Distribution of Anthropogenic and Natural Debris on the Mainland Shelf of the Southern California Bight

SHELLY L. MOORE* and M. JAMES ALLEN
Southern California Coastal Water Research Project, 7171 Fenwick Lane, Westminster, CA 92683, USA

Various studies have been conducted to quantify debris found along beaches; however, little information has been compiled about debris found on the seafloor. This study describes the distribution, types, and amounts of marine debris found in the Southern California Bight in July and August of 1994. Anthropogenic debris was most common in the central region, on the outer shelf, and in areas near publicly owned treatment works (POTWs). Fishing gear was the most common type of anthropogenic debris in the central region and in the outer shelf zone, whereas glass bottles and plastic were most common in POTW areas. Natural debris was more common close to shore in the inner shelf zone than anthropogenic debris. The deeper distribution of anthropogenic debris relative to natural debris, as well as the types of debris, suggest that the primary source of anthropogenic debris is marine vessel and fishing activity.

Keywords: debris; Southern California Bight; continental shelves; fishing gear; baseline studies; pollution monitoring.

Marine debris is a focal point for public concern and a visible expression of human impact on the marine environment. In the last few decades, marine debris has been recognized as an indicator of other forms of pollution that pose risks to marine organisms. Many organizations, such as the Center for Marine Conservation, are currently collecting and analyzing beach debris data as a means to inform the public of this growing problem (Ribic *et al.*, 1997).

Although marine debris has been a focus of many studies, most address only the types and distribution of anthropogenic debris found on coastal beaches (MBC, 1988; Ribic *et al.*, 1997; SMBRP, 1998). While many studies have concerned floating debris surveyed from ships (Baba and Kiyota, 1994; Matsumura and Nasu, 1997), very few have examined the types and distribution of marine debris on the seafloor (June, 1990; Golik, 1997).

Here we present the first study of debris on the seafloor of the Southern California Bight. The objectives of this study (part of a regional trawl survey of demersal fishes and megabenthic invertebrates; Allen *et al.*, 1998), were to (1) assess the distribution, types, and amounts of anthropogenic and natural (marine and terrestrial) debris on the seafloor of the mainland shelf of the SCB in 1994, and (2) provide a baseline for future comparisons.

Materials and Methods

Seafloor debris was surveyed in July and August of 1994 at 113 trawl stations on the mainland shelf of the SCB, Point Conception, California, to the United States-Mexico international border, at bottom depths of 10 to 200 m (Fig. 1). Trawl stations were selected using a stratified random design, with strata defined by three subpopulation categories: 1) depth — inner shelf (10-25 m), middle shelf (26-100 m), and outer shelf (101-200 m); 2) location — northern region (Point Conception to Point Dume), central region (Point Dume to Dana Point), and southern region (Dana Point to the United States-Mexico international border); and 3) proximity to POTW monitoring areas (i.e. POTW and non-POTW)(Stevens, 1997; Allen *et al.*, 1998).

*Corresponding author.

Trawl sampling used standardized methods described in a field operations manual prepared by the Southern California Bight Pilot Project (1994). Samples were collected with 7.6-m head-rope and 8.8-m foot-rope semiballoon otter trawls using a 1.25-cm cod-end mesh. Otter boards were 76.2 cm wide, 40.8 cm tall, and bridles 22.9 m long. Trawls were towed along isobaths for 10 min at 0.8-1.2 m/sec (1.5-2.4 kn).

Debris was categorized into 13 predetermined types of anthropogenic and natural debris: plastic; metal; paper; medical waste; cans; glass bottles; fishing gear; tires; modified wood; terrestrial vegetation (twigs, branches, leaves, and uprooted plants); marine vegetation (drift algae, kelp, and seagrasses); rocks; and other debris. Debris in each category was then counted and placed into one of four categories based upon numerical classification: trace (1 item); low (2-10 items); moderate (11-100 items); and high (>100 items). Debris was also weighed and placed into four categories by weight: trace (0.0-0.1 kg); low (0.2-1.0 kg); moderate (1.1-10.0 kg); and high (>10.0 kg).

