

WORKING OUR WAY UPSTREAM: A SNAPSHOT OF LAND-BASED CONTRIBUTIONS OF PLASTIC AND OTHER TRASH TO COASTAL WATERS AND BEACHES OF SOUTHERN CALIFORNIA

C.J. Moore, G.L. Lattin, A.F. Zellers

Algalita Marine Research Foundation, 148 N. Marina Drive, Long Beach, CA 90803, USA

Introduction

The most abundant type of debris impacting coastal beaches in Southern California's Orange County is pre-production plastic pellets, the plastic industry's principal feedstock. Hard plastic objects and pieces are over a hundred times less common but weigh one and a half times as much as the pellets¹. The presence of pre and post consumer plastics in the marine environment and on beaches is not only a Southern California phenomenon. "The literature on marine debris leaves no doubt that plastics make-up most of the marine litter worldwide."² Murray Gregory showed in 1989 that plastic debris can be found throughout the southwest Pacific, with high densities of plastic in surface waters north of New Zealand, and abundant plastic pellets on New Zealand beaches adjacent to manufacturing centers.³ Algalita Marine Research Foundation (AMRF) has documented land based sources of plastic and debris in neuston samples from the North Pacific Central Gyre⁴ (NPCG) as well as along the Southern California Coast.⁵ Plastic debris has also been shown to occur at subsurface depths of 10m and 30m in the NPCG,⁶ Southern California coastal waters, and near the bottom of the sea floor off Ballona Creek.⁷

Most studies of marine debris have focused on easily visible and identifiable plastic objects. The studies by AMRF and Southern California Coastal Water Research Project (SCCWRP), however, have shown that plastic fragments less than 5mm have a mass that is 30% of the mass of the associated zooplankton in the NPCG. In near coastal waters off the San Gabriel River, the mass of plastic less than 5 mm was found to be 60% of the mass of the associated zooplankton.⁷

Policies in California have been established to restrict trash and plastic greater than 5 mm in size through the process of regulating Total Maximum Daily Loads (TMDLs). In order to quantify debris not subject to regulation by TMDLS, this study analyzed plastic trash between 1 and 5mm in size as well as that >5mm from two Southern California Rivers; the Los Angeles River and the San Gabriel River. The goal of this study was to answer the following questions:

