Research on Solid Waste Pollution along the Israeli Mediterranean Coast

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Executive Summary

Marine debris has been acknowledged as a severe problem, bearing significant economic and human related impact and significant reduction of the health and integrity of marine ecosystems. Characterization of marine debris in various parts of the world has shown that the bulk of the solid material consists of a wide array of plastic compounds. A large part of this plastic material is small (<5 mm) and is collectively classified as “micro-plastics”. Micro-plastics may resemble planktonic organisms, which makes them potentially attractive to many marine species, and due to their physical and chemical characteristics, they readily adsorb a variety of pollutants, raising concern that these pollutants may bio-accumulate in the marine food web.

The Mediterranean coast of Israel suffers from an accumulation of marine debris. however, scientific data regarding the sources and distribution of marine debris, needed for creating a coherent policy for managing the problem, was until now lacking. The studies described here are the result of a joint effort of **University of**

Haifa, **EcoOcean** and the **Ministry of Environmental Protection's Marine and Coast Division**, from spring 2013 until August 2015. The report present first comprehensive and comparative data on Israeli coastal and marine debris. The data include marine litter and micro-plastic abundances in the Mediterranean coastal zone, indicating types of marine litter and sources, as well as accumulation of pollutants on micro-plastic particles.

The results indicate that the abundance of macroscopic marine **debris on the Israeli coast** is lower than the global average, and that benthic debris accumulates in patches in certain areas but it also generally does not occur in great abundances. Nevertheless, the abundance of **floating debris** is high on the global range and the abundances of **micro-plastic particles** in coastal waters is strikingly high, reaching values as high as 10 fold that measured in the northwestern Mediterranean, similar to the abundances found in the North Pacific garbage patch'. In addition, these small plastic particles have high concentrations of organic **pollutants**, especially along the northern Israeli Mediterranean coastline. Marine debris in the Israeli coastal zone is composed mainly of plastics, with a very high proportion of plastic bags as well as food wrappers and disposables, originating mainly from trash left by vacationers and other land based sources, such as streams and drainage systems, but also from the sea and from other countries, especially in the south beaches.

While these findings are worrisome, they also serve as the basis for potential solutions of the problem of marine debris in the Israeli coastal zone, which can be directed and adapted according to the type, abundance and sources of debris in different coasts. These solutions include the establishment of legislation and actions for the reduction of single-use plastic items, promotion of better recycling, education, law enforcement, enhanced cleanups of beaches and streams flowing to the sea as well as underwater and floating debris cleanups and the establishment of national and regional marine litter-monitoring programs.

Marine debris on the Mediterranean coastal area of Israel: Types, origin, and coastal distribution – Primary Observations

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Introduction

Marine debris has been recognized throughout the world as a severe environmental problem with significant ecological, economical and public health impacts. Although the problem of marine debris is undoubtedly prevailing in the Israeli coastal zone, a comprehensive coastal and marine litter survey has never been conducted in the eastern Mediterranean, and therefore comparative data was lacking[1].

[1] Variation of debris deposited along the Israel coast was previously examined by Golik and Gertner (1992) and Bowman et al. (1998), and the cleanliness of 60 undeclared beaches has been monitored since 2005 (Alkalay et al., 2007). Sediment transport along the coast was widely studied, but there is no information about the transportation of solid waste, mainly plastic which located is near the sea surface.

To fill this crucial lack of information, we initiated in 2012 a study to characterize the types of marine debris, its origins and distribution in space and time, in cooperation between Haifa University, EcoOcean and the Ministry of Environmental Protection. More specifically, the research was aimed at studying:

a. The sources of marine debris along the Mediterranean coast of Israel
b. The hydrodynamics mechanisms which drive marine debris along the Israeli coast
c. Establish recommended policies for the reduction of marine debris loads In Israel's Mediterranean waters and coasts

Methods

Eight 100 m sandy coastal segments along the Israeli Mediterranean coast were selected using the criteria in the UNEP/IOC Guidelines (Fig 1a) (Cheshire et al., 2009). These coastal areas are cleaned irregularly and surveys were done at least 4 days after a cleaning. Surveys were done from June 2012 to March 2015, spaced throughout the year (range 15-97 days) for a total of 19 surveys. Standing stock of debris was counted from the waterline to the backshore. Items were enumerated and categorized by composition and source (land-based, sea-borne).

