Marine Pollution Bulletin 88 (2014) 361–365

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

Deepwater marine litter densities and composition from submersible video-transects around the ABC-islands, Dutch Caribbean

A.O. Debrot [a,b,*], E. Vinke [c], G. van der Wende [c], A. Hylkema [c], J.K. Reed [d]

[a] Institute for Marine Research and Ecosystem Studies, Wageningen UR, P.O. Box 57, 1780AB Den Helder, The Netherlands
[b] CARMABI Foundation, Piscaderabaai z/n, P.O. Box 2090, Dutch Caribbean, Curaçao
[c] Hogeschool Van Hall Larenstein, Coastal and Marine Management, P.O. Box 1528, 8901 BV Leeuwarden, The Netherlands
[d] Harbor Branch Oceanographic Institute at Florida Atlantic University, 5600 U.S. 1 North, Fort Pierce, FL 34946, United States

ARTICLE INFO

Article history:
Available online 28 August 2014

Keywords:
Caribbean
Seafloor
Marine
Deepwater
Debris
Pollution

ABSTRACT

Baseline data on anthropogenic seafloor debris contamination in the year 2000 is provided for 24 submersible video transects at depths of 80–900 m, off the Dutch ABC-islands (Aruba, Bonaire, Curaçao), in the southeastern Caribbean Sea. In total, 202 objects were documented from a combined 21,184 m of transect, ranging from sandy lower island-slope to rocky upper island-slope habitat. Debris densities differed significantly with depth. Highest debris accumulation (0.459 items 100 m^{-2} or 4590 items per km^2) occurred at depths of 300–600 m on more shallow-sloping (20–30°) sand and silt bottoms. The overall average debris density was 0.27 objects per 100 m^2 (or 2700 items per km^2), which is an order of magnitude higher than most other deepwater debris studies. What we describe may be representative for other small, populated, steep volcanic Caribbean islands. Food and beverage-related items were the single largest usage category identified (44% of objects; mostly glass beverage bottles).

The deleterious effects of man-made debris in the marine environment have recently been reviewed by Gregory (2009) and Engler (2012). These effects include entanglement, entrapment, ingestion, rafting of invasive species, concentration of man-made pollutants and even habitat alterations that can cause major changes in benthic community structure (Katsanevakis et al., 2007). The various effects of marine litter combined with its explosive growth in abundance and distribution, make it one of the key new areas of marine stewardship requiring policy action (UNEP (United Nations Environment Programme), 2008; Galgani et al., 2013).

Most available information is for marine debris of beaches, whereas studies on seafloor marine debris are becoming available for more and more areas of the world's oceans (e.g.; Mediterranean: Galil et al. (1995); Europe: Galgani et al. (2000); US West coast: Keller et al. (2010); Watters et al. (2010); Schlining et al. (2013); Hawaii: Ribic et al. (2012)). Wei et al. (2012) recently documented the distribution and composition of anthropogenic litter in the Gulf of Mexico and concluded that certain areas of the seafloor may form focal points for litter due to topography, currents or shipping lanes. For the southeastern Caribbean, some recent data is available on anthropogenic marine litter but this is practically limited to intertidal (e.g. Debrot et al., 1999, 2013a) and shallow sublittoral habitats (Nagelkerken et al., 2001; Debrot et al., 2013b). These litter densities are generally extremely high compared to other regions of the world, but no data are yet available for deeper tropical waters in the Caribbean.

In May 2000, 24 submersible dives were conducted with the Johnson-Sea-Link II research submersible of Harbor Branch Oceanographic Institution, Florida, USA, down to depths of 900 m, off Curaçao, Bonaire and Aruba (Reed and Pomponi, 2000). The focus of the expedition was on deep sea biodiversity and bioprospecting, particularly of lithistid sponges which are a dominant group of hard-bottom macroinvertebrates at depths greater than 150 m (Pomponi et al., 2001). The local marine park management agency, Carmabi Foundation, requested that video footage be made of all fish and seafloor debris encountered during the expedition. We here present the results pertaining to the seafloor litter documented around these southeastern Caribbean islands.