Data analysis was focused upon determining the spatial coverage (percentage of area) of the different debris types on the mainland shelf as a whole and by subpopulation. Spatial coverage was calculated using a ratio estimator (Thompson, 1992; Stevens, 1997; Allen *et al.*, 1998). Debris data were expressed as values per standard 10-min trawl haul (representing approximately 2,944 m^2 of seafloor) (Allen *et al.*, 1998). The spatial coverage of a debris type in a subpopulation was defined as the occurrence of a debris type in a standard trawl haul collected at stations representing a given percent of the total subpopulation (e.g. depth or location) area.

Results

Anthropogenic Debris

Anthropogenic debris occurred on approximately 14% of the mainland shelf of the SCB (Fig. 2). Fishing gear had the highest spatial coverage, followed by plastic, metal, and other debris (shoe soles and automobile parts) (Table 1). All of these categories occurred primarily in trace numerical and weight densities (Tables 2 and 3). However, glass bottles and metal debris occurred most commonly at low weight densities.

The distribution and spatial coverage of anthropogenic debris varied by region, depth, and proximity to POTWs (Figs. 2 and 3). Regionally, the percent of area where anthropogenic debris occurred was highest (32%) in the central region, followed by the southern and northern regions. Bathymetrically, the percent of area where anthropogenic debris occurred increased with increasing depth (inner shelf < middle shelf < outer shelf). Anthropogenic debris occurred over more area in middle-shelf POTW areas and less area in non-POTW areas.

The types of anthropogenic debris also varied by region, depth, and proximity to POTWs (Tables 1 and 4). Regionally, fishing gear and plastic were the most common types of debris found in the central region, whereas metal, plastic, and cans were the most common types of debris found in the southern region; only modified wood occurred in the northern region (Table 1). Bathymetrically, the most common types of debris found in each zone are as follows: fishing gear, plastic, and modified wood on the outer shelf zone; fishing gear and metal debris on the middle shelf zone; and fishing gear, metal debris, and modified wood on the inner shelf zone (Table 1). On the middle shelf, glass bottles, plastic, and cans occurred exclusively in areas near POTWs (Table 4). The spatial coverage of fishing gear and metal debris was slightly higher in POTW areas than in non-POTW areas (Table 4). Fishing gear was found primarily in the Redondo Canyon area and eastern San Pedro Shelf. Glass bottles and cans were found near Redondo Canyon, Oceanside, and off Point Loma.

Natural Debris

Overall, natural debris was more widespread than anthropogenic debris, occurring on 73% of the mainland shelf (Figs. 2 and 3). Marine vegetation was the most commonly occurring natural debris overall and in all subpopulations on the mainland shelf of the SCB (Fig. 4), followed by terrestrial vegetation, benthic debris (worm tubes and shells), and rocks. Spatial coverage was highest for debris with low numerical densities, followed by those with trace, moderate, and finally high numerical densities (Table 2). The spatial coverage of marine and terrestrial vegetation was highest at trace weight densities and decreased with increasing weight (Table 3). Benthic debris was equally common at trace and low weight densities and decreased at moderate weight densities. However, rocks were found in a higher percentage of area at high and low weight densities than at moderate weight densities.

Natural debris also varied in spatial coverage by depth, region, and proximity to POTWs, but differed from the pattern of variation found in anthropogenic debris (Fig. 2). Spatial coverage for natural debris ranged from 36% in middle shelf POTW areas to 80% in the northern region. Regionally, the percent of spatial coverage

was higher in the northern region than in southern and central regions. Bathymetrically, natural debris covered a higher percentage of area on the middle shelf zone, followed by the inner shelf and outer shelf zones. Spatial coverage for natural debris was higher in non-POTW areas than in POTW areas.

The types of natural debris also varied by region, depth, and proximity to POTWs (Tables 1 and 4). Marine vegetation was most widely distributed on the inner shelf and middle shelf non-POTW areas and least widely distributed on the outer shelf and middle shelf POTW areas. Regionally, marine vegetation was nearly equally distributed among all subpopulations (Table 1). Terrestrial vegetation occurred most commonly in the northern region, middle and outer shelf zones, and non-POTW areas. Terrestrial vegetation was least common in the southern region and inner shelf zone and was completely absent from POTW areas (Tables 1 and 4). Benthic debris occurred mostly in the northern region, middle shelf zone, and non-POTW areas; it was absent in the central region and POTW areas. Rocks were most widely distributed on the outer shelf, were absent on the inner shelf, and were generally equally distributed among all other subpopulations.