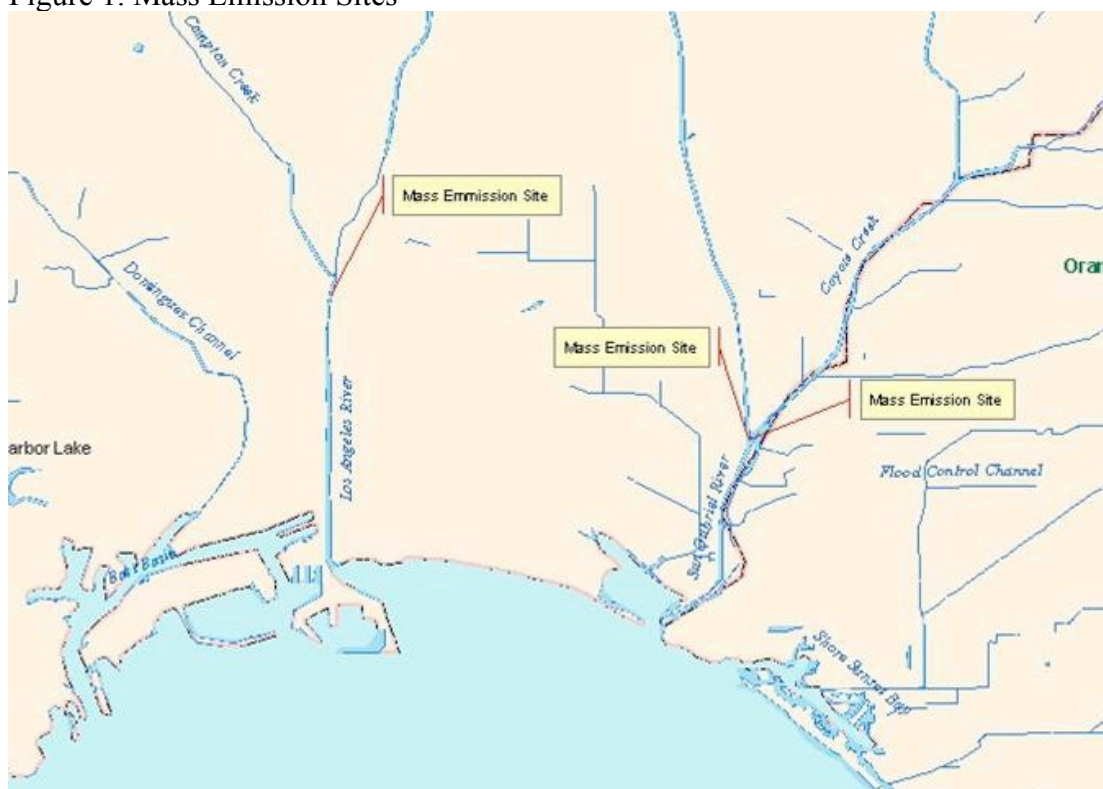
- 1) What are the amounts of different types of debris flowing down the rivers to the sea?
- 2) What are the quantities of debris in two size classes (1-4.75mm and >4.75mm) flowing down the rivers to the sea?
- 3) What is the weight of the debris flowing down the rivers to the sea?
- 4) What differences in the above quantities are observed in dry vs wet conditions?

Methods

Monitoring sites were selected in each watershed that represent a point at which all materials coming down the river from the watershed have to pass before reaching the ocean. Such sites are known as "mass emission" sites. Each was also chosen because it had access for sampling, and was above the area of tidal influence.

In the Los Angeles River one mass emission site was adequate, however, in the San Gabriel River two mass emission sites were necessary. One was located on the San Gabriel River and the other on Coyote Creek (see Fig. 1). These two sites are slightly upstream from where the Creek and the River merge. The reason for having two sites is that after they merge, they are subject to tidal influence.

Figure 1. Mass Emission Sites



The mass emission sites were sampled during both a dry and a wet period. The dry period was considered to be at least two weeks without 0.25" of rain, after which the dry period sample could be taken. The wet period samples were taken within 24 hours of a 0.25" rainfall. At each site grab samples were collected at the middle and edge of the channel, and at the surface and depth. For both wet and dry weather sampling, surface samples were collected at the center of the river using a manta trawl (see Table 1). Surface samples were also collected at the river/bank interface, and in laminar flow near the mid channel (Nov. 22 only) using two

different sized hand nets. All nets used had less than a 1mm mesh. Mid-depth to bottom samples were collected using a heavy streambed sampler. A large crane was used to lower the manta net and the streambed sampler for sampling. During the high flow of the wet period, the use of a crane was not possible, instead, a heavily weighted rectangular net was dropped from an upstream bridge nearby, allowed to extend to the length of the rope, then pulled to the side of the river for the collection of the sample. The hand nets were again used along the side of the river/bank interface. Table 1 summarizes the characteristics of our collection devices.

Table 1. Collection Device Characteristics

Collection Device	Handnets	Manta Trawl	Streambed	Rectangular net
Net Aperture Dimensions (m)	.46 x .25 .43 x .22	.9 x .15	.15 x .15	.46 x .25
Mesh Size (mm)	.800 .500	.333	.333	.333
Usage	Surface Edge	Surface Middle	Bottom Middle	Surface Middle Subsurface Bottom(mostly)

Flow rate was determined by using a General Oceanics flowmeter, or the time and distance method of a floating object. The original sampling time was 15 minutes; however, due to fouling of the net and flowmeter by algae and debris in the Spring samples, some deployment times were as short as 30 seconds. Three sample replicates were collected with each device. All sampling times and devices were normalized to obtain count or weight per cubic meter of river water.