The Harbor Branch Oceanographic Institution expedition to the leeward Dutch islands took place during 1–22 May 2000, and had 14 operation days, 10 of which in Curaçao, 4 in Bonaire and only 1 in Aruba, due to poor weather. The dives were conducted by means

* Corresponding author at: Institute for Marine Research and Ecosystem Studies, Wageningen UR, P.O. Box 57, 1780AB Den Helder, The Netherlands. Tel.: +31 (0)317 487395.

E-mail addresses: dolfi.debrot@wur.nl (A.O. Debrot), erwin.vinke@wur.nl (E. Vinke), guusvanderwende@hotmail.com (G. van der Wende), alwin.hylkema@wur.nl (A. Hylkema), jreed12@hboi.fau.edu (J.K. Reed).

http://dx.doi.org/10.1016/j.marpolbul.2014.08.016
0025-326X/

of the Johnson-Sea-Link II research submersible which was launched from the RV Edwin-Link, a 51.2 m, 781 ton (displacement), converted former offshore supply vessel. The Johnson-Sea-Link II, was equipped, among others, with a video camera, a 35 mm camera, and a data recorder for time, depth, salinity and temperature. Dives were made at 24 locations at depths of 80–900 m (Fig. 1). Table 1 provides basic data for each dive including total bottom time and distance covered at each site. Dive

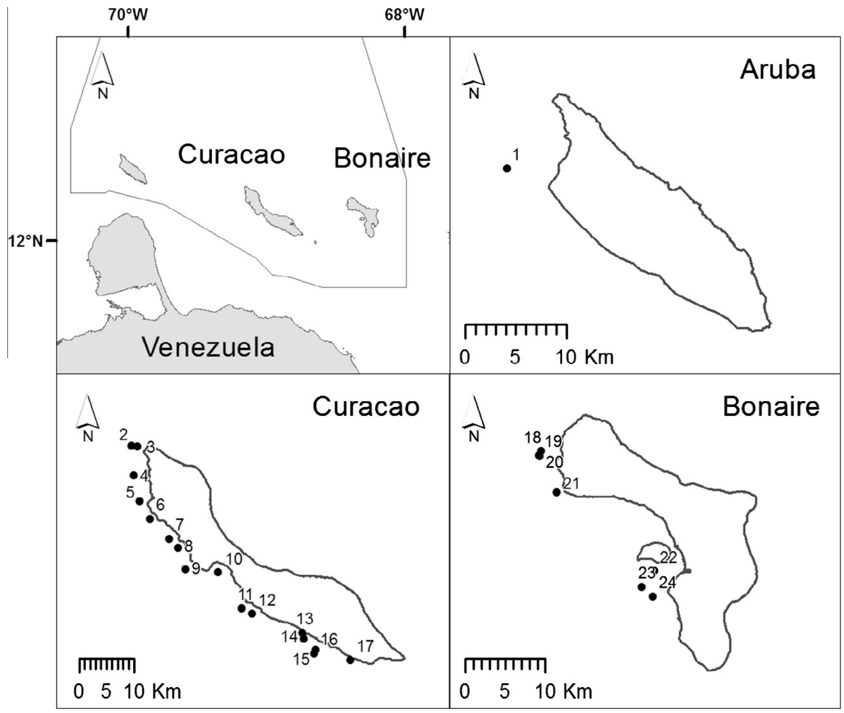

Fig. 1. Map of 24 deep submersible dive-sites in the Leeward Dutch Caribbean ABC-islands. Borders of the southern Caribbean Dutch Caribbean Exclusive Economic Zone (EEZ) are shown in the upper-left, geographic overview map.

Table 1
Anthropogenic debris densities (n/100 m^2) and count (n) for four depth zones as observed during submersible dives around the Leeward Dutch Caribbean ABC-islands, May 2000.