Discussion

Anthropogenic debris was not widespread on the mainland shelf, but was relatively common in the central region, outer shelf zone, and POTW areas (Figs. 2 and 3). The higher occurrence in the central region (and southern region) can be attributed to the proximity of large population centers in these areas (e.g., Los Angeles and San Diego). The higher prevalence of anthropogenic debris on the outer shelf relative to the inner shelf—as well as the types of debris found on the outer shelf (fishing gear and plastic)—suggest that the source of this debris is the disposal of trash and incidental items from boats.

An alternative hypothesis is that most of the anthropogenic debris in the outer shelf zone originates from urban runoff that is washed offshore by currents associated with stormwater events. Approximately 13 mt of anthropogenic debris were discharged by stormwater from Ballona Creek into Santa Monica Bay in a single storm event in 1997 (SMBRP, 1998; J. Woodson, Los Angeles County Department of Beaches and Harbors, Planning Division, Los Angeles, CA, pers. comm., 1998). In addition, approximately 4,036 mt of litter were collected each year, 1988 to 1996, on beaches from the Ventura-Los Angeles county line to San Pedro by the Los Angeles County Department of Beaches and Harbors (SMBRP, 1998). However, this alternative hypothesis appears to be unlikely because of the disparity in spatial distribution between natural and anthropogenic debris. If urban runoff was primarily responsible for the distribution of anthropogenic debris, its distribution would be more similar to that of terrestrial vegetation, which comes from a stormwater source.

The types of anthropogenic debris (glass bottles, cans, and plastic) found in areas near POTWs offer additional evidence that marine vessels are a primary source of offshore anthropogenic debris. Glass bottles and cans, which were prevalent near POTW outfalls, are too large to pass through the screens covering POTW outfall pipes and thus could not be discharged from this source. However, because these outfall pipes are essentially artificial reefs, they are popular fishing spots for recreational anglers. The disposal of trash (bottles and cans) and incidental items from fishing boats is the likely source of these types of anthropogenic debris in POTW outfall areas.

In contrast to anthropogenic debris, natural debris was most common in the northern region, on the middle and inner shelf zones, and on the middle shelf zone in non-POTW areas (Figs. 2 and 3). The more frequent occurrence in the northern (rural) region may be due to the increased availability of marine and terrestrial vegetation in this area. Although the primary reason for describing the occurrence of natural debris in this study was to provide a marker for nearshore sources (e.g., stormwater runoff and nearshore reefs), an additional purpose was served because natural debris (particularly of marine vegetation) is an important microhabitat for juvenile fishes on sediment bottoms (Allen and Franklin, 1988; Allen and Herbinson, 1991). This study is the first to estimate the potential spatial coverage (73%) of natural debris, and hence of this microhabitat, on the mainland shelf of southern California. Because no historical data are available from the mainland shelf of the SCB for assessing trends in anthropogenic or natural debris, this study provides baseline information for future comparisons.

This study was conducted as part of the Southern California Bight Pilot Project. The authors wish to thank workers at the following organizations for their assistance in field collection and data processing: City of Los Angeles, Department of Public Works, Bureau of Sanitation, Environmental Monitoring Division; County Sanitation Districts of Los Angeles County; County Sanitation Districts of Orange County; City of San Diego, Metropolitan Wastewater Department; Southern California Coastal Water Research Project; MEC Analytical Systems, Inc.; and MBC Applied Environmental Sciences.

Allen, L. G. & Franklin, M. P. (1988). Distribution and abundance of young-of-the-year white seabass, *Atractoscion nobilis*, in the vicinity of Alamitos Bay - Long Beach Harbor, California, 1983-1985. *Bull. Southern California Acad. of Sci.* 87, 19-30.

Allen, M. J. & Herbinson, K. T. (1991). Beam-trawl survey of bay and nearshore fishes of the soft-bottom habitat of southern California in 1989. *Calif. Cooper. Oceanic Fisheries Investigations Reports* 32, 112-137.

