This page intentionally left blank

Composition and distribution of beach debris in Orange County, California

Shelly L. Moore, Dominic Gregorio[1], Michael Carreon[2], Stephen B. Weisberg, and Molly K. Leecaster[3]

ABSTRACT

Many studies have quantified the amount of debris collected along beach shoreline areas in various locations around the world. Only a few of those studies have been conducted in the United States, and they are largely limited to semi-quantitative efforts performed as part of volunteer clean-up activities. In this study, we quantified the distribution and types of beach debris by sampling 43 stratified random sites from Seal Beach to San Clemente on the Orange County, California, coast from August to September, 1998. An area of shoreline was delineated for each site that was 25 yards in length and extended from the water's edge to the first pavement or rocky cliff. All trash was collected by at least three people walking systematically along transects. In addition, a five-gallon bucket was used to sieve one bucket of sand at each site to collect and quantify the small items that were undetectable by visual examination. Based upon the survey data results, it was estimated that more than 106 million items, weighing approximately 13 tons, occur on Orange County shorelines. The most abundant items were pre-production plastic pellets, followed by foamed plastics and hard plastics. Debris density on the remote rocky shoreline was greater than that on high-use sandy beaches for most debris items. This finding partially reflects the periodic cleanup of high-use beaches by local municipalities, and also indicates that a high percentage of the observed debris was transported to the site from waterborne sources. The amount of Orange County beach debris estimated by this study is 50 times that (excluding pre-production plastic pellets) collected in the California Coastal Cleanup Day. The difference appears to be attributable to Cleanup Day's focus on large, visible debris at a subset of high-use beaches that are periodically cleaned by mechanical combers.

INTRODUCTION

Beaches along the southern California coast are used extensively for a variety of recreational purposes, attracting almost 150 million visitors annually (Schiff *et al.* 1999). Recreational uses such as boating, swimming, surfing, sunbathing, and picnicking generate debris along the shoreline including food bags and wrappers, cups and utensils, trash bags, fast-food and other product containers, toys, fishing lures and floats, and plastic. In addition, southern California has the highest coastal population density of any area in the country (Culliton *et al.* 1988), providing an additional source of debris via urban runoff and maritime disposal (including accidental spills). Debris is one of the most highly visible expressions of human impact on the marine environment, which is one of

This picture not available at this time

Debris from an Orange County beach.

[1]*Southern California Marine Institute, 820 South Seaside Avenue Terminal Island, CA 90731*

[2]*Divers Involved Voluntarily in Environmental Rehabilitation and Safety, P. O. Box 241, Fullerton, CA 92834*

[3]*Present address: INEEL, Bechtel WBXT Idaho, LLC, P.O. Box 1625, Idaho Falls, ID 83415-3779*

the factors that has led to the popularity of public cleanup efforts along the shoreline (Ribic *et al.* 1997). More than an aesthetic issue, debris can threaten marine mammals, birds, and turtles through ingestion and entanglement (Bjorndal *et al.* 1994, Fowler 1987, Robards 1993, Ryan 1987). Marine debris is also becoming a regulatory focal point. The Los Angeles Regional Water Quality Control Board recently implemented legal limitations, through the total maximum daily load (TMDL) process, on the amount of trash that local governments can allow to enter the ocean through storm drains.

Many studies have enumerated the types and amount of marine debris on beaches (Corbin and Singh 1993, Garrity and Levings 1993, Golik 1997, Golik and Gertner 1992, Lucas 1992, Ross *et al.* 1991, Ribic *et al.* 1997, Walker *et al.* 1997, Willoughby 1986), and a few studies have quantified subsurface nearshore debris (June 1990, Moore and Allen 2000). Most of the debris data for beaches outside of the United States have been collected through systematic, scientifically rigorous studies, while most of the information within the United States has been derived from volunteer beach cleaning efforts. Although cleaning efforts are valuable for removing debris from beaches, they provide only semi-quantitative estimates of debris. Here we present the first study to quantitatively assess the types and amount of debris on the California coast, with a secondary objective of describing how debris differs among shoreline types.