Map location #	Dive code name	Date of dive	Total bottom time (h:min)	Total transect length (m)	Transect width (m)	Depth 80–100 m	Depth 100–300 m	Depth 300–600 m	Depth 600–900 m	Total debris counts
Debris observed (density/count)										
Aruba										
1	JSL-3220	5/17/2000	2:25	875	3.63	0	0.440 (1)	–	–	1
Curaçao										
2	JSL-3222	5/19/2000	2:40	752	3.26	-	–	0 (0)	0 (0)	0
3	JSL-3223	5/19/2000	2:37	477	3.39	0 (0)	0.114 (4)	0 (0)	–	4
4	JSL-3212	5/12/2000	2:21	1243	3.15	0 (0)	0.054 (4)	0.229 (3)	0 (0)	7
5	JSL-3211	5/12/2000	2:43	775	3.89	–	0 (0)	0.052 (1)	–	1
6	JSL-3225	5/20/2000	2:35	1163	2.85	0 (0)	0 (0)	0 (0)	0 (0)	0
7	JSL-3224	5/20/2000	2:33	902	3.34	0 (0)	0.058 (1)	0.253 (3)	–	4
8	JSL-3210	5/11/2000	3:00	617	3.02	NA (4)	–	0.624(1)	–	5
9	JSL-3209	5/11/2000	2:44	1369	4.2	–	0.115 (3)	0.159 (5)	NA (2)	10
10	JSL-3221	5/18/2000	2:27	908	3.31	–	–	0.200 (6)	–	6
11	JSL-3208	5/10/2000	2:37	1057	2.89	–	–	0.163 (5)	–	5
12	JSL-3226	5/21/2000	2:44	1414	3.75	–	0.568 (16)	1.045 (26)	–	42
13	JSL-3204	5/8/2000	1:46	610	3.95	–	0.249 (6)	–	–	6
14	JSL-3203	5/8/2000	0:22	210	2.93	–	–	2.275 (14)	–	14
15	JSL-3205	5/9/2000	2:31	2261	3.19	–	–	0.123 (5)	0.223 (7)	12
16	JSL-3206	5/9/2000	2:26	545	3.27	–	–	–	0.505 (9)	9
17	JSL-3207	5/10/2000	2:51	602	3.04	0 (0)	0.194 (3)	0 (0)	–	3
			Mean:	932	3.34	0	0.15	0.366	0.148	128
Bonaire										
18	JSL-3216	5/15/2000	2:12	523	3.97	–	–	–	0.048 (1)	1
19	JSL-3217	5/15/2000	2:40	431	3.33	–	–	0.077 (1)	0 (0)	1
20	JSL-3215	5/14/2000	2:23	465	3.63	–	–	–	0 (0)	0
21	JSL-3214	5/14/2000	2:48	1157	3.6	0.024 (1)	0.144 (6)	2.220 (26)	–	33
22	JSL-3213	5/13/2000	2:54	1644	3.46	0.035 (2)	0 (0)	0.378 (8)	–	10
23	JSL-3218	5/16/2000	2:54	357	3.5	–	0.480 (6)	–	–	6
24	JSL-3219	5/16/2000	2:01	827	3.22	–	0.826 (22)	–	–	22
			Mean:	772	3.53	0.03	0.363	0.892	0.016	73
	Mean, all islands:			882	3.37	0.007	0.216	0.459	0.098	202

sites preferentially targeted areas of steep topography to maximize chances for benthic macroinvertebrates. Prior to each dive, depth profiles for the island slope at the dive site were plotted with the ship's fathometer. Based on this, the general starting depth and initial track of the dive were determined. The submersible was launched at the deepest part of the dive and once on the bottom, followed a general course up the island slope moving slowly (max speed, 1 knot, cruising speed, 0.25 knots) with floodlights directed forwards and sideways in search of sponges and stopping frequently to collect biological material. Transects were exploratory in nature but quite consistently followed a linear course (Reed and Pomponi, 2000, appendix 5) up the island slope. Therefore, a limited number of waypoints were sufficient to document track course. All major changes in track direction were marked with a waypoint while additional waypoints were inserted when marking special biotic collections. Hence, the number of waypoints used per site differed depending on track length, changes in direction and number of collections and varied between 2 and 9 per site (mean ± 1 SD: 5.2 ± 1.8). While with a few exceptions, bottom time varied little between dives, the total distance actually covered varied greatly (Table 1), as this depended on how much macroinvertebrate fauna was encountered and how much collecting was done.

