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Marine Pollution Bulletin xxx (2002) xxx-xxx

MARINE
POLLUTION
BULLETIN

www.elsevier.com/locate/marpolbul

A comparison of neustonic plastic and zooplankton abundance in southern California's coastal waters

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Abstract

The density of neustonic plastic particles was compared to that of zooplankton in the coastal ocean near Long Beach, California. Two trawl surveys were conducted, one after an extended dry period when there was little land-based runoff, the second shortly after a storm when runoff was extensive. On each survey, neuston samples were collected at five sites along a transect parallel to shore using a manta trawl lined with 333 μ mesh. Average plastic density during the study was 8 pieces per cubic meter, though density after the storm was seven times that prior to the storm. The mass of plastics was also higher after the storm, though the storm effect on mass was less than it was for density, reflecting a smaller average size of plastic particles after the storm. The average mass of plastic was two and a half times greater than that of plankton, and even greater after the storm. The spatial pattern of the ratio also differed before and after a storm. Before the storm, greatest plastic to plankton ratios were observed at two stations closest to shore, whereas after the storm these had the lowest ratios. © 2002 Published by Elsevier Science Ltd.

Keywords: Southern California; Neuston; Plastics; Zooplankton; Debris; Pollution monitoring

1. Introduction

Numerous researchers have documented the magnitude of marine debris and the threat that its ingestion poses to marine biota (Fowler, 1987; Ryan, 1987; Bjorndal et al., 1994; Moore et al., 2001). Most of these studies, however, have focused on large debris or debris that accumulates on the shoreline. Few studies (Shaw and Mapes, 1979; Day and Shaw, 1987) have examined the small floating debris that presents a potential risk to filter feeders, which have limited capacity for distinguishing small debris from planktonic food.

Moore et al. (2001) recently compared the density of neustonic plastic with that of potential zooplankton prey and found that mass of debris can rival zooplankton biomass in the upper water column. However, their study was conducted in the North Pacific central gyre, which is a large eddy system that can concentrate debris. Moreover, the gyre is a nutrient poor environment with low biological productivity, which would serve to exaggerate comparisons between debris and

zooplankton. It is unclear whether a similar pattern occurs in other marine environments.

This study compares the density of neustonic debris and zooplankton along the southern California coast, an area that is subject to nutrient upwelling and has a higher biological productivity than the North Pacific central gyre. The study area is located adjacent to a major population center, providing additional geographic contrast because of the proximity to land-based sources of debris. To assess the importance land-based sources, identical surveys were conducted after an extended dry period, when there was little land-based runoff and, shortly after a storm, when runoff was extensive.

2. Materials and methods

The first neustonic trawl survey was conducted on October 30, 2000, following 63 days without rain. The second was conducted on January 12, 2001, immediately following a 9 cm rainstorm. Five sites located sequentially offshore from the San Gabriel River were sampled on each survey (Fig. 1). The first station was located approximately 200 m offshore in front of the San Ga-

