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Marine Pollution Bulletin xxx (2004) xxx–xxx

MARINE
POLLUTION
BULLETIN

www.elsevier.com/locate/marpolbul

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 conducted two trawl surveys, one before and one shortly after a rain event, in which debris and zooplankton density were measured at three depths in Santa Monica Bay, California. Surface samples were collected using a manta trawl, mid-depth samples with a bongo net and bottom samples with an epibenthic sled, all having 333 micron nets. Density of debris was greatest near the bottom, least in midwater. Debris density increased after the storm, particularly at the sampling site closest to shore, reflecting inputs from land-based runoff and resuspended matter. The mass of plastic collected exceeded that of zooplankton, though when the comparison was limited to plastic debris similar to the size of most zooplankton, zooplankton mass was three times that of debris.
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Keywords: Southern California; Neuston; Plastics; Zooplankton; Debris; Pollution monitoring

1. Introduction

Most studies of marine debris have focused on large, visible material found on beaches, 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. More recent studies have shown that the mass of neustonic plastic can be comparable to that of zooplankton in both the mid-Pacific gyre (Moore et al., 2001) and along the California coast (Moore et al., 2002).

Studies of neustonic debris have been limited so far to sampling of surface waters. While some birds feed on plankton near the surface and could potentially consume surface debris, most filter feeding occurs below the surface. Plastics make up a high percentage of neustonic debris and many plastics are positively buoyant. Therefore, studies limited to collection in surface waters have the potential to overestimate prevalence of debris in the water column.

Our study extends previous work by comparing the density of neustonic debris and zooplankton at several

depths along the California coast. The study also addresses how distribution in the water column changes following a storm event, when higher wind conditions and urban runoff have the potential to enhance vertical mixing.

2. Materials and methods

Sampling was conducted at two Santa Monica Bay sites offshore from Ballona Creek, which drains downtown Los Angeles. The first site was located approximately 0.8 km offshore and the second about 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.

The sampling site closest to shore was 15 m deep and was sampled 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 0.9×0.15 m² rectangular opening manta trawl with a 3.5 m long, 333 micron net and a 30×10 cm² collecting bag. Mid-depth samples were collected using paired 61 cm diameter bongo nets with 3 m long, 333 micron nets and 30×10 cm² collecting bags. Bottom samples were collected using a 31

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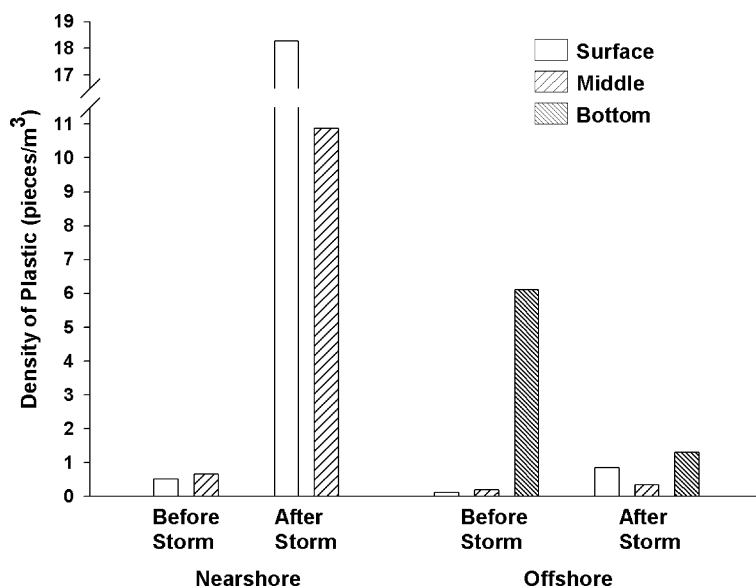


Fig. 1. Amount of plastic (pieces/m³) before and after a storm at different depths and proximities to shore.

62 cm² rectangular opening epibenthic sled with a 1 m long,
63 333 micron net and a 30 × 10 cm² collecting bag. The net
64 on the epibenthic sample was located 20 cm from the
65 bottom. Visual inspection by scuba divers showed no
66 sediment stirred from the bottom and entering the net.
67 All samples were fixed in 5% formalin in the field, and
68 later soaked in fresh water and transferred to 70% iso-
69 propyl alcohol.