Waypoints, collection-site coordinates and dive tracks were determined with GPS navigation (JVC DGPS 600 Global Positioning System) and an Integrated Mission Profiler which tracks the submersible's position with an accuracy of approximately 15 m (Reed and Pomponi, 2000). Underwater visibility typically was 15–30 m but was ultimately limited due to the darkness at deeper depths. Bottom substrate conditions were highly variable and ranged from sandy and muddy slopes, to large, 10-m-high boulders, rock ledges, rock pavement, and rock walls (Reed and Pomponi, 2000). Complex and steep bottom topographic features typically possessed more sponge and hydrocoral fauna and, during this expedition, were targeted in preference to shallow-sloping unconsolidated seafloor conditions. Consequently, steep rock faces, large boulders settled on the seafloor and seamounts were features especially targeted for exploration. While generalizations are therefore difficult, at depths greater than 300 m, island slope substrates generally were 20–40° and generally mud or sand, whereas from 300 to 80 m depths steeper 30–60° rocky slopes predominated. Below 100 m depth, and down to the foot of the island proper, bare volcanic rock abutted from the sandy slopes while at depths above 100 m hard substrates were generally dominated by coralline rock. Because of the steep island slopes, deep dives took place relatively close to shore. Submarine launches took place at an average 2.25 km from shore, whereas the most distant dive was launched at 4.9 km from shore (Aruba, Fig. 1). Depending on local bathymetry, and the depth zone(s) and distances covered, dives ended anywhere from 3.5 (only the Aruba dive) to 0.3 km from shore.

During each dive, video recordings were made with a forward-looking video camera. The video did not run continuously throughout the transect as most seafloor was monotonous and had neither macroinvertebrates of interest, nor debris. The video was turned on when fauna or objects of interest were encountered but also regularly turned off during lengthy collection efforts at stationary locations. Color, high 8-mm video tapes were taken with a Sony DX2 3000A video camera equipped with a Canon J8X6B KRS lens, 6–48 mm zoom and 0.3 m minimum focus (Reed and Pomponi, 2000). The average breadth of the seafloor within the field of vision, varied according to the height of the submersible above the sea floor. An average width was estimated for each visual transect at a maximum of 10 different spots with objects of known length (e.g. a discarded toilet or tire) and four parallel laser dots defining a 25 × 25 cm square. The largest and smallest of the 223 point estimates for transect width were 11.25 and 1.01 m, respectively. However, overall mean transect width was 3.37 ± 1.7 m and with few exceptions individual mean transect width consistently fell between 3 and 3.5 m (Table 1). Debris detectability in transects was not uniform but likely lower towards the transect edges due to weaker lighting levels. Based on the small number of replicates per transect no significant differences in transect width could be established (ANOVA, $p > 0.05$). Nevertheless, all site-specific density estimates were calculated using the site-specific average transect widths, as shown in Table 1. This contributed an additional yet realistic source of variation to our density estimates and acts to reduce test power. In the lab we scored the video track from each dive based on a few simplifying assumptions. First, we calculated transect length using straight-line approximation between waypoints, starting with the first waypoint marking arrival on the bottom, going from waypoint to successive waypoint and ending with the last waypoint signaling the ascent to the surface. This means that actual transect length is probably a bit longer than our approximation. Due to the seafloor topographic heterogeneity encountered, categorization according to general geomorphic zones was difficult, so we examined debris distribution with depth, using four different broad depth zones. These were as follows: shallower than 100 m (80–100 m, deep reef), from 100 to 300 m (top, steep, rocky island-slope), from 300 to 600 m (sandy shallow-sloping bottom of island slope) and more than 600 m (maximum depth was 914 m). While total track length was estimated for each dive based on waypoints, track length at individual depth zones was not. To estimate track distance per depth zone we used video time spent moving in each depth zone as a proxy for distance. Hence, relative track distance was estimated from the videos based on the relative time spent moving in each depth zone, after subtracting all stationary video time obtained while collecting and processing samples on the bottom. For two different depth zones of two sites (sites 8 and 9), debris was recorded but as the video was only turned on instantaneously to document the debris, no distance estimates (two points minimum) and also no surficial density estimates were possible for the two corresponding depth zones.