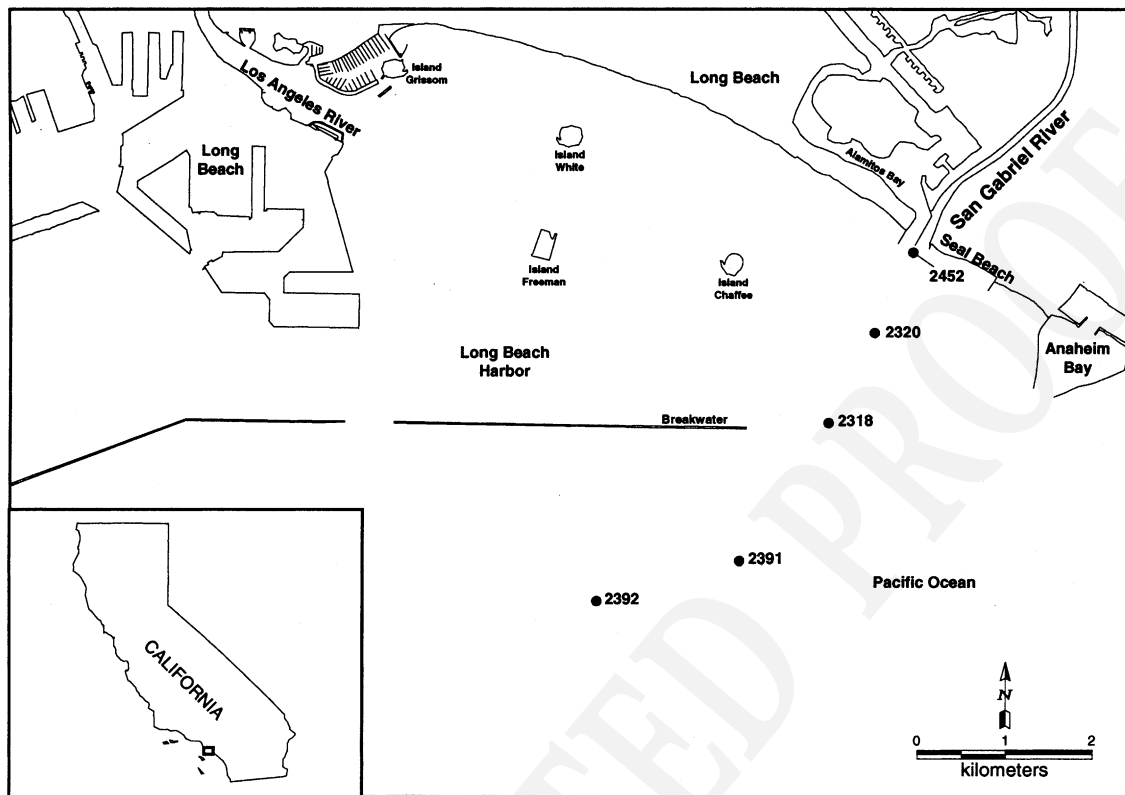


Fig. 1. Map of station locations and area of the San Gabriel River debris study, October, 2000 and January, 2001.

60 briel River mouth and the farthest station was about 5
61 km from shore.

62 Samples were collected using a manta trawl with a
63 $0.9 \times 0.15 \text{ m}^2$ rectangular opening (behind a G.O.
64 flowmeter) and a 3.5 m long, 333 μ net with a
65 $30 \times 10 \text{ cm}^2$ collecting bag. The net was towed at the
66 surface at a nominal speed of 1.5 m/s. Actual speed
67 varied from 1.25 to 2.5 m/s as measured with a B&G
68 paddlewheel sensor. Trawl transects were between 0.5
69 and 1.0 km long and were laid out in an east/west ori-
70 entation. Samples were fixed in 5% formalin, soaked in
71 fresh water, and transferred to 70% isopropyl alcohol.

72 Samples were split using a Folsom plankton splitter
73 after large pieces of debris and plant material were re-
74 moved. Samples were sorted through Tyler sieves of
75 4.75, 2.80, 1.00, 0.70, 0.50, and 0.35 mm. Debris, zoo-
76 plankton and plant material were separated from the
77 sorted fractions using a dissecting microscope; debris
78 were categorized into fragments, Styrofoam, pellet,
79 polypropylene/monofilament line, thin plastic films, re-
80 sin and nonplastics (including tar, rust, paint chip, car-
81 bon fragment) and counted. Plankton and plant
82 material were wet weighed and plastic, plankton and
83 plant material then oven dried at 65°C for 24 h and
84 weighed.

3. Results

85

86 Abundance of neustonic debris was several fold
87 higher on the sampling date following the storm (Fig. 2).
88 Prior to the storm, density was around three pieces per
89 cubic meter at the highest density station. After the
90 storm, density was more than twice that at all stations.
91 The mass of plastics was also generally higher after the
92 storm, though the storm effect on mass was less than it

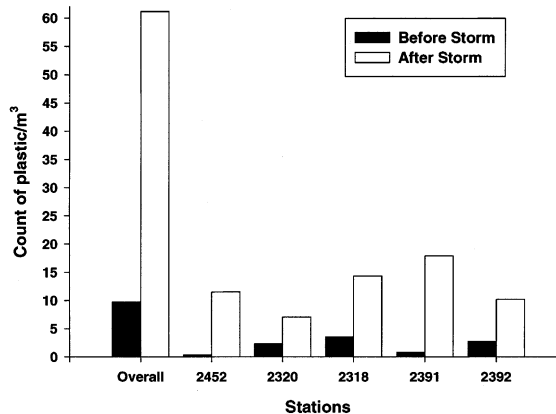


Fig. 2. Debris ratios for number of pieces (pieces/m³) of debris before and after a storm for the San Gabriel River debris study, October, 2000 and January, 2001.