All samples were taken to the AMRF Lab and analyzed. The samples were sorted wet. The large debris was sorted out first and placed in the appropriate category, either natural, plastic, or manmade items. A dissecting scope was used to sort out the rest of the smaller plastic and manmade items from the natural debris. Tyler sieves were then used to size class the small plastic items (4.75mm, 2.8mm, 1.0mm). The sieved items were oven dried at 65° C. Further sorting separated the plastic into types (fragments, foams, pellets, line, and films). Each type was counted, weighed, and recorded.

After each sample was sorted, the density or load of plastic per cubic meter of river water was determined by dividing the quantity of plastic (count or mass) collected by the product of the flow rate of the river, the area of the opening of the sampling device and the length of time the device was deployed. The three replicate samples were then averaged for that sampling device.

Wet period samples were collected first (November 22 and December 28, 2004) at all three sites. Dry period samples were collected on April 11, 2005.

Results

Results are shown in the following tables for the counts and weights of debris by their size class and type on each of the three sample dates.

Tables 2 and 3 present our mass emission density findings by size class for the three sampling sites. Data is presented for count density (pieces/m³), and weight density (g/m³), with the indicated collection method.

Tables 4 and 5 present our mass emission density findings by type of plastic debris.

Tables 6-9 show estimates for a one-day (24 hr) total of each debris category using flow data taken from available Flood Control Agency river-flow totals for that date.

The total count density of particles in the Los Angeles River between 1 and 4.75mm in size, collected on 11-22-04 from all sampling devices was 12,933 pieces/m³, while particles and whole objects greater than 4.75 mm from all sampling devices was 820/m³. The highest count density from any sampling device used in the Los Angeles River was on 11-22-04 with the hand net in laminar flow near mid-channel at 12,652 pieces/m³.

The total count density of particles in the San Gabriel River, including the Coyote Creek tributary, between 1 and 4.75mm in size, collected on 11-22-04 from all sampling devices was 411 pieces/m³, while particles and whole objects greater than 4.75 mm from all sampling devices was 125/m³. The highest count density from any sampling device used in the San Gabriel River or its Coyote Creek tributary was on 11-22-04 with the manta net; 171 pieces/m³.

Table 2. Total Count Density (number/m³)

	Coyote Creek		San Gabriel River		Los Angeles River	
	1 - 4.75 mm	>4.75 mm	1 - 4.75 mm	>4.75 mm	1 - 4.75 mm	>4.75 mm
November 22, 2004 (wet)						
Handnet	74	10	61	76	271	42
Manta	< 1	< 1	153	18	9	< 1
Streambed	< 1	< 1	123	21	< 1	< 1
Handnet Laminar	--	--	--	--	12652	777
December 28, 2004 (wet)						
Handnet	14	2	29	4	35	4
Thrownet	4	< 1	4	< 1	1	< 1
April 11, 2005 (dry)						
Handnet	2	< 1	< 1	0	22	22
Manta	5	< 1	<1	0	0	< 1
Streambed	< 1	0	0	0	<1	< 1

The highest weight density for any river sampled was in the San Gabriel River on 11-22-04, with the manta net at 81 g/m³. The handnet data for the same date and location was half as much, and the laminar net on the LA River was 56 g/m³.

