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MAN - MADE MARINE DEBRIS AND SEA TURTLE STRANDINGS ON BEACHES OF THE UPPER TEXAS AND SOUTHWESTERN LOUISIANA COASTS, JUNE 1987 THROUGH SEPTEMBER 1989

BY

Marcel J. Duronslet, Dickie B. Revera and Kerry M. Stanley

U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
John A. Knauss, Administrator

NATIONAL MARINE FISHERIES SERVICE
William W. Fox, Jr., Assistant Administrator for Fisheries

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I N T R O D U C T I O N

Documentation of strandings of sea turtles on beaches in the southeastern United States provides an important index of the numbers of sea turtles that become ill, injured, stressed or killed by man's activities or natural causes at sea. There are numerous documented causes of sea turtle injury or mortality at sea (Coston-Clements and Hoss, 1983; Conner, 1987; Henwood and Stuntz, 1987; Heinly et al., 1988; Manzella, Caillouet and Fontaine, 1988; Thompson, 1988; Murphy and Hopkins-Murphy, 1989; Ross et al., 1989) including ingestion of or entanglement in man-made marine debris (Balazs, 1985; Carr, 1986a, 1986b, 1987; Plotkin and Amos, 1988; Ruckdeschel and Shoop, 1988; Stanley, Stabenau and Landry, 1988).

In Autumn 1985, unprecedented strandings of sea turtles occurred on the upper Texas coast (Schroeder, 1987). This upsurge in strandings was attributed to use of explosives in salvaging petroleum platforms from waters of the northwestern Gulf of Mexico (Klima, Gitschlag and Renaud, 1988), and it emphasized the need for an intensified, systematic, beach sampling survey with the objectives of building a multi-year data base to document year-round, temporal-spatial distribution of sea turtle strandings as well as their possible causes. Such a multi-year data base on strandings, entanglement and ingestion of marine debris could contribute significantly to assessments of impacts of federal regulations aimed at reducing at-sea mortality in sea turtles.

The sea turtle carcasses themselves represent a kind of "marine debris" along with carcasses of fishes, jelly fishes, birds and other animals commonly found on beaches. Large numbers of sick, injured or dead animals on beaches are symptomatic of the frequent hazards, both natural and anthropogenic, that these animals are encountering.

This project represents one means of testing the working null hypothesis that sea turtle strandings are not related to man's activities at sea. There are a number of assumptions underlying the testing of this hypothesis, including but not limited to the following: (1) that those who take sea turtles incidentally (e.g., in commercial or recreational fishing ventures or when using explosives for petroleum platform removal, would not mutilate the carcasses in a manner that would prevent them from floating onto a beach, (2) that stranded sea turtles would exhibit evidence of natural or man-caused trauma, (e.g. shark attacks) ingestion of or entanglement in marine debris etc.), (3) that strandings and marine debris on a given beach reflect impacts within the adjacent coastal waters, and (4) that at-sea strandings represent a significant portion of total sea turtle mortalities.

The purposes of this study were (1) To document strandings of sea turtles, (2) to document types and amounts of man-made marine debris, and (3) to examine the relationship between strandings and man-made marine debris along the coastlines of Texas and southwestern Louisiana.

MATERIALS AND METHODS

Monthly documentation of marine debris and entanglement of sea turtles on beaches of the upper Texas and southwestern Louisiana coasts was coupled with semi-monthly surveys of sea turtle strandings from June 1987 through September 1989. This coupling offered one of the simplest and most cost-effective ways of determining temporal-spatial distribution and year to year trends in amounts of marine debris, sea turtle strandings and sea turtle entanglement and debris ingestion.

The NMFS Sea Turtle Stranding and Salvage Network (STSSN) has had a voluntary reporting system in place since 1980, to document temporal-spatial distribution and trends in strandings (Schroeder, 1989; Teas and Martinez, 1989). Systematic monthly coverage of sea turtle strandings by the NMFS Galveston Laboratory was started in March 1986. This increased the chances that stranded turtles were found before they were redistributed by tides or destroyed by decomposition and carrion feeders. More frequent sampling would have been desirable, but monthly surveys of strandings and marine debris and entanglement were considered adequate when conducted in a consistent year-round manner.

Marine Debris Surveys

Beaches on the upper Texas and southwestern Louisiana coasts were divided into six sampling zones or strata (Figure 1), each of which was usually surveyed once per month year-round for man-made marine debris and sea turtle entanglements. Portions of zones 4 and 5 were routinely cleaned by state or local government authorities, whereas zones 1-3 and 6 were not cleaned. Sampling both zone types provided an opportunity to compare cleaned and uncleaned zones with regard to amounts and rates of accumulation of marine debris. Cleaned zones would be expected to provide a measure of short term accumulation of debris, whereas sampling in uncleaned zones would measure longer term accumulation.

Sampling protocol within all six zones was based on that suggested by the American Littoral Society (unpublished and distributed by American Littoral Society, Sandy Hook, NJ). In cleaned zones 4 and 5, locations of three foreshore plots were chosen each month using a random numbers table to determine each plot's location at a randomly chosen distance from a zone boundary. New locations of these plots were randomly chosen each month. Locations of two foreshore plots in each uncleaned zone (1-3 and 6), were randomly chosen each month by the same procedure. In addition, one fixed foreshore plot and one abutting fixed backshore plot (Figure 1) were established in each uncleaned zone to assess debris accumulation between sampling intervals. The locations of fixed plots were randomly selected at the beginning of the study.