Allen, M. J., Moore, S. L., Schiff, K. C., Weisberg, S. B, Diener, D., Stull, J. K., Groce, A., Mubarak, J., Tang, C. L., & Gartman, R. (1998). Southern California Bight 1994 Pilot Project: V. Demersal fishes and megabenthic invertebrates. Southern California Coastal Water Research Project. Westminster, CA. 365 pp.

Baba, N., & Kiyota, M. (1994). Distribution and characteristics of marine debris in the North Pacific Ocean, 1989-1990. In Poster abstracts and manuscripts from the Third International Conference on Marine Debris, NOAA Technical Memorandum NMFS-AFSC 000, (J.C. Clary, ed.), pp. 1-7. U.S. Dept Commer., Nat. Oceanic Atmosp. Admin., Nat. Mar. Fish. Serv., Alaska Fish. Sci. Cen. Seattle, WA.

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

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. In Proceedings of the Second International Conference on Marine Debris, 2 - 7 April 1989, Honolulu Hawaii (R.S. Shomura and M.L. Godfrey, eds.), pp. 279-301. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154.

Matsumura, S., & Nasu, K. (1997). Distribution of floating debris in the North Pacific Ocean: Sighting surveys 1986-1991. In *Marine Debris: Sources, Impacts, and Solutions* (J.M. Coe and D.B. Rogers, eds.), pp. 15-24. Springer-Verlag. New York, NY.

MBC Applied Environmental Sciences. (1988). The state of Santa Monica Bay, Part one: Assessment of conditions and pollution impacts. Prepared for So. Calif. Assoc. Govts., Los Angeles, CA. Prepared by MBC Applied Environ. Sci., Costa Mesa, CA. 420 pp.

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

Santa Monica Bay Restoration Project. (1998). Taking the pulse of the Bay — State of the Bay 1998. Santa Monica Bay Restoration Project, Monterey Park, CA. 51 pp.

SCBPP. See Southern California Bight Pilot Project.

SMBRP. See Santa Monica Bay Restoration Project.

Southern California Bight Pilot Project. (1994). Southern California Bight Pilot Project field operations manual. So. Calif. Coastal Water Res. Proj., Westminster, CA.

Stevens, D. L., Jr. (1997). Variable density grid-based sampling designs for continuous spatial populations. *Environmetrics* 8:167-195.

Thompson, S. K. (1992). Sampling. J. Wiley and Sons, New York, NY.