In separate sessions, each dive was carefully examined to score all objects of anthropogenic origin observed. We scored debris according to material and usage categories following Debrot et al. (1999, 2013a). Due to limited resolution of the videos, only relatively large objects (>5 cm) could be generally detected and scored. We expressed litter concentrations in $n/100\ m^2$, as this is a commonly used unit of measure in marine benthic debris studies (Spengler and Costa, 2008). Combining our estimates of transect width and length, this allowed us to calculate surficial density estimated of anthropogenic debris for different depth zones around the islands. Debris density estimates are often expressed in terms of geometric means ± SD based on the log-normal distribution (e.g., Debrot et al., 1999, 2013a). However, due to the small number of estimates involved, the added-value of doing this was deemed limited and we therefore present simple arithmetic means instead. Statistical comparison of debris concentrations between depth zones was done with the distribution-free Kruskal–Wallis and Mann–Whitney U tests using IBM SPSS vers. 19.

Table 1 shows the main parameters for the 24 deepwater submersible tracks. In total, 21,184 m of transect were traversed and mean transect width was 3.37 m. A total of 202 objects were observed during the dives. Total objects divided by total area amounts to an overall density of 0.27 objects per 100 m^2. This corresponds to an overall density of 2700 items per km^2. Each dive yielded a density estimate for one or more of the four depth zones. The number of debris density estimates obtained for the 80–100 m zone was 8, the number for the 100–300 zone was 14, for the 300–600 m zone was 17 and for the 600–900 m zone was 8 (Table 1). The highest man-made debris density documented was for the 300–600 m depth zone, where overall debris densities were generally 2× higher than the steep island slope areas of 100–300 m, 5× higher than the deeper 600–900 m zone, but roughly 50× higher than deep reef waters of 80–100 m. The same apparent trends with depth was seen for both Curaçao and Bonaire (Table 1). By means of the non-parametric Kruskall–Wallis test, the difference in density between depth zones was found to be significant ($H = 11.90$, $p = 0.005$). Post-hoc pairwise comparisons revealed that there was a significant difference between the amount of marine litter in depth zone 80–100 m and depth zones 100–300 m (Mann–Whitney, $U = 15.00$, $p = 0.003$) and 300–600 m (Mann–Whitney, $U = 20.00$, $p = 0.003$).

The amount of debris encountered and corresponding surficial densities were particularly high at two sites in Curaçao (#12, Piscaderabaai and #14, Bapor Kibrá) and one site in Bonaire (#21, Wecua) (Table 1). All three of these sites correspond to former municipal shore-side dump sites. On Curaçao, the dumping of municipal litter was first transferred to the exposed and uninhabited northeast coast of the island, and subsequently gradually discontinued after the first terrestrial landfill was opened in 1978 (Debrot and Sybesma, 2000). On Bonaire, municipal dumping at Wecua was phased out by the mid-1970 after the current terrestrial landfill was opened (Debrot et al., 2013). A notable form of human debris encountered at two site off Curaçao (# 13 and 14, south of Lagun Janthiel and Bapor Kibrá) was sunken tar patches. The location that tar patches were observed, lies between the oil terminal of Caracasbaai (upstream) and the location where the steamer Oranje Nassau sank in 1906 (downstream). Tar patches of 60–90 cm diameter and 15 cm thickness were found at depths of 200–365 m.

The two principal materials overall represented by the debris items were glass (32%) and plastic (29%). These were followed in decreasing importance by metal, masonry, textile, rubber, tar and finally, wood (Fig. 2). Food and beverage related items were the single largest usage category identified and amounted to 44% of objects observed (mostly glass beverage bottles). The next two most abundant litter categories were maritime-associated litter (28%), followed by unspecified packaging material (10%) (Table 2). Particularly abundant in Bonaire were rocks used as anchors with tethers still attached. Nevertheless, other typically fishing-related debris was rare compared to its importance in offshore deepwater terraces targeted for fishing elsewhere (e.g. Reed et al., 2014). Due to the generally steep seafloor topographies and strong currents around Bonaire and Curaçao, effective targeting of deepwater snappers by handlining is tricky and limited (Debrot, pers. obs.).