Floating Litter Assessment was conducted on 17 marine sites (Fig. 1b) onboard EcoOcean's research vessel, the R/V Mediterranean Explorer, and the Ministry of Environmental Protection's Marine Pollution Control vessel. The survey was carried out for 15 minutes, while cruising at low speed (below 3 knots), along a ~ 10 m depth contour line. Visual observations of large debris were conducted from the bow of the vessel, during the net trawl for small debris using "Suitcase Manta Trawl" net (Figure 2).

Benthic surveys in all 17 marine sites were conducted by SCUBA diving in belt transects of 100 m by 4 m. In the first year, before the research cruises began, the 100 m transect was surveyed in the shallow water from the waterline to about 3m depth (perpendicular to the shoreline). During the second year, the dives were conducted at ~10 m depth (parallel to the shore line) during the research cruises. In the third year

benthic surveys were done in locations that were presumed to be "debris traps" - areas of low circulation and high sediment accumulation (Fig. 3).

Effect of currents on distribution of marine debris

The effect of currents on the distribution floating debris was examined by distributing a 'message in a bottle' along the Israeli coast. 300 used plastic bottles were filled with sand to allow them to sink to eliminate wind effect. In each bottle, a letter made of waterproof paper was inserted, explaining in English, Hebrew and Arabic, about the study and asking the finder to report the bottle finding to a designated email address, with detailed information about the place where the bottle was found, color and the number that appears on this note.

The bottles were distributed from the R/V Mediterranean Explorer during autumn 2014 survey, at depths of 5, 10, 15, 20 and 30 meters, adjacent to the following locations: Acre port, Shiqmona, Poleg stream, Palmahim, Nitzanim and Zikim.

The experiment was accompanied by news coverage in the media, published in a designated facebook page, and in "wanted" ads, distributed in marine activity locations. In the following weeks, the coastline was searched for washed ashore bottles. In order to make sure we didn't cause more damage than good, we promised to collect 3 bottles for every bottle that was not found within a year.

Results

Coastal debris

Abundance and composition

In the 3 years of the study, a total of 71,045 items was recorded in a total area of 636,600m^2 – averaging to 0.11 items per m^2. This is much less than densities in the average 1 item per m^2 range demonstrated in most studies, as reported by Galgani et al. (2015) (Table 1).

The significantly low abundance of coastal debris found in the survey may be the result of the regular cleaning of most of the surveyed beaches. Most of the debris found (90%), were categorized as 'plastics', (Figure 4). This information is consistent with

previous data collected along the Israeli coast (Alkalay et al., 2007) but exceeds the global average of 75% (Galgani et al., 2015; Ioakeimidis et al., 2014).

The 5 top items found along the Israeli coast during the study were different from the global and Mediterranean patterns presented in the data of the Ocean Conservancy[2] (2012, 2013, 2014) and UNEP/MAP (2015) respectively (Fig. 5). The first difference is in the amount of miscellaneous items (marked as 'other' in Fig. 5), which are twice in the global average compared to Israel and the Mediterranean. This may derive from the fact that the Mediterranean is a closed sea not subjected to open ocean debris.

Another difference is in the portion of the plastic bags in total coastal debris found in Israel - 3 times more than the global average and twice as much as the Mediterranean average (Ocean Conservancy 2012, 2013, 2014; UNEP/MAP, 2015). This is clearly a result of a lack of legislation for the reduction of the use of plastic bags in Israel, while many countries have taxes on the use of plastic grocery bags, or even prohibitions on usage of plastic bags. On the other hand, Israel has an efficient recycling solution for drinking bottles and cans, which is reflected in having almost a 1/3 of the average percentage of these items in the composition of coastal debris found in the rest of the world. Additionally, many plastic bottles found along the Israeli coast were sea-borne. Food wrappers and containers were also found in large numbers, as well as cigarette butts and bottle caps.