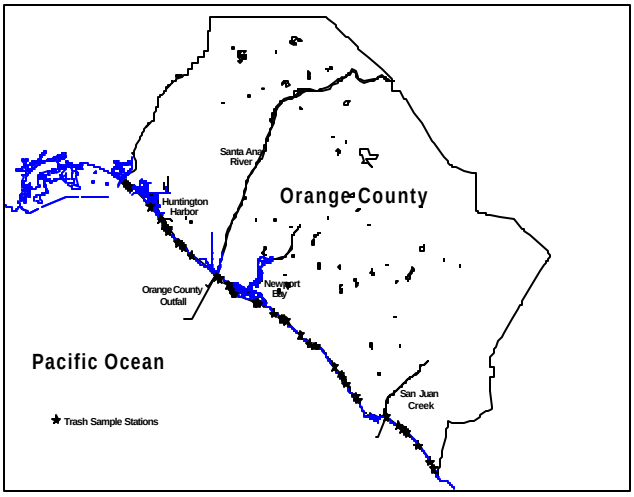
METHODS

Beach debris was surveyed and collected at 43 sites from Seal Beach to San Clemente on the Orange County, California, coast between August 2 and September 18, 1998 (Figure 1). Sites were selected using a stratified random design, stratified by shoreline type (rocky shoreline and sandy beach). Sample sites were selected randomly within the strata and a systematic component was overlayed to minimize clustering, following the sampling design used in the National Stream Survey (Overton 1987). Each stratum was subdivided into a series of sections (each identified by a count variable) of like-strata joined together into a stratum line. A partition was created for each stratum line, with the number of intervals in the partition equal to the sample size. The partition was placed over this stratum line by selecting a random starting point for the beginning of the first interval. Based upon this starting point, the intervals were defined as consecutive equal-width lengths. A simple random sample of one point was then chosen from within each interval. Each point was translated back to the shoreline using the section count variable. The partition structure ensures systematic separation of the sampling, while the random selection of sites within partitions ensures an unbiased estimate of beach debris.

Each sample site was delineated as an area 25 yards in length that extends from the water's edge to the first pavement or rocky cliff. All trash at the site was collected by at least three people walking systematically along transects to ensure that all areas within the sample site were examined. All debris was bagged and transported to the laboratory for identification and quantification. In addition, a five-gallon bucket was used to sieve one bucket of sand at each site to quantify the small items that were undetectable by visual examination. In the laboratory, debris was sorted into the broad categories used by the Center for Marine Conservation during their Coastal Cleanup days (i.e., glass, metal, plastics, foamed plastics, rubber, paper, wood, and cloth). From each broad category, debris was further sorted into more specific subcategories (e.g., cups, plates, etc.), enumerated, and weighed. Within the specific categories, brand names were recorded, when possible, to establish cross-brand trends.

The total amount of debris along the Orange County coast was estimated by calculating a mean amount of trash for a 25-yard segment within each strata and then weighting those means by the relative amount of shoreline distance in each strata. Estimates for smaller debris collected by sieving were calculated using a similar methodology, after estimating the number of yards from the water's edge to the first pavement or rocky cliff for each site then extrapolating the abundance for each sample site area.

FIGURE 1. Sample sites for the Orange County beach debris study, August to September 1998.



RESULTS

More than 106 million items, weighing approximately 13 tons, were estimated to occur along the Orange County shoreline (Table 1). Three categories of plastics (pre-production plastic pellets, foamed plastics, and hard plastics) accounted for 99% of the total abundance and 51% of the total weight. Cigarette butts were fourth in abundance and accounted for less than 1% of the total abundance and weight. Cigarettes, candy, fast–food products, beer, and other beverages were the most identified brand-related debris (Table 2). Marlboro®, Starburst®, Jack in the Box®, Budweiser Light®, and Coca Cola® all led in their respective categories.

Most of the plastics encountered were in the form of small pieces of plastic (Table 3). Foamed plastic pieces accounted for 88% of the total foamed plastics and hard plastic pieces accounted for 50% of the total hard plastics. Of the whole plastic items, food and beverage items were the most abundant.

The distribution of debris differed among shoreline types. Sandy beaches are eight times more abundant than rocky shoreline in Orange County, but most debris did not reflect this ratio (Table 4). Foamed and hard plastics, glass, rubber, and animal droppings all occurred at higher proportions on rocky beaches. Pre-production plastic pellets, paper, wood, and cloth all occurred at higher proportions on sandy beaches. Cigarette butts and metal were found at approximately equal ratios between beach types.

TABLE 1. Estimated total abundance and weight of trash on Orange County beaches, August to September, 1998.

