A comparison of neustonic plastic and zooplankton at different depths near the southern California shore

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ABSTRACT - Previous studies of neustonic debris have been limited to surface sampling. Here, we measure debris and zooplankton density at three depths in Santa Monica Bay, California, using one trawl survey before a rain event and one trawl survey shortly after a rain event. Surface samples were collected using a manta trawl, mid-depth samples using a bongo net, and bottom samples using an epibenthic sled. All collection devices were equipped with 333 micron nets. Density of debris was greatest near the bottom, and least in mid-water depths. Debris density increased after the storm, particularly at the sampling site closest to the shore, reflecting inputs from land-based runoff and resuspended matter. The mass of plastic collected exceeded that of zooplankton. However, zooplankton mass was three times that of debris when the comparison was limited to plastic debris similar in size to most of the zooplankton.

INTRODUCTION

Most studies of marine debris have focused on material along the coastal shoreline easily identified through visual inspection, with only a few studies describing abundances of small material in the water column (Derraik 2002). The earliest of these was Shaw and Mapes (1979), who found a high density of plastics near the surface in the central Pacific. Recent studies have identified neustonic plastic mass comparable to that of zooplankton in both the mid-Pacific gyre (Moore, C. *et al.* 2001) and along the California coast (Moore, C. *et al.* 2002).

Studies of neustonic debris in the water column have been limited to surface water sampling. Plastics make up a high percentage of neustonic debris and many plastics are positively buoyant. Therefore, studies limited to sample collection in surface waters have the potential to overestimate the prevalence of debris in the water column. In addition, while some animals, such as birds, feed on plankton near the surface and could potentially consume surface debris, other animals participate in filter feeding below the surface and could be exposed to the same risk from debris in the water column.

This study extends previous work by comparing the density of neustonic debris and zooplankton at several depths along the California coast. The study also addresses changes in the water column following a storm event, when higher wind conditions and increased urban runoff have the potential to enhance vertical mixing.

METHODS

Sampling was conducted at two Santa Monica Bay sites offshore of Ballona Creek, which drains the heavily developed western area of Los Angeles. The first site was located approximately 0.8 km offshore and the second approximately 4.5 km offshore. Sampling took place on March 21, 2001, following six weeks without rain, and on March 25, 2001, following a 20 mm rain event.

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The sampling site closest to shore was 15 m deep and samples were collected near the surface and at 5 m depth. The second site was 30 m deep and samples were collected at three depths: surface, 5 m, and near the bottom. Surface samples were collected using a 0.9 x 0.15 m^2 rectangular opening manta trawl with a 3.5 m long, 333 micron net and a 30 x 10 cm^2 collecting bag. Mid-depth samples were collected using paired 61 cm diameter bongo nets with 3 m long, 333 micron nets and 30 x 10 cm^2 collecting bags. Bottom samples were collected using a 31 cm^2 rectangular opening epibenthic sled with a 1 m long, 333 micron net and a 30 x 10 cm^2 collecting bag. The net on the epibenthic sample was located 20 cm from the bottom. Visual inspection by scuba divers showed no sediment stirred from the bottom and entering the net. All samples were fixed in 5% formalin in the field, and later soaked in fresh water and transferred to a 70% isopropyl alcohol solution.

Trawls were conducted parallel to shore for 10 minutes. Trawl speed varied between 1.0 to 2.3 m/s as measured with a B&G paddlewheel sensor (Clearwater, Florida), resulting in a trawl distance of between 0.5 and 1.0 km. A General Oceanics flowmeter (Miami, Florida) was mounted across the net mouth during all deployments to measure the volume filtered.

In the laboratory, samples were placed in fresh water and floating plastic was removed. A dissecting microscope was used to remove any remaining debris and plankton. Debris was sorted by category (plastics, tar, rust, paint chips, carbon fragments, and feathers) and plastics were further categorized (fragments, Styrofoam®, pellets, polypropylene/monofilament line, thin plastic films, and resin). Each category was sorted through Tyler sieves of 4.75, 2.80, 1.00, 0.71, 0.50, and 0.35 mm and counted. Plastics were oven dried at 65º C for 1 h and plankton and plant material were oven dried at 65º C for 24 h, then weighed.

