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, and 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 u 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 one half times higher than that of plankton and was even higher after the storm. The spatial pattern of the ratio also differed before and after the storm. Before the storm, the highest plastic:plankton ratios were observed at the two stations closest to shore, whereas after the storm these stations had the lowest ratios.

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, S. *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, C. *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 of the 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.

METHODS

The first neustonic trawl survey was conducted on October 30, 2000, following 63 d 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 (Figure 1). The first station was located approximately 200 meters offshore in front of the San Gabriel River mouth, and the farthest station was about 5 km from shore.

Samples were collected using a manta trawl with a 0.9 m x 0.15 m rectangular opening (behind a G.O. flowmeter) and a 3.5 m long, 333 u net with a 30 cm x 10 cm collecting bag. The net was towed at the surface at a nominal speed of 1.5 m/sec. Actual

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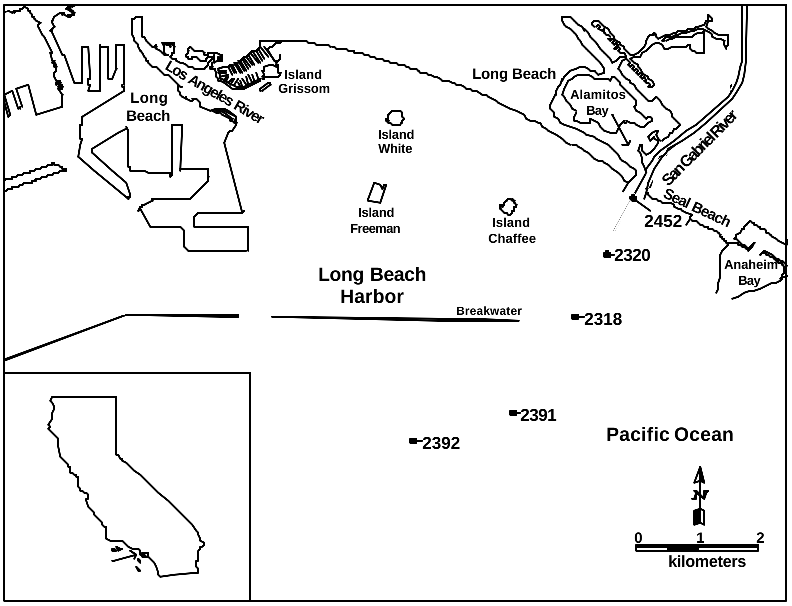

Figure 1. Map of station locations and area of the San Gabriel River debris study, October 2000 and January 2001.

speed varied from 1.25 m/sec to 2.5 m/sec as measured with a B&G paddlewheel sensor. Trawl transects were between 0.5 km and 1.0 km long and were laid out in an east/west orientation. Samples were fixed in 5% formalin, then soaked in fresh water and transferred to 70% isopropyl alcohol.

Samples were split using a Folsom plankton splitter after large pieces of debris and plant material were removed. Samples were sorted through Tyler sieves of 4.75 mm, 2.80 mm, 1.00 mm, 0.70 mm, 0.50 mm, and 0.35 mm. Debris, zooplankton, and plant material were separated from the sorted fractions using a dissecting microscope; and debris were categorized into fragments, Styrofoam, pellet, polypropylene/monofilament line, thin plastic films, resin, and nonplastics (including tar, rust, paint chip, carbon fragment) and counted. Plankton and plant material were wet weighed; and plastic, plankton, and plant material were then oven dried at 65°C for 24 h and weighed.

RESULTS

Abundance of neustonic debris was several-fold higher on the sampling date following the storm (Figure 2). Prior to the storm, density was around three pieces per cubic meter at the highest density station. After the storm, density was more than twice that at all stations. The mass of plastics was also generally higher after the storm, though the storm effect on mass was less than it was for abundance (Figure 3). This reflects the smaller average size of plastic particles that we observed after the storm (Table 1).

The spatial distribution of debris also differed before and after the storm. Prior to the storm, the mass of plastic debris was greatest at the three stations located closest to land (Figure 3). After the storm, mass of debris was highest at the three stations farthest from land.

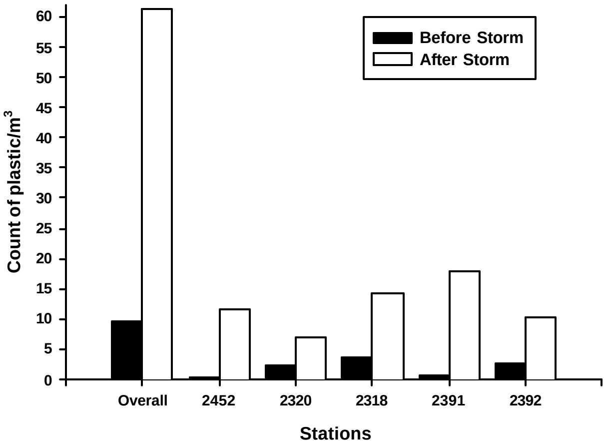

Figure 2. Number of pieces (piceces/m3) of debris before and after a storm.

