-1} across all 10 sites.

Plastics were numerically the most important material component of the collected debris and represented 72% of all items collected. The next principal components were respectively, styrofoam (16%) and wood (7%) (Table 1). The numerical differences in material distribution by coast differed significantly (Pearson Chi-square = 61.3, df = 5, $p = 0.000$). While plastics followed by styrofoam fragments were thus numerically dominant on both beach categories, their contribution to the total weight of debris differed significantly (Table 2). On windward beaches, the weight