Results

Plastics were present throughout the water column on both sampling dates, but relative concentrations within the water column varied between dates and sites. The site closest to shore had nearly equal density at the two sampling depths before the storm (Figure 1), but density on the surface was considerably higher after the storm.

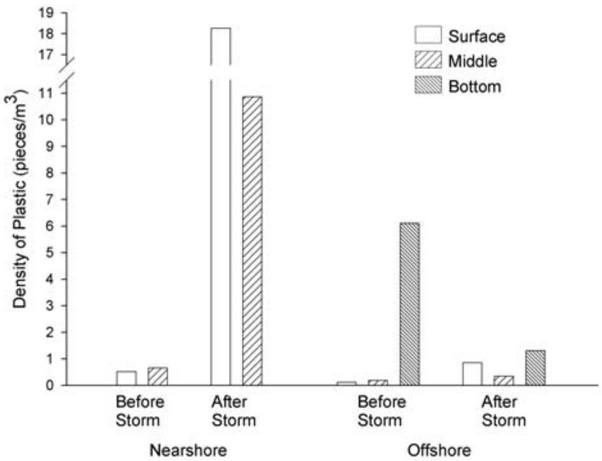

Figure 1. Amount of plastic (pieces/m3) before and after a storm at different depths and proximities to shore.

Debris densities at surface and mid-water depths of the offshore station were similar to that at the nearshore station; the increase in density after the storm was not nearly as large as at the inshore site. Debris density near the bottom at the offshore station was considerably greater than at surface and mid-water depths. Unlike surface samples, debris density was reduced at the bottom following the storm.

The spatial patterns for mass were similar to that of density, though the differences between dates were exaggerated (Figure 2). For example, the weight of plastic increased by more than two hundred times on the surface after the storm. Much of this increase was attributable to the presence of larger items at the surface after the storm (Table 1).

The average mass of plastic was 1.4 times that of plankton in this study, but much of the plastic mass was large material that is unlikely to be confused for planktonic prey (Table 2). When the comparison was limited to smaller particles (less than 4.75 mm), the mass of plankton was approximately three times that of plastics. This ratio was consistently higher near the surface and on the bottom than at mid-depth (Figure 3).

Discussion

The plastic-to-plankton ratio observed near the surface was similar to that found in previous studies (Table 2); however, this study was the first to measure this ratio at other depths. While more debris was found near the surface than in mid-water, the highest mass of plastic was found at the bottom. When only

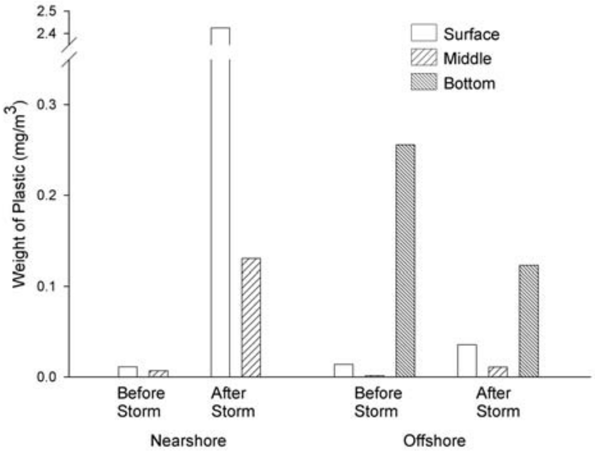

Figure 2. Mass of plastic (mg/m3) before and after a storm at different depths and proximities to shore.

Table 1. Percent weight and density of plastic by size and depth category.