Sources of debris

Over 58% of the coastal marine debris along the coasts of Israel was identified as land-based, 5% of the debris was sea-borne, and the source of the rest was uncertain (37%). The northern beaches Betzet and Naharia have ~ 80% debris identified as land-based (Fig. 6). The amount of the debris identified as land-based declines gradually in Acre, Kiryat Haim and Maagan Michael to less than 50%, then rises back to 75% in Poleg

[2] The most comprehensive international database of debris in the coastal environment is managed by the Ocean Conservancy whose volunteers perform informal surveying of waste in the framework of the International Coastal Cleanup (ICC), held worldwide since 1989. The organization publishes an annual data report.

Stream, and falls back in the southern beaches, Zikim and Nitzanim, with less than 50% debris identified as land-based.

Floating marine debris:

During 8 visual surveys in 17 sites, conducted between July 2013 and May 2015, a total of 1107 items were observed in an area of ~4Km^2, which means 276.5 items per km^2, which is high on the global range, reported by galgani et al., 2015.

Benthic marine debris:

Benthic marine debris varied spatially. Most of the benthic debris in the coastal observations was found in Herzliya north to the marina, just adjacent to a very popular beach, and in Michmoret, between rocks. In the open sea most of the debris was found in the northern part of Haifa Bay (i.e. Acre Bay) and was mostly construction material.

The effect of currents on distribution of marine debris:

109 bottles (out of 300) were found within 9 month from the beginning of the experience. Most of the bottles found, reached the shore in the first week, mainly in the south part of Israel. Most of these bottles were discarded back to shore not very far from their origin (up to 14 km). Six of the bottles discarded in Acre and Shiqmona were found in North Cyprus, Greece and Turkey.

Main conclusions:

The abundance of debris on the Israeli coast was found to be lower than the global average. On the other hand, floating debris was relatively high, compared to the global average. Benthic debris seemed to accumulate in patches in certain areas and was not abundant altogether.

The results indicate that the majority of debris along the Mediterranean coast of Israel derives from land. Mean 58% of the sampled debris has been identified as local land-based debris, most of which was left by vacationers and were mainly disposable items. However, there is difference in types, amounts and sources of marine debris in different coastal sections. Betzet and Naharia coasts, located at the northern part of

Israel, are populated during the weekends, especially with sun-bathers, and are cleaned regularly. The coasts of Zikim and Nitzanim, located at the southern part of Israel, serve many anglers. Almost 10% of the debris found on these coasts was identified as sea-borne, but we assume that at least 50% of the 'uncertain source' arrived also from the sea, probably mostly from the close-by Gaza Strip and Egypt.

Acre and Kiryat Haim, located in Haifa Bay, serve also for anglers, with around 60% land-based marine debris.

The coast of Maagan Michael, which was the cleanest, is cleaned at least once a week. It is less accessible to the general public and thus less debris is left on the beach by vacationers. That is probably also the reason why almost half of the debris on this coast arrived from uncertain source.

New findings on Microplastics in the eastern Mediterranean Sea and impacts on local marine biota

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Introduction

Marine debris is one of the many problems that affect the health and integrity of marine ecosystems and may exert considerable stress on marine food webs (Derraik, 2002; Thompson et al., 2004). A large part of this material is made of plastic, small (<5 mm) and is collectively classified as “microplastics” (Barnes et al., 2009). Until recently microplastic debris was not identified as an important form of marine pollution and there has been little documentation of its abundance and composition in the water column and on the seafloor. Although many larger items are a lot more conspicuous and are what we generally associate with plastic waste, it is noteworthy that large plastic debris is eventually broken down to smaller particles, contributing to the microplastic pool, as 'secondary' microplastics (Fendall and Sewell, 2009).