Until recently, the use of submersibles to study of seafloor debris was uncommon due to the high associated costs (Spengler and Costa, 2008), but today more and more studies using this approach are gradually becoming available (e.g. Pham et al., 2014; Schlining et al., 2013; Watters et al., 2010). Objects are not collected, allowing only rough classification into categories, and small objects can be missed. Therefore, compared to other studies using fine-meshed trawls for debris collection (e.g., Galgani et al., 2000; Wei et al., 2012), the use of video transects can be expected to under-estimate total debris densities. We point out and discuss above several additional potential (and often opposing) limitations to our density estimates (opportunistic nature of track course, limitations to transect width and length estimation, differences in detectability, etc.). Nevertheless, overall debris densities as found in this study (2700/km^2) were an order of magnitude higher than comparable deepwater debris studies from elsewhere (e.g., 99/km^2 from the French Mediterranean by Galgani et al. (1996); 240/km^2 from the Greek Mediterranean by Stefatos et al. (1999); 150/km^2 from Argentina by Acha et al. (2003); and 67/km^2 from the US west coast by Keller et al. (2010)). In light of such large differences, our conclusion of high levels of documented seafloor debris is robust. We ascribe the exceptionally high overall density of debris we found to deep water depths being found close to shore and close to the principal (past and present) input sources in the Dutch Caribbean. Hence, what we describe may be representative for small populated volcanic islands throughout much of the Caribbean.

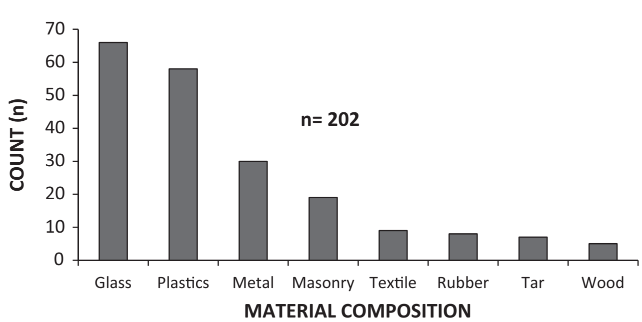

Fig. 2. Material composition of 202 man-made objects observed during 24 submersible dives at depths of 80–900 m off the Leeward Dutch Caribbean ABC-islands.

Table 2
Debris usage categories for 202 objects observed on the seafloor at depths of 80–900 m around the Leeward Dutch Caribbean Dutch ABC-islands, May 2000.

Usage categories	Count (*n*)	Percent (%)
Food and beverage		
Bottles	66	33
Cans	16	8
Plastic cups	4	2
Other	1	1
Maritime		
Ropes	25	12
Fishing lines	8	4
Stone anchors	13	6
Hoses	2	1
Sunken oil	7	3
Other	5	2
Automotive		
Tires	6	3
Household	4	2
Garments	8	4
Packaging	21	10
Miscell	16	8
Total	202	100

The distribution of man-made debris on the sea floor is influenced by a combination of factors such as bathymetry, winds and currents, material buoyancy and human activity. At depth, with colder temperatures, debris decomposition is also slower (Barnes et al., 2009). Our results document significant differences in debris density at different depth strata around the Dutch Caribbean ABC-islands. Highest debris concentrations were observed at 300–600 m depths characterised as shallow-sloping, sediment-dominated seafloor conditions. Pham et al. (2014) found that in European waters, litter densities were generally highest closer to land but also tend to concentrate in canyons. Likewise, Keller et al. (2010) found mean debris densities increasing with depth. Our results show a similar pattern with man-made debris accumulating at depth but decreasing gradually at deeper depths further from the island. We suggest that distance from the main shallow coastal zone of litter input, rate of transport off-shore, relative sinking rate and seafloor slope are the main factors accounting for the peak concentration of litter in the 300–600 m depth-zone.

In our survey we found more glass whereas other reviews (e.g. Keller et al., 2010) often find plastic and metal to be the most common debris items. We suggest this may in part be due to their sampling using a fine-meshed net, with which the ubiquitous small plastic fragments are less easily missed. Our "indirect" sampling was limited to large items based on video images (i.e., visual sighting). The material composition documented also differed significantly from that described for nearby beaches, where plastics and polystyrene foam dominated (Debrot et al., 1999, 2013a) instead of glass and plastic. The important role of different buoyancies of the materials concerned, seems clear. Notable is also the important contribution of recreationally-derived food and beverage debris to deep island waters. This suggests the potential value and effectiveness of simple management measures directed specifically at recreational beach users. Nagelkerken et al. 2001 found a large difference in seafloor litter concentrations (particularly cups and cans) between managed and unmanaged recreational beaches in Curaçao. Therefore, beach management measures towards litter control (awareness in combination with trash bins and disposal) should be able to help address this generally unseen problem. In Curaçao and Bonaire, particularly promising measures towards litter control have been the widely-supported virtual ban and awareness campaign on the use of disposable plastic shopping bags. If the same could be achieved with respect to the use of plastic beverage cups, great progress might be realized in terms of controlling the worst form of recreational plastic litter in the shallow coastal zone (Nagelkerken et al., 2001; Debrot et al., 2013b).