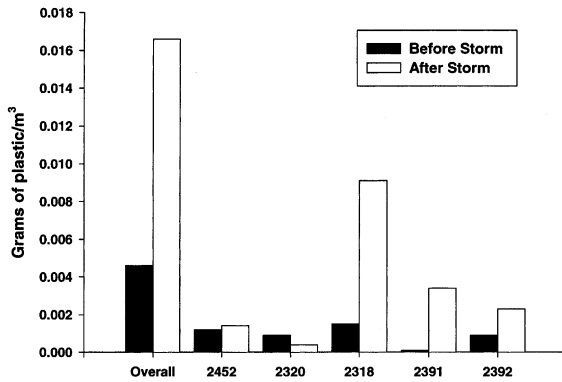


Fig. 3. Debris ratios for mass (g/m^3) of debris before and after a storm for the San Gabriel River debris study, October, 2000 and January, 2001.

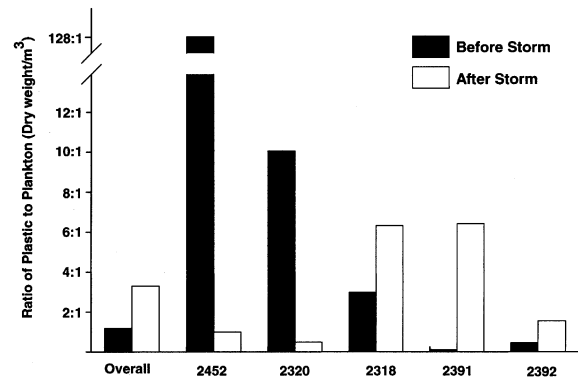


Fig. 4. Plastic and plankton ratios before and after a storm for the San Gabriel River debris study, October, 2000 and January, 2001.

93 was for abundance (Fig. 3). This reflects the smaller
94 average size of plastic particles that we observed after
95 the storm (Table 1).

96 The spatial distribution of debris also differed before
97 and after the storm. Prior to the storm, the mass of
98 plastic debris was greatest at the three stations closest
99 to land (Fig. 3). After the storm, mass of debris was
100 greatest at the three stations farthest from land.

101 The mass of plastic was about two and a half times
102 higher than that of plankton across the entire study.
103 Following the storm, this ratio exceeded 3:1 (Fig. 4).
104 The spatial pattern of the ratio also differed before and

105 after a storm. Before the storm, the highest plastic to
106 plankton ratios were observed at the two stations closest
107 to shore, whereas after the storm these stations had the
108 lowest ratios.

109 Most of the debris was in the form of plastic frag-
110 ments regardless of sampling date and sampling location
111 (Table 2). Thin plastic films, such as those used in gar-
112 bage and sandwich bags, was the second most common
113 type of debris, but it exceeded 5% of the mass only at the
114 station closest to land after the storm. Styrofoam, fish-
115 ing line and plastic pellets never exceeded 2% of the mass
116 at any station.

Table 1

Percent of each debris size class before and after a storm for the San Gabriel River debris study, October, 2000 and January, 2001

Small plastics Size class (mm)	Percent of each debris size class by station									
	2452		2320		2318		2391		2392	
	BS	AS	BS	AS	BS	AS	BS	AS	BS	AS
0.355–0.499	0.1	8.9	3.1	21.2	2.4	0.1	4.2	7.0	1.9	2.4
0.500–0.709	0.1	8.4	2.3	20.6	9.6	2.9	12.3	13.8	3.7	9.3
0.710–0.999	0.1	3.1	2.0	13.9	1.7	12.7	9.2	11.0	10.7	21.0
1.000–2.799	1.9	14.1	10.2	35.1	13.3	24.8	0.8	22.1	34.0	13.1
2.800–4.749	1.5	56.1	0.0	4.1	2.2	39.2	0.0	9.6	49.7	1.5
>4.750	96.2	9.5	82.3	5.1	70.9	20.3	73.5	36.5	0.0	52.7

BS: Before storm; AS: After storm.