One of the phenomena that has captured widespread attention worldwide in recent years is the Great Pacific garbage patch – a massive aggregation of floating particulate debris in the central subtropical North Pacific ocean. An analysis of data generated from 1972-1987 and 1999-2010 from the North Pacific Subtropical Gyre, and in Continuous Plankton Recorder (CPR) surface samples from the North Atlantic and the North Sea indicate that the abundances of marine microplastic debris are increasing

(Thompson et al., 2004; Goldstein et al., 2012). In a recent study of the surface waters of the western Mediterranean Sea microplastic particles were found in 90% of samples examined with an overall average abundance of 0.116 particles per m^3 (Collignon et al., 2012).

Microplastics may resemble sediment particles, suspended particles and planktonic organisms, which makes them potentially attractive to many marine species including planktivores, detritivores, suspension, deposit and filter feeders ranging from baleen whales to small invertebrates (Thompson et al., 2004; Murray and Cowie, 2011; Fossi et al., 2012). Whereas the impact on biota caused by ingestion of microplastics is variable and still not very clear, a variety of "persistent organic pollutants" (POPs), including many that are quite toxic (e.g. Polychlorinated Biphenyls - PCBs, Polycyclic Aromatic Hydrocarbons - PAHs) adsorb readily to microplastic particles. Due to their large surface area to volume ratio, some particles may have as much as 6 orders of magnitude or more of these pollutants adsorbed to them as compared to the surrounding seawater, and there is concern that these could biomagnify with ecosystem scale ramifications (Thompson et al., 2007; Teuten, 2007).

. The potential harm of microplastics in marine systems and the subsequent social and economic impacts underlines the importance of analyzing their effects on a variety of different biota.

Methods

We are currently carrying out a research project along the Israeli shores of the Mediterranean Sea in order to provide, for the first time, information on the abundance and the potential toxicity associated with the microplastic particles found in this region. This work characterizes the microplastic particles with respect to the type, size, shape and color of these particles in order to improve our understanding of the potential of these particles to be ingested by and influence marine biota.

Sampling of floating microplastic is done by means of a floating Manta net at a series of 17 stations along the Mediterranean coast of Israel (Fig 1b and 2).

In addition to sampling the upper layer of the water column, we also sampled shallow coastal sediments at 8 sites (at a depth of 10m) along the coast. Sediment

samples were taken at each station by SCUBA divers from the top 10cm of the sediments by means of small hand held cores. Micro-plastic particles were separated from the sediments by means of flotation.

In order to understand the potential contribution of microplastics to the exposure of marine biota to persistent organic pollutants (POPs), several randomly collected microplastic particles were examined for adsorbed persistent organic pollutants (POPs).

Results

Preliminary results of marine debris sampling indicate that microplastic particles occur in all samples at abundances that are 10 fold higher on average in comparison with the average of microplastic debris found in the Western Mediterranean and twice the abundance of the global average (1.3 particles per m^3).

The abundances of microplastic in the sediment were much smaller than what was found in the surface waters.

Preliminary results of the organic pollution analysis indicate a high concentration of 2 types of PAHs and 2 types of PCBs. Future research will quantify the concentration of POP's adsorbed to the microplastic particles in comparison to their concentration in the ambient Mediterranean Sea waters.

Microplastic abundance, the adsorbance of toxic POP's to microplastics and their ingestion by marine biota are all being examined in order to elucidate the damage these particles may have on the marine food web. This research endeavors to shed light on these questions and to assist in our efforts to clean up the sea.

Discussion

Reducing marine litter: policy and management recommendations

Presented here are the results of the first comprehensive studies of marine litter and micro-plastic in the eastern Mediterranean. The results, summarizing 3 years of data collection, indicate several new significant findings.

The abundance of debris on the Israeli coast was found to be lower than the global average. Benthic debris seemed to accumulate in patches in certain areas and was not abundant altogether, but floating debris abundance was high on the global range. Debris was composed mainly (90%) of slow degrading plastics, with very high abundance of plastic bags as well as food wrappers and disposables. These litter items originated mainly from trash left by vacationers and other land based sources, such as streams and drainage systems. Trash arrived also from the sea and from other countries, especially in the south beaches close to Gaza. It is also noteworthy that large amounts of trash may accumulate at certain times on the beach and washed to the sea before the beach is cleaned, especially during holidays and vacations, when the beaches are full with vacationers.