70 Trawls were done parallel to shore for 10 min. Trawl
71 speed varied between 1.0 to 2.3 m/s as measured with a
72 B&G paddlewheel sensor, resulting in a trawl distance of
73 between 0.5 and 1.0 km. A General Oceanics flowmeter
74 was mounted across the net mouth during all deploy-
75 ments to measure the volume filtered.

76 In the laboratory, samples were placed in fresh water
77 and floating plastic removed. A dissecting microscope
78 was then used to remove remaining debris and plankton.
79 Debris was sorted by category (plastics, tar, rust, paint
80 chips, carbon fragments, and feathers) and plastics were
81 further categorized (fragments, styrofoam, pellets,
82 polypropylene/monofilament line, thin plastic films, and
83 resin). Each category was sorted through Tyler sieves of
84 4.75, 2.80, 1.00, 0.71, 0.50 and 0.35 mm and counted.
85 Plastics were oven dried at 65 °C for 1 h and plankton
86 and plant material oven dried at 65 °C for 24 h, then
87 weighed.

88 3. Results

89 Plastics were present throughout the water column on
90 both sampling dates, but relative concentrations within
91 the water column varied between dates and sites. The
92 site closest to shore had nearly equal density at the two

sampling depths before the storm (Fig. 1), but density 93
94 on the surface was considerably higher after the storm.

95 Debris densities at surface and midwater depths of
96 the offshore station were similar to that at the nearshore
97 station; the increase in density after the storm was not
98 nearly as large as at the inshore site. Debris density near
99 bottom at the offshore station was considerably greater
100 than at both the surface and midwater depths. Unlike
101 surface samples, there was reduced debris density at
102 bottom following the storm.

103 The spatial patterns for mass were similar to that of
104 density, though the differences between dates were
105 exaggerated (Fig. 2). For example, the weight of plastic
106 increased by more than two hundred times on the sur-
107 face after the storm. Much of this increase was attrib-
108 utable to the presence of larger items at surface after the
109 storm (Table 1).

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

119 4. Discussion

120 The plastic to plankton ratio that we observed near
121 surface was similar to that found in previous studies
122 (Table 2); ours was the first study, however, to measure
123 it at other depths. While we found that there was more
124 debris near the surface than in midwater, we also found

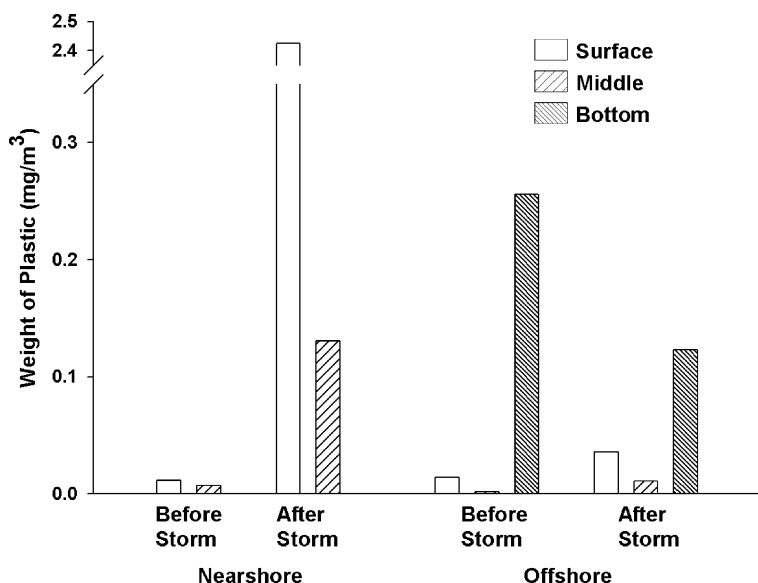


Fig. 2. Mass of plastic (mg/m³) before and after a storm at different depths and proximities to shore.

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

Size class	Category	Depth		
		Surface	Middle	Bottom
0.355–0.499	Weight	0.5	10.6	6.1
	Density	3.2	5.7	0.3
0.500–0.709	Weight	0.8	19.7	36.5
	Density	2.9	2.3	9.1
0.710–0.999	Weight	1.9	12.5	23.0
	Density	33.4	10.6	22.7
1.000–2.799	Weight	7.0	27.6	17.9
	Density	24.4	21.2	17.8
2.800–4.749	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 et al., 2002), and North Pacific Gyre study (Moore 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

125 that there was more on the bottom than on the surface.
126 When only small size classes were considered, there was
127 little difference between surface and midwater densities.