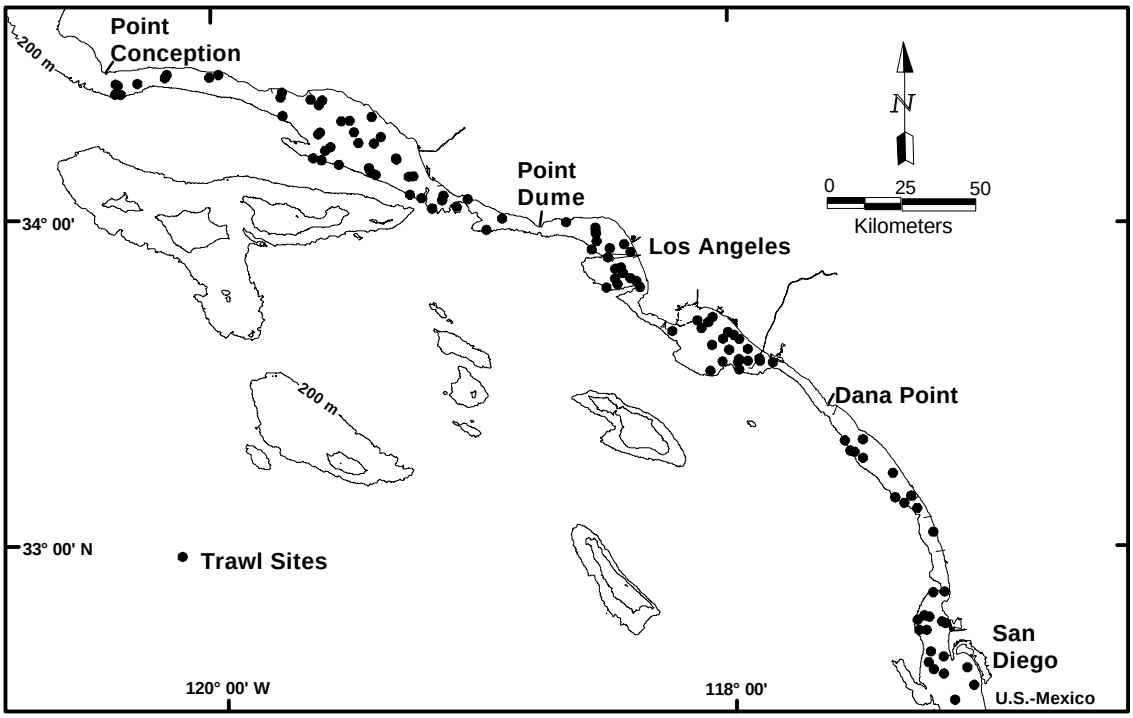

Fig. 1 Stations sampled by trawl in the regional survey of the mainland shelf of Southern California at depths of 10-200 m, July-August 1994.

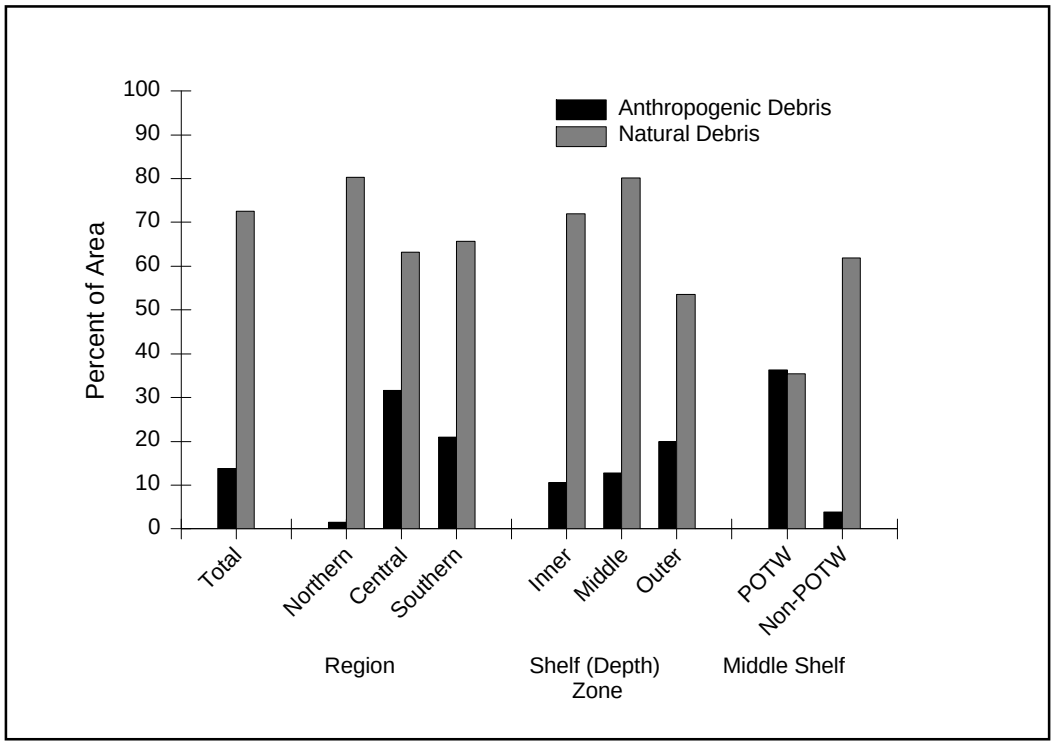

Fig. 2 Percent of area with natural and anthropogenic debris in the regional survey of the mainland shelf of southern California at depths of 10-200 m by subpopulation, July to August 1994.