Table 3. Total Weight Density (g/m³)

	Coyote Creek		San Gabriel River		Los Angeles River	
	1 - 4.75 mm	>4.75 mm	1 - 4.75 mm	>4.75 mm	1 - 4.75 mm	>4.75 mm
November 22, 2004 (wet)						
Handnet	< 1	2	< 1	40	< 1	< 1
Manta	< 1	< 1	< 1	81	< 1	< 1
Streambed	< 1	2	< 1	< 1	< 1	< 1
Handnet Laminar	--	--	--	--	43	13
December 28, 2004 (wet)						
Handnet	< 1	< 1	< 1	1	< 1	1
Thrownet	< 1	< 1	< 1	< 1	< 1	< 1
April 11, 2005 (dry)						
Handnet	< 1	< 1	< 1	0	< 1	1
Manta	< 1	< 1	< 1	< 1	< 1	< 1
Streambed	< 1	0	0	0	0	< 1

Table 4 presents the total count density by material type in each river, and Table 5 presents the total weight density by type in each river. The Los Angeles River in November had the greatest number of particles, with foam as the most abundant material. Foamed plastics were also the most abundant particles in the San Gabriel River on that date.

Table 4. Total Count Density (number/m³) by Type

Coyote Creek							
	Whole Items	Fragments	Foam	Pellets	Line	Film	Total
November 22, 2004	0.04	53.00	10.82	0.00	10.38	10.42	84.66
December 28, 2004	0.19	12.24	2.47	1.86	1.75	1.79	20.30
April 11, 2005	0.02	0.23	7.09	0.11	0.00	0.03	7.48
San Gabriel River							
	Whole Items	Fragments	Foam	Pellets	Line	Film	Total
November 22, 2004	17.95	177.24	208.26	0.00	11.91	36.32	451.68
December 28, 2004	0.68	19.48	9.71	3.14	0.84	3.75	37.60
April 11, 2005	0.00	0.12	0.37	0.00	0.00	0.00	0.48
Los Angeles River							
	Whole Items	Fragments	Foam	Pellets	Line	Film	Total
November 22, 2004	0.00	823.59	11,410.15	1,459.03	23.50	35.48	13,751.75
December 28, 2004	0.56	5.57	28.06	4.33	0.36	1.51	40.39
April 11, 2005	0.00	0.31	23.00	0.00	0.02	22.52	45.85

Table 5. Total Weight Density (g/m³) by Type

Coyote Creek							
	Whole Items	Fragments	Foam	Pellets	Line	Film	Total
November 22, 2004	1.72	0.06	0.01	0.00	0.00	2.11	3.89
December 28, 2004	0.40	0.15	0.00	0.04	0.00	0.01	0.61
April 11, 2005	0.00	0.01	0.01	0.00	0.00	0.00	0.02
San Gabriel River							
	Whole Items	Fragments	Foam	Pellets	Line	Film	Total
November 22, 2004	118.75	0.29	1.99	0.00	0.00	0.03	121.07
December 28, 2004	0.41	0.84	0.11	0.07	0.00	0.00	1.45
April 11, 2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Angeles River							
	Whole Items	Fragments	Foam	Pellets	Line	Film	Total
November 22, 2004	0.00	9.73	14.92	31.91	0.00	0.15	56.71
December 28, 2004	0.32	0.72	0.25	0.11	0.00	0.09	1.48
April 11, 2005	0.00	0.00	0.01	0.00	0.00	0.97	0.97

Pellets were found in both rivers, and were the second most abundant material found after expanded polystyrene in the LA River. Small plastics, 1-4.75mm diam. were the most common debris item in this study, constituting approximately 80% of all plastics sampled, but were outweighed 6 to1 by debris >4.75 mm in diameter.

Discussion

California policy defines trash as debris that is trapped by a 5 mm mesh screen (Trash TMDL). Our data confirms the abundance of plastic debris greater than 5 mm; however, our data shows that plastic particles less than 5 mm in size are far more abundant. The most common plastics found were bits of foamed polystyrene (commonly but incorrectly called Styrofoam, which is a patented insulation made by Dow Chemical Co.), followed by pre-production plastic pellets, hard plastic fragments, thin films, line, and whole items. Our findings indicate that there is a significant amount of plastic debris, which, due to its size, is not subject to regulation under current TMDLs for trash, passing our sampling stations and discharging to the estuaries.