Contrary to the abundance of large marine litter, the abundance of micro-plastic in the coastal waters was strikingly high, and it is reasonable to believe that this is due to the composition of marine debris in Israel's coastal zone. Significantly adding to this, and somewhat worrying, is the finding of high concentrations of contaminants on micro-plastic particles, especially in Akko area.

Although raising concern, the findings also provide understanding of the directions for solutions of the problem of marine debris in the Israeli coastal zone.

There is a strong evidence of the importance of national and international legislation in order to establish a mix of at-source and end-of-the-pipe solutions, in order to eliminate the arrival of debris to the marine environment.

There is clearly a need for legislation for the reduction of the use of plastic bags, straws and single use utensils. Recycling of plastic items and plastic bags should be encouraged by improving the recycling system for these materials as well as

encouraging product design and especially packaging in a way that will ease the separation of material by the consumers and recycling. Steps such as production of bottles with attached caps can also be considered.

Although not seasonally reflected from this study, it is clear that drainage systems and winter streams which overflow during intense rain falls spill vast amounts of debris into the sea. Preventing from drainage systems to flow directly to the sea, and clean up campaigns along rivers and seasonal streams, may reduce the amount of debris arriving from land.

In popular vacation coasts (like Betzet, Naharia and Poleg Stream), the best way to prevent arrival of debris to the sea is by preventing vacationers from littering – either by explanation and education campaigns or by enforcement.

In coasts such as Zikim and Nitzanim in the south, where plenty of marine debris clearly derives from the sea, more effort should be put on regular cleaning of the coasts.

Lastly, since marine debris is a problem with no boundaries, it is important to establish a national marine litter monitoring program, as well as take part in regional monitoring programs, using uniform methods and comparable data.

Tables and Figures

Figure 1a. Coastal Surveys Sites.

Figure 1b. Marine Surveys Sites

Nachal Betzet	Shavey Zion
Acco	Kiryat Chaim
Shikmona	Nachal Oren
Neve Yam	Maagan Michael
Sdot Yam	Nachal Poleg
Herzlya North	Herzlya South
Jaffo	Ashdod
Nizanim	Ashkelon
Zikim	

Figure 1b. Marine Surveys Sites.

Figure 2. Manta net trawl and observation (photo by Galia Pasternak)

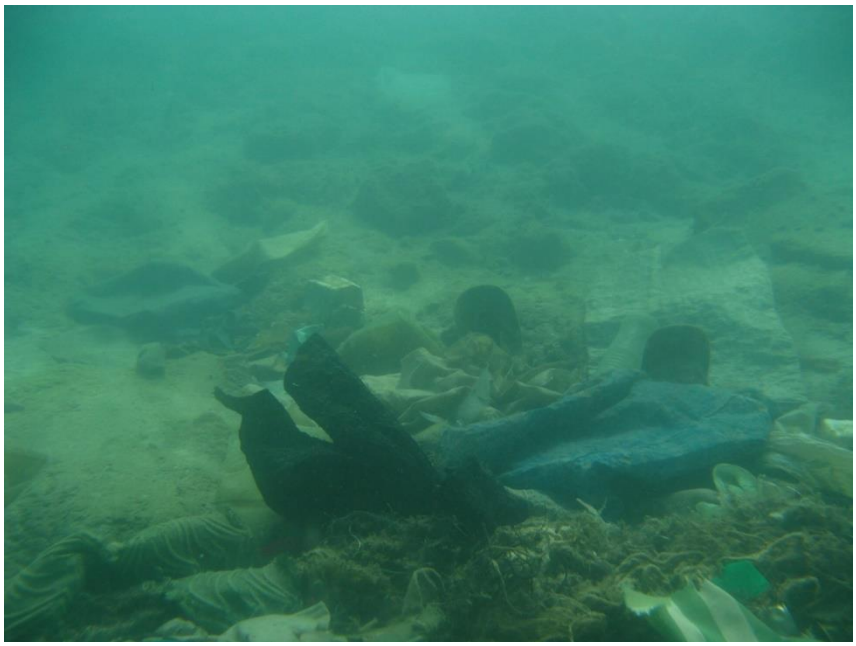

Figure 3. "Debris Traps" - areas of low circulation and high sediment accumulation