Table 2

Percent of each debris type before and after a storm for the San Gabriel River debris study, October, 2000 and January, 2001

Debris type	Percent of each debris type by station									
	2452		2320		2318		2391		2392	
	BS	AS	BS	AS	BS	AS	BS	AS	BS	AS
Fragments	100.0	93.7	95.9	96.5	94.8	94.0	100.0	98.8	100.0	92.7
Styrofoam	0.0	0.6	2.1	0.9	0.0	0.0	0.0	0.3	0.0	1.8
Pellets	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.3	0.0	1.8
Line	0.0	0.6	2.1	0.9	2.6	6.0	0.0	0.3	0.0	1.8
Thin films	0.0	5.1	0.0	0.9	2.6	6.0	0.0	0.3	0.0	1.8

BS: Before storm; AS: After storm.

117 **4. Discussion**

118 The density of neustonic plastic along the southern
119 California coast was about three times higher than
120 Moore et al. (2001) found in the mid-Pacific gyre,
121 though the mass was 17 times lower (Table 3). This
122 disparity between density and mass reflects the dramatic
123 difference in size of neustonic debris between the gyre
124 and the coast. Most of the neustonic plastic mass ob-
125 served in the North Pacific central gyre was large ma-
126 terial associated with the fishing and shipping industry.
127 Most of the plastic we observed near the coast were
128 small fragments attributable to land-based runoff.

129 The average plastic:plankton mass ratio was less in
130 southern California, reflecting its higher plankton den-
131 sity. However, the plastic to plankton ratio on the day
132 after the storm was higher in southern California than in
133 the North Pacific central gyre. This change resulted from
134 an increase in debris following a storm, rather than from
135 a reduction in plankton. Moreover, the ratio in the
136 North Pacific central gyre was driven by large debris.
137 When the comparison of ratios between these two areas
138 is limited to debris smaller than 4.75 mm, which is the
139 fraction that filter feeders are most likely to confuse with
140 plankton, the southern California ratio becomes twice
141 that of the North Pacific central gyre.

142 The differences between our findings and those in the
143 North Pacific central gyre largely reflect differences in
144 proximity to land-based sources, but the effects of land-
145 based runoff are probably exaggerated in southern
146 California compared to the rest of the country. Southern
147 California rivers are highly modified stormwater con-
148 veyance systems that are independent of the sewage
149 treatment system, so urban debris flows unimpeded to
150 the ocean. Moreover, southern California has an arid
151 environment with a short rainy season and long dry
152 periods when the rivers provide minimal runoff. Thus,
153 land-based debris will accumulate between storms and
154 enhance the amount of runoff following a storm com-
155 pared to more temperate areas.

156 Reducing marine debris is a worldwide concern;
157 however, in southern California it presents a different
158 challenge than in the North Pacific central gyre or other
159 open water areas. In the open ocean, the input materials
160 are larger and the sources far more diffuse. Here, the
161 land-based sources are more definable, but the material

is smaller and therefore harder to capture. Several steps 162
are being taken to reduce land-based contributions to 163
the coastal ocean. Barrier nets to capture larger debris 164
have recently been constructed on several of the largest 165
river systems in southern California. The Los Angeles 166
Regional Water Quality Control Board has set a total 167
maximum daily load of zero trash for several area 168
watersheds. However, these orders focus on the large 169
debris (>5 mm) and the aesthetic effects they have on 170
beaches and harbors. Presumably some of the same 171
management steps will serve to reduce the smaller 172
fragments, but it is unclear to what extent. 173

It is also unclear what effects that the plastic debris we 174
observed in coastal waters have on planktonic filter 175
feeders. Little is known about how ingestion of plastics 176
affects filter feeders, though plastics have been shown to 177
sorb contaminants (Mato et al., 2001). Moreover, our 178
study, as well as that of Moore et al. (2001), was limited 179
to the upper water column. While some filter feeders 180
focus their consumption on the upper water column, 181
most pelagic feeders use a much larger portion of the 182
water column than we sampled and density of debris 183
compared to that of plankton has not been investigated 184
deeper in the water column. 185

Acknowledgements 186

The authors wish to thank Kevin Herbinson of 187
Southern California Edison and Giancarlo Cetrulo of 188
the Los Angeles Conservation Corps for the use of the 189
S.E.A. Lab in Redondo Beach, California. 190

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Table 3
Comparison between this study and the 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	0.002	7.25	2.5:1	0.6:1
Gyre study	0.034	2.23	6.1:1	0.3:1