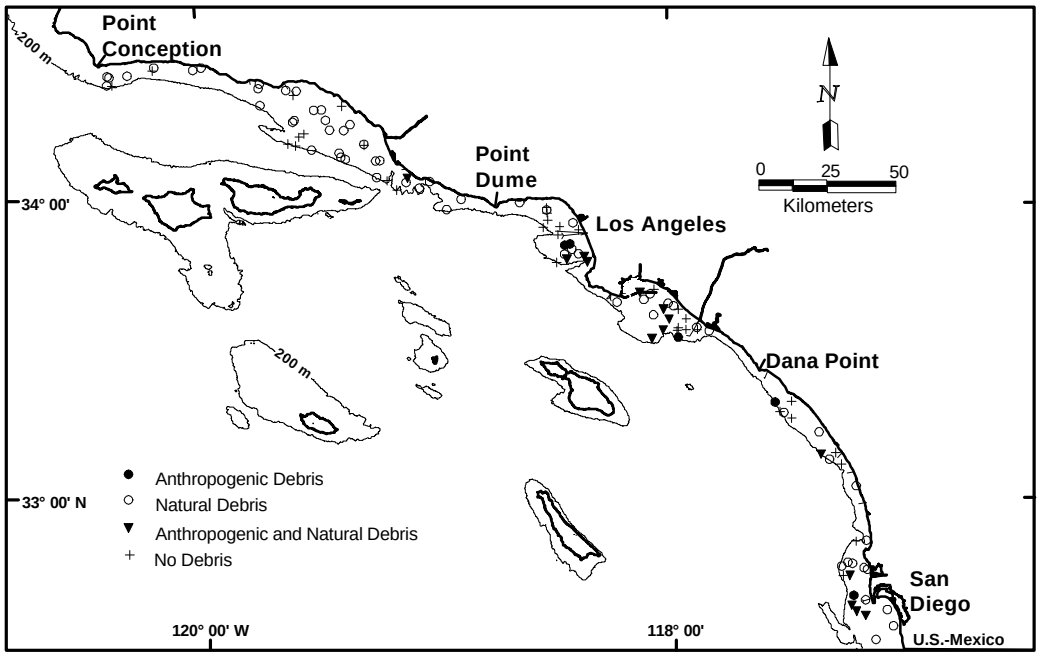

Fig. 3 Distribution of anthropogenic and natural debris in the regional survey of the mainland shelf of southern California at depths of 10-200 m, July to August 1994.

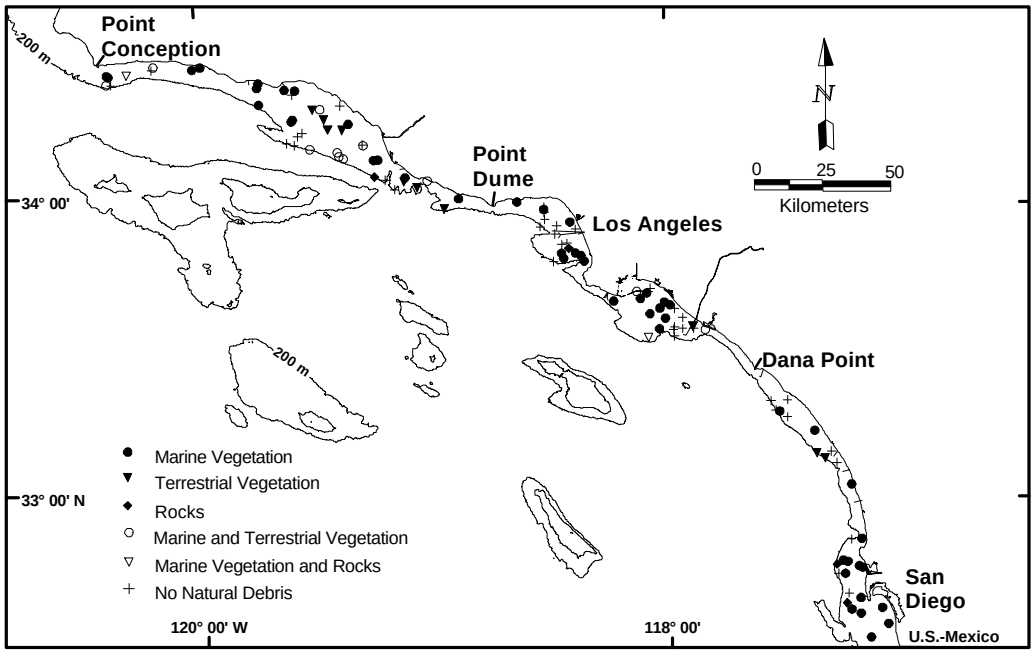

Fig. 4 Distribution of marine vegetation, terrestrial vegetation, and rocks in the regional survey of the mainland shelf of Southern California at depths of 10-200 m, July to August 1994.