(photo by Galia Pasternak)

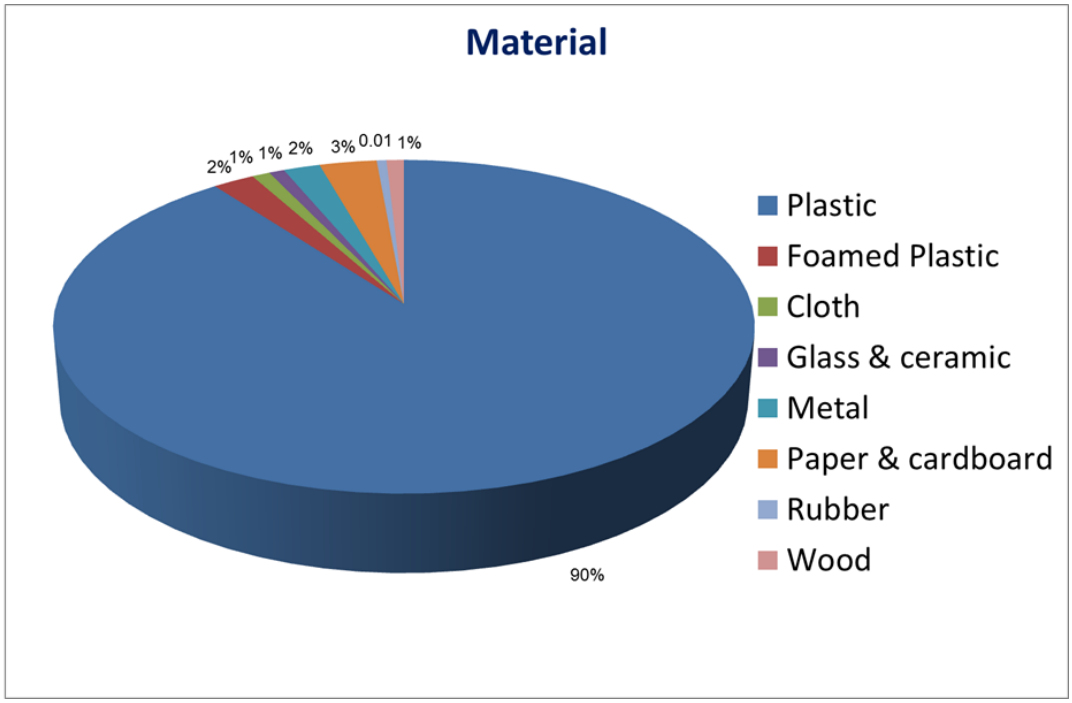

Figure 4. Percentage Coastal marine debris' items according to material

(based on the UNEP/IOC Guidelines categories)

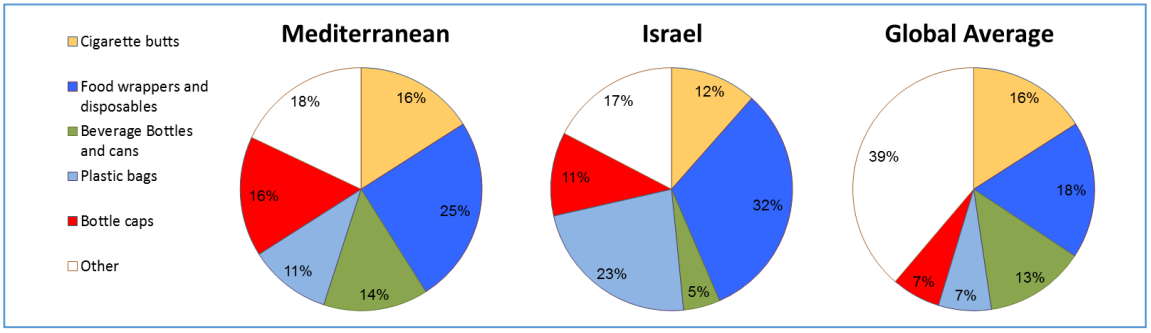

Figure 5. Top 5 items found along the Israeli coast vs. Mediterranean and global averages Source: Ocean Conservancy (2013, 2014, 2015); UNEP/MAP (2015)