Size Class	Category	Depth: Surface	Middle	Bottom
0.355 to 0.499	Weight	0.5	10.6	6.1
	Density	3.2	5.7	0.3
0.500 to 0.709	Weight	0.8	19.7	36.5
	Density	2.9	2.3	9.1
0.710 to 0.999	Weight	1.9	12.5	23.0
	Density	33.4	10.6	22.7
1.000 to 2.799	Weight	7.0	27.6	17.9
	Density	24.4	21.2	17.8
2.800 to 4.749	Weight	2.5	4.6	12.6
	Density	23.5	31.8	36.1
>4.750	Weight	87.2	25.0	3.9
	Density	12.6	28.4	14.0

Table 2. Comparison between this study, San Gabriel River study (Moore, C. *et al.* 2002), and North Pacific Gyre study (Moore, C. *et al.* 2001).

	Average Debris		Ratio of Plastic to Plankton for Mass	
	(g/m^3)	($pieces/m^3$)	All Debris	Debris <4.75 mm
This Study	0.003	3.92	1.4:1	0.3:1
San Gabriel River Study	0.002	7.25	2.5:1	0.6:1
Gyre Study	0.034	2.23	6.1:1	0.3:1

small size classes were considered, surface and mid-water densities were nearly equal.

Plastics are commonly perceived to be positively buoyant, but research has shown this to be true with only 46% of manufactured plastics (U.S. EPA 1992). Many buoyant plastic products have been injected with air, the most common of which is Styrofoam®. Even plastics manufactured to be positively buoyant can become negatively buoyant as the result of fouling by biota or accumulation of debris. Environmental factors also contribute to the buoyancy of plastics. We observed sand embedded in many negatively buoyant items, such as plastic bags, that might otherwise float.

The absence of turbulence leads to natural separation of debris from top to bottom in the water column. The amount of turbulence necessary for resuspension of debris into mid-water appears to be small. Bottom density declined and mid-water density was elevated after a storm, suggesting that storm-related or wind-related turbulence may be adequate for resuspension. This finding is consistent with studies that indicate that the density of most plastics differs from that of seawater by a small amount (U.S. EPA 1992).

While mixing occurred in the shelf waters sampled, the influence of resuspension in deeper waters is less clear. The distance from the bottom to the middle of the water column is greater in deeper waters, and the influence of wind on mixing decreases with depth. Therefore, more turbulent energy is required to resuspend bottom material to the middle of the water column. Our study found sufficient routine turbulence to indicate that potential biological effects of plastics in the water column extend below the surface waters.

Many marine fauna are known to ingest debris (Fowler 1987, Bjorndal *et al*. 1994, Robards *et al*. 1995, Blight and Burger 1997), but few studies have examined whether they become artificially sated on this non-nutritive material (Ryan 1987). Mato *et al.* (2001) found that contaminants adsorb to plastics, creating a potential for indirect effects of debris consumption; however, no study has considered whether this is a viable pathway for contaminant uptake by biota. These types of studies need to be conducted

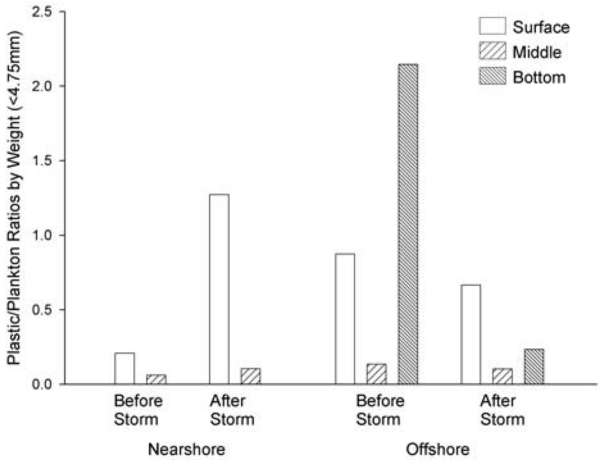

Figure 3. Plastic/plankton ratios (pieces less than 4.75mm) before and after a storm at different depths and proximities to shore.

before the importance of debris in the water column can be fully assessed.

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Acknowledgements

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