TABLE 1

Spatial coverage by subpopulation of debris types collected in the regional trawl survey of the mainland shelf of southern California at depths of 10-200 m, July to August 1994.

Category	Percent of area						
	Region			Shelf depth zone			Entire
	N	C	S	IS	MS	OS	SCB
Anthropogenic debris	-						
Fishing gear	-	18	-	4	4	9	5
Plastic	-	8	5	-	2	9	3
Metal debris	-	3	9	4	4	-	3
Other	-	9	2	-	4	4	3
Glass bottles	-	5	4	-	2	4	2
Modified wood	2	2	3	4	-	6	2
Cans	-	2	5	-	2	4	2
Natural debris							
Marine vegetation	59	60	54	70	63	34	58
Terrestrial vegetation	38	8	7	16	25	25	23
Benthic debris	20	-	2	4	14	9	11
Rocks	5	5	5		4	13	5
Overall	80	68	71	72	82	59	75

[a]N = Northern; C = Central; S = Southern ;IS = Inner Shelf; MS = Middle shelf; OS = Outer shelf; SCB = Southern California Bight.

TABLE 2

Spatial coverage of abundance categories by debris types collected in the regional trawlsurvey of the mainland shelf of Southern California at depthsw of 10-200 m, July-August 1994.[a]

Category	No. of Stations	Percent of Area in SCB			
		T	L	M	H
Anthropogenic debris					
Fishing gear	6	4	1	-	-
Plastic	5	2	1	-	-
Other	3	-	3	-	-
Metal debris	4	3	-	-	-
Glass bottles	4	2	0	-	-
Modified wood	3	1	1	-	-
Cans	3	2	-	-	-
Natural debris					
Marine vegetation	61	18	34	5	1
Terrestrial vegetation	21	6	12	5	-
Benthic debris	9	2	5	2	1
Rocks	8	1	3	0	-
Overall	80	40	60	13	2

T = Trace (1 item); L = Low (2-10 items); M = Moderate (11-100 items); H = High (>100 items); SCB = Southern California Bight.

TABLE 3

Spatial coverage of weight categories by debris types collected in the regional trawl survey of the mainland shelf of southern California at depths of 10-200 m, July to August 1994.[a]

Category	No. of Stations	Percent of Area in SCB			
		T	L	M	H
Anthropogenic debris					
Fishing gear	6	3	2	-	-
Plastic	5	2	1	-	-
Other	3	2	0	-	-
Metal debris	4	1	2	-	-
Glass bottles	4	0	2	-	-
Modified wood	3	1	1	-	-
Cans	3	2	-	-	-
Natural debris					
Marine vegetation	61	30	19	7	2
Terrestrial vegetation	21	16	5	3	-
Benthic debris	9	5	5	1	-
Rocks	8	0	2	1	2
Overall	80	61	37	13	4

[a]T = Trace (0.0-0.1 kg); L = Low (0.2-1.0 kg); M = Moderate (1.1-10 kg); H = High (>10 kg); SCB = Southern California Bight.

TABLE 4

Spatial coverage by publicly owned treatment work (POTW) sub-population of debris types collected in the regional trawl survey of the mainland shelf of southern California at depths of 10-200 m, July to August 1994.

Category	Percent of Area on Middle Shelf	
	P	NP
Anthropogenic debris		
Fishing gear	3	2
Plastic	10	
Metal debris	3	2
Other	3	2
Glass bottles	10	
Modified wood		
Cans	7	
Natural debris		
Marine vegetation	32	48
Terrestrial vegetation		21
Benthic debris		12
Rocks	3	2
Overall	45	62

[a]P = POTW monitoring area; NP = Non-POTW monitoring area.