Debris Type	Abundance	Weight (lbs)
Pre-production plastic pellets	105,161,101	4,780
Foamed plastics	742,296	1,526
Hard plastics	642,020	7,910
Cigarette butts	139,447	344
Paper	67,582	870
Wood	27,919	4,554
Metal	23,500	3,015
Glass	22,195	1,944
Rubber	10,742	817
Pet and bird droppings	9,388	17
Cloth	5,949	1,432
Other	10,363	401

TABLE 2. Percent of total of top three brands in main brand categories collected on Orange County beaches, August to September, 1998.

Brand Name	Percent of Total	Percent of Market Share
Cigarette Products		
Marlboro	62	32.3
Camel	7	4.6
Benson & Hedges	7	<2.4
Candy Products		
Starburst	16	na
Snickers	13	na
Blow Pop	9	na
Fast-Food Products		
Jack in the Box	27	3.6
Carls Jr.	19	1.9
KFC	12	<0.9
Beer Products		
Budweiser Light	27	12.9
Budweiser	16	18.3
Corona	7	2.0
Drink Products		
Coca Cola	16	20.6
Pepsi	15	14.2
Capri Sun	8	<1.2

na = Not available

DISCUSSION

The most abundant item found on southern California beaches was pre-production plastic pellets, which are probably lost in transport from the raw materials producers to the processors who mold the pellets into plastic products. The pellets, collected primarily through sieving the surface layers of sand, come in a variety of shapes (ovoid, cylindrical, etc.) and are typically less than 5 mm in diameter. Approximately one quadrillion of these pellets, representing 60 billion pounds of resin, are manufactured annually in the United States alone (U.S. EPA 1992). The presence of these pellets is not unique to U.S. beaches; Gregory (1977, 1978) estimated that approximately 1,000 tons of these pellets occur on New Zealand beaches.

The relative distribution of brand-name products in the debris we collected largely reflects the product's relative market share. For example, we collected 10 times more Marlboro cigarette butts than any other brand, consistent with Marlboro's 32% market share. Similarly, Budweiser and Budweiser Light dominated the beer debris category, as they do in sales. One exception to the high correlation between brand-related debris quantity and market share was in the fast-food container category. Industry leader McDonalds constituted less than 10% of the total debris measured, while Jack in the Box accounted for nearly three times that level. Perhaps the geographic distribution of fast-food restaurants in relation to Orange County beaches was responsible for the

TABLE 3. Estimated total abundance of plastics on Orange County beaches, August to September, 1998.

Trash Type	Abundance
Foamed Plastics	
Foamed plastic pieces	652,639
Fast food containers	43,167
Other foamed plastics	25,415
Cups	10,595
Packaging material	9,940
Plates	270
Meat trays	180
Buoys	90
Total:	742,296
Plastics	
Plastic pieces	318,790
Caps and lids	88,548
Straws	84,990
Food bags and wrappers	58,394
Other plastic	48,799
Cups and utensils	9,641
Other plastic bags	7,164
Cigarette lighters	5,810
Beverage bottles	4,550
Trash bags	3,729
Toys	2,159
Buckets	1,973
Rope	1,848
Other bottles	1,563
Milk and water bottles	1,182
Diapers	1,003
Strapping bands	449
6-pack holders	321
Fishing line	321
Tampon applicators	301
Fishing lures and floats	281
Oil and lube bottles	114
Light sticks	90
Total:	642,020
Total Plastics	1,384,316

discrepancy in the amount of fast-food product debris collected compared to the brand's respective market share.

Four major sources have been identified as pathways in the transport of debris to the Orange County shoreline: (1) littering by beachgoers, (2) wind currents from upland sources, (3) runoff from land-based activities, and (4) overboard disposal from boating activities (including accidental spills). Each of these sources requires a different management action to effect a reduction in beach debris. Although our study was not designed to differentiate sources, our data suggest that water- based sources (runoff and overboard disposal) were more important than direct littering or wind. One line of evidence for this is that plastic pellets were found in abundance on all shoreline areas and are unlikely to originate from littering or wind. The second line of evidence is the greater density of most debris items found on less-frequented rocky shoreline compared to the sandy beaches (Table 4). While this pattern was true for most debris, an exception was the greater amount of paper products, such as food wrappers, found on sandy beaches, suggesting that they were left by beachgoers.

The only previous quantification of debris on the Orange County shoreline was from data collected by volunteers during the annual California Coastal Cleanup Day. Their 1998 cleanup event occurred the week after the present survey was completed and their estimate of the amount of debris was 50 times lower than our data (Table 5). Moreover, our estimate for Orange County debris exceeded the California Coastal Cleanup Day estimate for the entire state.