Abundant plastic debris was found in both rivers, during wet and dry periods. The first wet period sampling in November 2004 was after a couple of rain events had moved through the area, so a lot of debris that had been collecting in the rivers since the last notable rain had already washed down the river. Also, the samples were not taken at the crest of each river's flood stage, so our estimates likely underestimate the actual storm water loading of plastic debris. The dry period sample was taken after the highest annual rainfall in over 100 years, which was the second highest annual rainfall in recorded history for this area. Again, a lot of debris had passed through the rivers before samples were taken, and there was considerable loading from the masses of filamentous algae that proliferated and broke loose along the river's course, filling sampling nets quickly and making debris separation and quantification difficult. Short deployment times may have allowed nets to miss debris present in the rivers. Nevertheless, there were substantial amounts of plastic debris in both rivers during each of the sampling events, including the Spring sampling when flow was low and algae abundant.

The highest total count density was found on the Los Angeles River on November 22, 2004, with 13,752 pieces collected in our samples. Based on data furnished by the Los Angeles Department of Public Works, the mean flow for 24 hours on the LA River on November 22, 2004 was 354,592 cubic meters near where our samples were collected. Extrapolation from our collected samples would likely underestimate the total count of debris since our sampling devices collected from a small proportion of the total river cross section. Applying the total flow to our average collected debris counts per cubic meter on that day yields the data set in Table 6. Applying the same flow total to our average weight density yields the weights for debris listed in Table 7. It is unlikely that these tables exaggerate the actual totals. With more systematic and comprehensive monitoring it should be possible to obtain a fairly complete picture of how much debris is being transported by the rivers. Such data could form a baseline to support decisions by policy makers regarding how to reduce trash and plastic entering our rivers and estuaries. Unless measures are taken to control debris less than 5 mm in diameter, billions of plastic particles per day will make their way to the marine ecosystem, where they exist in all strata of the water column⁷, have been observed to be readily ingested by a wide variety of marine invertebrates⁸, firmly embed themselves in the tissue of filter feeding organisms⁴, and appear in the stomach contents of many species of marine fishes and birds².

Table 6. Average Count (number * 10⁴) by Size Class in 24 hours

	Coyote Creek		San Gabirel River		Los Angeles River		Total
	1.0 - 4.75mm	>4.75 mm	1.0 - 4.75mm	>4.75 mm	1.0 - 4.75mm	>4.75 mm	
November 22, 2004	499.39	70.04	5,166.51	1,749.84	106,058.73	15,847.86	129392.37
December 28, 2004	15208.93	2133.07	2,389.07	331.97	74,830.33	8,314.48	103207.85
April 11, 2005	140.66	3.46	42.72	7.96	330.10	319.70	844.60
Total	15848.99	2206.56	7598.31	2089.76	181219.16	24482.04	233444.82

Table 7. Average Weight Density (kg) by Size Class in 24 hours

	Coyote Creek		San Gabirel River		Los Angeles River		Total
	1.0 - 4.75mm	>4.75 mm	1.0 - 4.75mm	>4.75 mm	1.0 - 4.75mm	>4.75 mm	
November 22, 2004	4.19	257.61	18.54	18,520.06	3,851.29	1,176.51	23828.20
December 28, 2004	789.35	4403.75	97.36	949.54	3,360.31	27,187.99	36788.30
April 11, 2005	3.35	0.35	0.01	0.00	0.96	136.54	141.21
Total	796.89	4661.71	115.91	19469.60	7212.57	28501.03	60757.71

Table 8. 24 Hour Average Count (N * 10⁴) estimate by type.