In conclusion, we here provide baseline data and insights into the density, distribution and composition of deepwater seafloor man-made debris in the Leeward Dutch Caribbean. Earlier studies have documented exceptionally high densities of beach and shallow seafloor litter in these same islands (Nagelkerken et al., 2001; Debrot et al., 1999, 2013a,b). All results corroborate the view that the litter problem is very serious in the Caribbean Sea, and stress the need for urgent joint action (UNEP (United Nations Environment Programme), 2008). However, our results also highlight the immediate potential for simple unilateral measures to help address the burgeoning litter problem at a local level.

Acknowledgments

Most of the preparatory phases of this work were conducted while the lead author was employed at the Carmabi Foundation in Curaçao. Our thanks to all Carmabi personnel and staff for providing essential support in untold ways. On Bonaire the expedition received full cooperation from STINAPA Bonaire, especially from the late board member Jack Chalk. We thank the Harbour Branch Johnson-Sea-Link crew for their expert handling of the submersible and for providing the videos on which this contribution is based. Wim Has of the Van Hall Larenstein University generously transformed the videos to DVD. Principal funding for analysis was provided by the Ministry of Economic Affairs - Netherlands, under project number 4308701044 as part of the Wageningen University BO research program (BO14HD3530, A. Debrot, PI). Special thanks are due to Astrid Hilgers and Paul Hoetjes for their support of this project and Elze Dijkman who drew our maps. We thank anonymous reviewers for pointing out several valuable improvements.

References

Acha, E.M., Mianzan, H.W., Iribarne, O., Gagliardini, D.A., Lasta, C., Daleo, P., 2003. The role of the Río de la Plata bottom salinity front in accumulating debris. Mar. Pollut. Bull. 46, 197–202.

Barnes, D.K.A., Galgani, F., Thompson, R.C., Barlaz, M., 2009. Accumulation and fragmentation of plastic debris in global environments. Philos. Trans. Royal Soc. Lond. B: Biol. Sci. 364, 1985–1998.

Debrot, A.O., Sybesma, J., 2000. The Dutch Antilles. In: Sheppard, C.R.C. (Ed.), Seas at the millennium: an environmental evaluation, Regional chapters: Europe, The Americas and West Africa, vol. I. Amsterdam, Elsevier, pp. 595–614 (Chapter 38).

Debrot, A.O., Tiel, A.B., Bradshaw, J.E., 1999. A study of beach debris contamination in Curaçao, Netherlands Antilles. Mar. Pollut. Bull. 38, 795–801.

Debrot, A.O., Bron, P.S., de León, R., Meesters, H.W.G., 2013b. Marine debris in mangroves and on the seabed: largely-neglected litter problems. Mar. Pollut. Bull. 72, 1.

Debrot, A.O., van Rijn, J., Bron, P.S., de Leon, R., 2013a. A baseline assessment of beach debris and tar contamination in Bonaire, Southeastern Caribbean. Mar. Pollut. Bull. 72, 325–329.

Engler, R.E., 2012. The complex interaction between marine debris and toxic chemicals in the ocean. Environ. Sci. Technol. 46, 12302–12315.

Galgani, F., Souplet, A., Cadiou, Y., 1996. Accumulation of debris on the deep sea floor off the French Mediterranean Coast. Mar. Ecol. Prog. Ser. 142, 225–234.

Galgani, F., Leaute, J.P., Moguedet, P., Souplets, A., Verin, Y., Carpenter, A., Goraguer, H., Latrouite, D., Andral, B., Cadiou, Y., Mahe, J.C., Poulard, J.C., Nerisson, P., 2000. Litter on the sea floor along European coasts. Mar. Pollut. Bull. 40, 516–527.