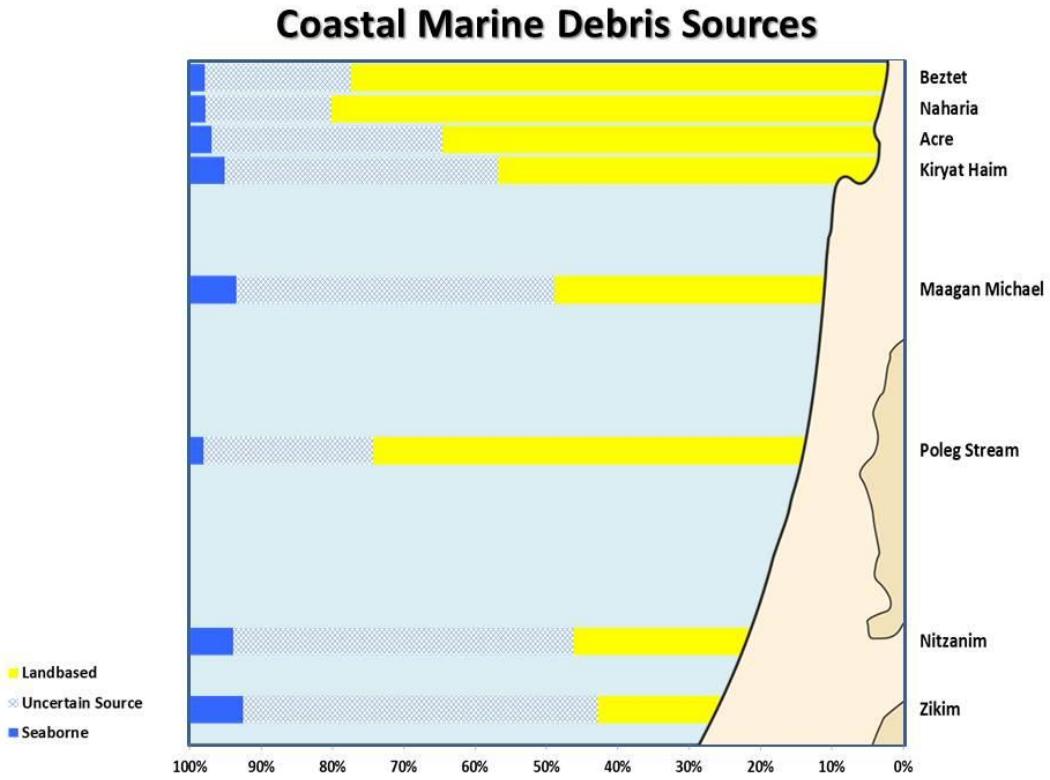

Figure 6. Marine debris on the coast- distribution and sources

Region	Density (m^2)	Reference
SW Black Sea	0.88	Topçu et al. (2013)
Gulf of Aqaba	2	Al-Najjar and Al Sheyabet (2011)
Monterey, USA	1	Rosvelt et al. (2013)
South Caribbean, Bonaire	1.4	DEbrot et al. (2013)
Bootless Bay, Papua New Guinea	15.3	Smith (2012)
Nakdong, South Korea	0.97-1.03	Lee et al. (2013)
Kaosiung, Taiwan	0.9	Liu et al. (2013)
Tasmania	0.016-2.03	Slavin et al. (2012)

Table 1: Comparison of mean litter densities from recent data worldwide.

(From: Galgani et al., 2015)

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