Coyote Creek							
	Whole Items	Fragments	Foam	Pellets	Line	Film	Total
November 22, 2004	0.27	356.48	72.78	0.00	69.85	70.06	569.43
December 28, 2004	163.91	10,451.03	2,106.26	1,591.23	1,497.28	1,532.29	17,342.00
April 11, 2005	0.26	3.94	120.51	18.90	0.00	0.51	144.12
San Gabriel River							
	Whole Items	Fragments	Foam	Pellets	Line	Film	Total
November 22, 2004	274.87	2,714.01	3,188.94	0.00	182.45	556.07	6,916.35
December 28, 2004	49.29	1,410.02	702.84	226.90	60.43	271.55	2,721.04
April 11, 2005	0.00	38.58	12.10	0.00	0.00	0.00	50.68
Los Angeles River							
	Whole Items	Fragments	Foam	Pellets	Line	Film	Total
November 22, 2004	0.02	7,300.96	101,148.72	12,934.01	208.32	314.56	121,906.59
December 28, 2004	1,148.64	11,463.78	57,759.41	8,915.36	743.12	3,114.51	83,144.81
April 11, 2005	0.00	4.42	324.82	0.00	2.53	318.03	649.80

Tabel 9. 24 Hour Average Weight (kg) estimate by type..

Coyote Creek							
	Whole Items	Fragments	Foam	Pellets	Line	Film	Total
November 22, 2004	115.9	3.7	0.3	0.0	0.1	141.8	261.8
December 28, 2004	3,425.0	1,315.3	17.1	350.2	17.1	68.3	5,193.1
April 11, 2005	0.4	1.3	1.4	0.5	0.0	0.0	3.7
San Gabriel River							
	Whole Items	Fragments	Foam	Pellets	Line	Film	Total
November 22, 2004	18,183.4	45.2	304.7	0.0	0.5	4.9	18,538.6
December 28, 2004	298.2	608.0	82.5	54.2	0.6	3.5	1,046.9
April 11, 2005	0.0	0.0	0.1	0.0	0.0	0.0	0.1
Los Angeles River							
	Whole Items	Fragments	Foam	Pellets	Line	Film	Total
November 22, 2004	0.0	862.5	1,322.6	2,828.8	0.3	13.6	5,027.8
December 28, 2004	6,690.1	14,759.4	5,125.7	2,202.6	0.2	1,770.3	30,548.3
April 11, 2005	0.0	0.1	0.9	0.0	0.0	136.4	137.5

References:

¹S.L. Moore, D. Gregorio, M. Carreon, M.K. Leecaster, and S.B. Weisberg. 2001. Composition and Distribution of Beach Debris in Orange County, California. *Marine Pollution Bulletin* 42:241-245.

²Derraik, J.G.B., The pollution of the marine environment by plastic debris: a review. 2002, *Marine Pollution Bulletin* 44:842-852

³M.R. Gregory, 1990. In R.S. Shomura and M.L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Department of Commerce, NOAA Technical Memorandum NMFS, NOAA-TM-NMFS-SWFSC-154. 55-84.

⁴C.J. Moore, S.L. Moore, M. K. Leecaster, and S.B. Weisberg. 2001. A comparison of plastic and plankton in the North Pacific central gyre. *Marine Pollution Bulletin* 42:1297-1300.

⁵C.J. Moore, S.L. Moore, S.B. Weisberg, G. Lattin and A. Zellers. 2002. A comparison of neustonic plastic and zooplankton abundance in southern California's coastal waters. *Marine Pollution Bulletin* 44:1035-1038.

⁶C.J. Moore, G.L. Lattin, and A. Zellers. 2005. Density of Plastic Particles found in zooplankton trawls from Coastal Waters of California to the North Pacific Central Gyre. Proceedings of the *Plastic Debris Rivers to Sea Conference*, September 8, 2005

⁷G.L. Lattin, C.J. Moore, S.L. Moore, S.B. Weisberg, and A. Zellers. 2004. A comparison of neustonic plastic and zooplankton at different depths near the southern California shore. *Marine Pollution Bulletin* 49:291-294.

⁸Thompson, Richard C., et al, Lost at Sea: Where Is All the Plastic?, *Science*, Vol. 304, 2004, 843