128 It is commonly perceived that plastics are positively
129 buoyant, but only 46% of manufactured plastics actually
130 are (USEPA, 1992). Many buoyant items are products
131 such as Styrofoam, in which air is injected. Even those
132 plastics that are lighter than water at the time of man-
133 ufacture can become negatively buoyant as they are
134 fouled by biota or accumulate debris. We observed sand
135 embedded in many items, such as plastic bags, that
136 might otherwise float.

137 Few plastics are neutrally buoyant, which in the ab-
138 sence of turbulence would lead to a natural separation
139 of debris top to bottom in the water column. The

amount of turbulence necessary for resuspension of 140
debris into midwater appears to be small. We observed 141
that density near the bottom declined and midwater 142
density was elevated after a storm, suggesting that storm 143
or wind-related turbulence may be adequate for resus- 144
pension. This is consistent with the density of most 145
plastics differing from that of seawater by a small 146
amount (USEPA, 1992). 147

148 While mixing occurred in the shelf waters we sam- 148
pled, the influence of resuspension in deeper waters is 149
less clear. The distance from bottom to the middle of the 150
water column is greater in deeper waters, meaning that 151
more turbulent energy is required to resuspend bottom 152
material to the middle of the water column and the 153
influence of wind on mixing decreases with depth. Still, 154
our study suggests that there is sufficient routine tur- 155
bulence that potential biological effects of plastics in the 156
water column are not limited to surface waters. 157

158 Many marine fauna are known to ingest debris 158
(Fowler, 1987; Bjorndal et al., 1994; Robards et al., 159
1995; Blight and Burger, 1997), but few studies have 160

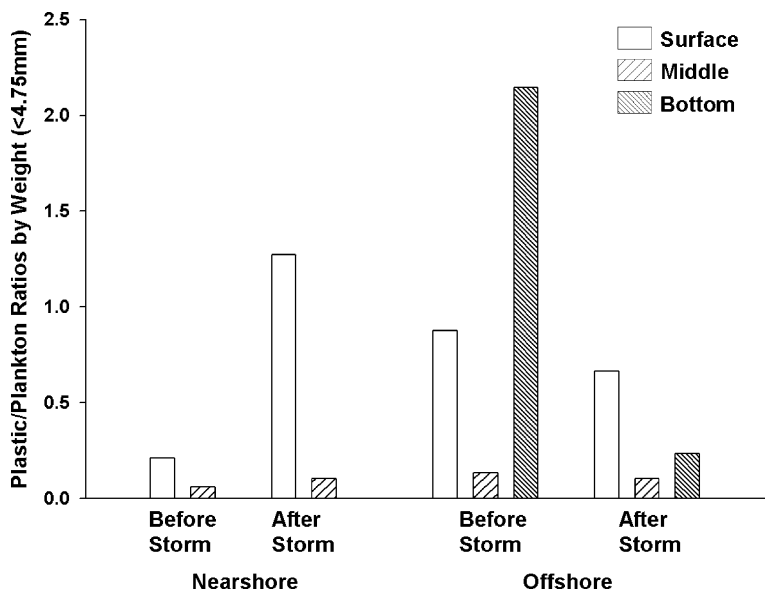


Fig. 3. Plastic/plankton ratios (pieces less than 4.75 mm) before and after a storm at different depths and proximities to shore.

161 examined whether they become artificially sated on this
 162 non-nutritive material (Ryan, 1987). Mato et al. (2001)
 163 found that contaminants adsorb to plastics, creating a
 164 potential for indirect effects of debris consumption;
 165 however, no study has considered whether this is a
 166 viable pathway for contaminant uptake by biota. These
 167 kinds of studies need to be conducted before we can
 168 fully assess the importance of debris in the water column.
 169

170 **Acknowledgements**

171 We thank Kevin Herbinson of Southern California
 172 Edison and Giancarlo Cetrulo of Los Angeles Conserva-
 173 tion Corps for the use of the S.E.A. Lab in Redondo
 174 Beach, California.

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