The estimates provided by the two surveys differ for several reasons. First, the California Coastal Cleanup Day is conducted by volunteers whose purpose it is to clean the beach rather than to quantify debris. As a result, it is likely that the some of the debris collected during this event was not recorded. Second, the volunteers focus their cleaning efforts on a subset of the coastline, which excludes the rocky shoreline where 10% of the debris was encountered in the present study. Third, the California Coastal Cleanup Day event focuses on many of the popular, easily accessible beaches that are regularly cleaned by mechanical combers. Moreover, the cleanup events usually cover only an area 1/4 to 1/2 of a mile from their starting locations (Mark Patrick, County of Orange, Harbors, Beaches, and Parks, personal communication), rather than the whole beach.

TABLE 4. Estimated total abundance of trash by beach type on Orange County beaches, August to September, 1998.

Debris Type	Beach Type: Sandy	Beach Type: Rocky	S:R Ratio
Percent of Shoreline	89	11	8:1
Pre-production plastic pellets	96,211,029	8,950,072	11:1
Foamed plastics	557,319	184,977	3:1
Hard plastics	424,257	217,763	2:1
Cigarette butts	124,422	15,025	8:1
Paper	64,729	2,853	23:1
Wood	25,611	2,308	11:1
Metal	20,468	3,032	7:1
Glass	4,055	18,140	1:4
Rubber	9,039	1,703	5:1
Pet and bird droppings	7,217	2,171	3:1
Cloth	5,529	420	13:1
Other	10,300	63	163:1
Total	97,463,975	9,398,527	10:1

TABLE 5. Comparison of abundance for the Orange County summer trash survey and Center for Marine Conservation 1998 California Coastal Cleanup Day.

Debris Type	Bight'98	Coastal Cleanup Day	
	Orange County	Orange County	California
Pre-production Plastic Pellets	105,161,101	-	-
Foamed Plastics	742,296	8,170	211,406
Hard Plastics	642,020	10,860	382,380
Cigarette Butts	139,447	6,717	309,910
Paper	67,582	2,504	133,335
Wood	27,919	720	27,136
Metal	23,500	1,456	110,201
Glass	22,195	1,033	94,333
Rubber	10,742	643	25,666
Pet and Bird Droppings	9,388	-	-
Cloth	5,949	317	10,620
Other	10,363	-	-
Total with pellets	106,862,502	32,420	1,304,987
Total without pellets	1,701,401	32,420	1,304,987

Another variable that could partially account for the discrepancy in the two survey results is that volunteers traditionally focus on larger, more visible debris to the exclusion of small, undetectable debris. To assess the impact of this variable, two beach sites (Salt Creek Beach and Sunset Beach) were sampled using the same methods as the present study. Sampling occurred immediately after the September 18, 1999, California Coastal Cleanup Day. While more than 8,000 pieces of debris were collected from these beaches as part of the cleanup effort, we estimated 67,795 pieces remaining (Table 6). Most of the remaining items were small; the majority of large items, such as glass bottles, were effectively removed by the California Coastal Cleanup Day volunteers.

TABLE 6. Comparison of beach debris amounts between Coastal Cleanup Day volunteers and the Orange County beach debris follow-up study.

	Total abundance of beach debris			
	Sunset Beach		Salt Creek	
Trash Type	CCD	OC*	CCD	OC*
No. of Volunteers	56	8	197	5
Total Weight (lbs)	137	106	405	35
Foamed plastics	313	19,219	1,057	6,336
Hard plastics	1,419	13,658	1,775	5,667
Cigarette butts	222	9,293	1,646	2,464
Paper	139	3,133	711	1,338
Wood	28	387	121	246
Metal	26	1,126	244	2,534
Glass	15	950	257	-
Rubber	67	282	157	387
Cloth	5	634	48	141
Total	2,234	46,682	6,016	19,113

CCD = Coastal Cleanup Day.
OC = Orange County beach debris follow-up study.
* Orange County beach debris follow-up study abundences are estimates of trash found in 1/2 mile based on a 25 yard sample.

LITERATURE CITED

Bjorndal, K. A., A. B. Bolton and C. J. Lagueux. 1994. Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. *Marine Pollution Bulletin* 28:154-158.