Galgani, F., Hanke, G., Werner, S., de Vrees, L., 2013. Marine litter within the European Marine Strategy Framework Directive. ICES J. Mar. Sci. 70, 1055–1064.

Galil, B.S., Golik, A., Tuerkay, M., 1995. Litter at the bottom of the sea. A sea-bed survey in the eastern Mediterranean sea. Mar. Pollut. Bull. 30, 22–24.

Gregory, M.R., 2009. Environmental implications of plastic debris in marine settings – entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philos. Trans. Royal Soc. B: Biol. Sci. 364, 2013–2025.

Katsanevakis, S., Verriopoulos, G., Nicolaidou, A., Thessalou-Legaki, M., 2007. Effect of marine litter on the benthic megafauna of coastal soft bottoms: a manipulative field experiment. Mar. Pollut. Bull. 54, 771–778.

Keller, A.A., Fruh, E.L., Johnson, M.M., Simon, V., McGourty, C., 2010. Distribution and abundance of anthropogenic marine debris along the shelf and slope of the US West Coast. Mar. Pollut. Bull. 60, 692–700.

Nagelkerken, I., Wiltjer, M., Debrot, A.O., Pors, L.P.J.J., 2001. Baseline study of submerged marine debris at beaches in Curaçao, West Indies. Mar. Pollut. Bull. 42, 786–789.

Pham, C.K., Ramirez-Llodra, E., Alt, C.H.S., Amaro, T., Bergmann, M., et al., 2014. Marine litter distribution and density in European Seas, from the shelves to deep basins. PLoS ONE 9, e95839. http://dx.doi.org/10.1371/journal.pone.0095839.

Pomponi, S.A., Kelly, M., Reed, J.K., Wright, E., 2001. Diversity and bathymetric distribution of lithistid sponges in the tropical western Atlantic region. Bull. Biol. Soc. Wash. 10, 344–353.

Reed, J.K., Pomponi, S.A., 2000. Final cruise report. Submersible and SCUBA Collections in the Netherlands Antilles (Curacao, Bonaire) and Aruba: Biomedical and Biodiversity Research of the Benthic Communities with Emphasis on the Porifera and Gorgonacea. Harbor Branch Oceanographic Institution, Ft. Pierce, FL. 183 pp.

Reed, J.K., Harter, S., Farrington, S., David, A., 2014. Characterization and interrelationships of deepwater coral/sponge habitats and fish communities on Pourtalès Terrace, Florida. In: Bortone, S.A. (Ed.), Interrelationships between corals and fisheries. CRC Press, Boca Raton, Florida, USA, pp. 50–80 (Chapter 5).

Ribic, C.A., Sheavly, S.B., Rugg, D.J., Erdmann, E.S., 2012. Trends in marine debris along the U.S. Pacific Coast and Hawai'i 1998–2007. Mar. Pollut. Bull. 64, 994–1004.

Schlining, K., vonThun, S., Kuhnz, L., Schlining, B., Lundsten, L., Jacobsen Stout, N., Chaney, L., Connor, J., 2013. Debris in the deep: using a 22-year video annotation database to survey marine litter in Monterey Canyon, central California, USA. Deep-Sea Res. I 79, 96–105.

Spengler, A., Costa, M.F., 2008. Methods applied in studies of benthic marine debris. Mar. Pollut. Bull. 56, 226–230.

Stefatos, A., Charalampakis, M., Papatheodorou, G., Ferentinos, G., 1999. Marine debris on the seafloor of the Mediterranean Sea: examples from two enclosed gulfs in Western Greece. Mar. Pollut. Bull. 36, 389–393.

UNEP (United Nations Environment Programme), 2008. Marine litter in the wider Caribbean: a regional overview and action plan. Caribbean Environmental Progrogram/CRCU, Kingston, Jamaica, p. 81.

Watters, D.L., Yoklavich, M.M., Love, M.S., Schroeder, D.M., 2010. Assessing marine debris in deep seafloor habitats off California. Mar. Pollut. Bull. 60, 131–138.

Wei, C.-L., Rowe, G.T., Nunnally, C.C., Wicksten, M.K., 2012. Anthropogenic "litter" and macrophyte detritus in the deep Northern Gulf of Mexico. Mar. Pollut. Bull. 64, 966–973.