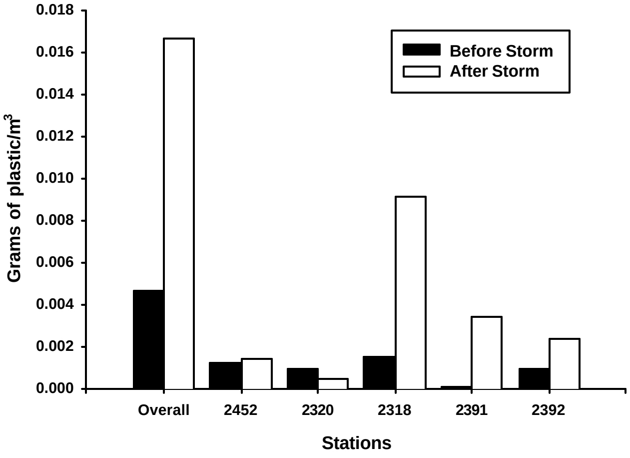

Figure 3. Mass (g/m^3) of debris before and after a storm.

Table 1. Percent of each debris size class before and after a storm.

Small Plastics	Percent of Each Debris Size Class by Station									
	2452		2320		2318		2391		2392	
Size Class (mm)	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.

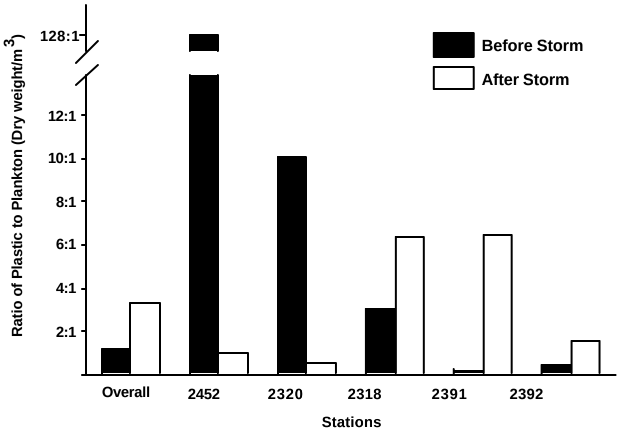

Figure 4. Plastic and plankton ratios before and after a storm.

The mass of plastic was about two and one half times higher than that of plankton across the entire study. Following the storm, this ratio exceeded 3:1 (Figure 4). The spatial pattern of the ratio also differed before and after a storm. Before the storm, the highest plastic:plankton ratios were observed at the two stations closest to shore, whereas after the storm these stations had the lowest ratios.

Most of the debris was in the form of plastic fragments regardless of sampling date and sampling location (Table 2). Thin plastic films, such as those used in garbage and sandwich bags, was the second most common type of debris, but it exceeded 5% of the mass only at the station closest to land after the storm. Styrofoam, fishing line, and plastic pellets never exceeded 2% of the mass at any station.

DISCUSSION

The density of neustonic plastic along the southern California coast was about three times higher than Moore *et al.* (2001) found in the mid-Pacific gyre, though the mass was 17 times lower (Table 3). This disparity between density and mass reflects the dramatic difference in size of neustonic debris between the gyre and the coast. Most of the neustonic plastic mass observed in the North Pacific central gyre was large material associated with the fishing and shipping industries. Most of the plastic we observed near the coast were small fragments attributable to land-based runoff.

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

The differences between our study and those in the North Pacific central gyre largely reflect differences in proximity to land-based sources; but the effects of land-based runoff are probably exaggerated in southern California compared to the rest of the country. Southern California rivers are highly modified stormwater conveyance systems that are

Table 2. Percent of each debris type before and after a storm for the San Gabriel River debris study, October 2000 and January 2001.

	Percent of Each Debris Type by Station									
	2452		2320		2318		2391		2392	
Debris Type	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	0.0	0.0	0.3	0.0	1.8

BS = Before storm; AS = After storm .

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

independent of the sewage treatment system, so urban debris flows unimpeded to the ocean. Moreover, southern California has an arid environment with a short rainy season and long dry periods when the rivers provide minimal runoff. Thus, land-based debris will accumulate between storms and enhance the amount of runoff following a storm compared to more temperate areas.

Reducing marine debris is a worldwide concern. In southern California, it presents a different challenge than in the North Pacific central gyre or other open water areas. In the open ocean, the input materials are larger and the sources are more diffuse. Here, the land-based sources are more definable, but the material is smaller and therefore harder to capture. Several steps are being taken to reduce land-based contributions to the coastal ocean. Barrier nets to capture larger debris have recently been constructed on several of the largest river systems in southern California. The Los Angeles Regional Water Quality Control Board has set a total maximum daily load (TMDL) of zero trash for several area watersheds. However, these orders focus on the large debris (>5 mm) and the aesthetic effects they have on beaches and harbors. Presumably, some of the same management steps will serve to reduce the smaller fragments, but it is unclear to what extent.

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

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