Corbin, C. J. and J. G. Singh. 1993. Marine debris contamination of beaches in St. Lucia and Dominica. *Marine Pollution Bulletin* 26:325-328.

Culliton, T., M. Warren, T. Goodspeed, D. Remer, C. Blackwell and J. McDonough II. 1988. 50 years of population changes along the nation's coast. Coastal Trends Series, Report No. 2. National Oceanic and Atmospheric Administration, Strategic Assessments Branch. Rockville, MD.

Fowler, C.W. 1987. Marine debris and northern fur seals: A case study. *Marine Pollution Bulletin* 18:326-335.

Garrity, S.D. and S.C. Levings. 1993. Marine Debris along the Caribbean coast of Panama. *Marine Pollution Bulletin* 26:317-324.

Golik, A. 1997. Debris in the Mediterranean Sea: Types, quantities, and behavior. pp. 7-14 *in:* J.M. Coe and D.B. Rogers (eds.), Marine Debris: Sources, Impacts, and Solutions. Springer-Verlag. New York, NY.

Golik, A. and Y. Gertner. 1992. Litter on the Israeli coastline. *Marine Environmental Research* 33:1-15.

Gregory, M.R. 1977. Plastic pellets on New Zealand beaches. *Marine Pollution Bulletin* 8:82-84.

Gregory, M.R. 1978. Accumulation and distribution of virgin plastic granules on New Zealand beaches. *New Zealand Journal of Marine and Freshwater Research* 12:399-414.

June, J.A. 1990. Type, source, and abundance of trawl-caught marine debris off Oregon, in the Eastern Bering Sea, and in Norton Sound in 1988. pp. 279-301 *in:* R.S. Shomura and M.L. Godfrey (eds.), 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.

Lucas, Z. 1992. Monitoring persistent litter in the marine environment on Sable Island, Nova Scotia. *Marine Pollution Bulletin* 24:192-199.

Moore, S.L. and M. J. Allen. 2000. Distribution of anthropogenic and natural debris on the mainland shelf of the Southern California Bight. *Marine Pollution Bulletin* 40:83-88.

Overton, S.W. 1987. A Sampling and Analysis Plan for Streams, in the National Surface Water Survey Conducted by EPA. Technical Report No. 117. Department of Statistics, Oregon State University. Corvallis OR.

Ribic, C.A., S.W. Johnson and C.A. Cole. 1997. Distribution, type, accumulation, and source of marine debris in the United States, 1989-1993. pp. 35-47 *in*: J.M. Coe and D.B. Rogers (eds.), Marine Debris: Sources, Impacts, and Solutions. Springer-Verlag. New York, NY.

Robards, M.D. 1993. Plastic ingestion by North Pacific seabirds. U. S. Department of Commerce. NOAA-43ABNF203014. Washington, DC.

Ross, J.B., R. Parker and M. Strickland. 1991. A survey of shoreline litter in Halifax Harbour 1989. *Marine Pollution Bulletin* 22:245-248.

Ryan, P. G. 1987. The effects of ingested plastic on seabirds: Correlations between plastic load and body condition. *Environmental Pollution* 46:119-125.

Schiff, K.C., S.B. Weisberg and J. H. Dorsey. 1999. Microbiological monitoring of marine recreational waters in southern California. pp. 179-186 *in:* S. Weisberg (ed.), Southern California Coastal Water Research Project Annual Report 1997-1998. Southern California Coastal Water Research Project. Westminster, CA.

U.S. Environmental Protection Agency (U.S. EPA). 1992. Plastic Pellets in the Aquatic Environment: Sources and Recommendations. U.S. EPA 842-B-92-010. Washington, DC.

Walker, T.R., K. Reid, J.P.Y. Arnould and J. P. Croxall. 1997. Marine debris surveys at Bird Island, South Georgia 1990-1995. *Marine Pollution Bulletin* 34:61-65.

Willoughby, N. G. 1986. Man-made litter on the shores of the Thousand Island Archipelago, Java. *Marine Pollution Bulletin* 17:224-228.

ACKNOWLEDEGMENTS

The authors wish to thank the following organizations and their volunteers/employees for assistance with this project: Divers Involved Voluntarily in Environmental Rehabilitation and Safety, Southern California Marine Institute, Southern California Coastal Water Research Project, Cabrillo Marine Aquarium, and the Long Beach Conservation Corps. We would also like to thank Mark Patrick for his assistance in the comparison with the 1999 Coastal Cleanup Day activities.