Each foreshore plot was 3.3 m wide and extended from the waterline to the first storm line or, if no storm line was present, 8.1 m landward of the high tide line (Figures 2 and 3). While the width of the plots was constant, the lengths varied from 2.7 to 69.2 m depending on the position of the first storm line and tide stage. The total area per plot therefore was different for each sample. In uncleaned zones 1-3 and 6, the additional backshore plot associated with each fixed foreshore plot was also 3.3 m wide and extended landward from the first storm line to the base of the foredune. Backshore plots were of variable lengths also (2.4 to 53.8 m) depending on positions of the first storm line and foredune. The boundaries of each plot were marked with stakes and connecting lines.

Marine debris sampling included measuring and photographing each plot followed by collection of all man-made items within the plot boundaries. Debris items were stored in labeled plastic bags and taken to the laboratory where they were categorized, enumerated and weighed. Nine major categories of marine debris were recognized: plastic, polystyrene foam (Styrofoam™), tar balls, glass, metal, rubber, paper, wood and miscellaneous. Weights recorded for most debris items were slightly biased upwards because of adhering sand particles. Every attempt was made to remove excess sand particles before weights were taken. Weights of wooden items also were biased upwards because of high moisture content. In some cases, wooden items too large to weigh (e.g., parts of boats, pallets, large planks, etc.) were measured and described and dimensions and descriptions recorded, so these could later be converted to weight estimated roughly by weight:volume ratio. Natural debris items (tree trunks, detached grasses and animal carcasses, except for sea turtles) were not included in the samples.

To accommodate differences in plot size due to variations in characteristics of the beach profile and variations in tide stage at the time and place of sampling, the area of each plot was calculated, and the counts and weights of debris items were expressed in numbers or kilograms per 100 m^2, respectively. When a debris category was not represented in the sample from a given plot in a given month zeros were included in the monthly average density for that category.

From June 1987 through September 1989, marine debris was collected from a total of 473 plots (Table 1). This included 181 randomly located foreshore plots, 85 fixed foreshore plots and 87 fixed backshore plots from uncleaned zones 1-3 and 6, and 120 randomly located foreshore plots from cleaned zones 4 and 5. Occasionally, some plots could not be sampled as planned (e.g., high tides, large quantities of sargassum weed on the beaches (May, June and July, 1989), mechanical problems with 4 wheel-drive vehicles and insufficient personnel resources from time to time). This produced considerable imbalance in the data set (Table 1).

Statistical analyses were performed with SAS™ for personal computers (SAS Institute, Inc., Cary, NC). Descriptive statistics

(mean, X, and variance, s^2) were calculated for three variables derived from the marine debris data: (1) area of the sampling plot (in 100 m^2 units), (2) number of debris items (all types combined) per 100 m^2 and

(3) weight of debris items (all types combined) per 100 m^2, by year, month and zone. Only the randomly located foreshore plots were included in these analyses.

To determine whether the number per 100 m^2 and weight per 100 m^2 needed transformation prior to parametric analysis, we deleted all cases in which the number of randomly located foreshore plots was less than two (in a given year-month-location combination) and regressed $\ln(s^2)$ on $\ln(X)$, (Figures 4 and 5). Slopes of these lines were close to 2 so a logarithmic transformation was necessary to normalize the number and weight of debris items per 100 m^2 (Taylor, 1961). Similar transformations were applied to debris counts and weights for backshore and fixed foreshore plots.

Because of the imbalance in the data set (Tables 1 and 2), we conducted general linear model analyses of the transformed number per 100 m^2 and transformed weight per 100 m^2, instead of analyses of variance.

Stranding, Entanglement And Ingestion Surveys

The NMFS Galveston Laboratory participated in STSSN surveys of the entire Texas and southwestern Louisiana coasts, from the Rio Grande River, Texas to the Mermentau River, Louisiana during the study. This report includes only strandings from those portions of the Texas and Louisiana coasts covered by our debris survey. Beaches were traversed at least once each month using 4-wheel-drive vehicles, 4-wheel all-terrain-vehicles, or dirt bikes, depending upon remoteness and accessibility. Surveyed beaches were accessible barrier beaches bordering the Gulf of Mexico from Pass Cavallo, Texas to Calcasieu Pass, Louisiana (Figure 1; Table 2). Overwater transportation was required to gain access to some barrier beaches (e.g., west Matagorda Peninsula and Matagorda Island).

The NMFS beach surveyors also responded to reports of strandings from other agencies and from the general public. These carcasses were treated in the same manner as those found on routine surveys.

When a stranded sea turtle was found, species, size, sex, location, condition, external injuries, mutilations, fouling (including entanglement) and abnormalities were recorded on standardized STSSN stranding reports (field data forms; Schroeder, 1989). If a stranding involved entanglement, the type and possible source of entangling material was identified. Amount and size, diameter or length of the entangling material were recorded and photographs taken.

Carcasses were collected and transferred to Texas A&M University for necropsy and gastrointestinal content analysis to provide additional information on incidence of injuries, mutilations, propeller wounds, entanglement in discarded fishing gear or debris, diseases, fouling by oil or barnacles, ingestion of tar or debris, and papillomas or other abnormalities (Heinly et al.,1988; Plotkin and Amos, 1988; Schroeder, 1988; Stanley, Stabenau and Landry, 1988). Necropsies were performed according to Wolke and George (1981).

RESULTS

Marine Debris

Mean areas of randomly located foreshore plots by year month and location are given in Table 3. A GLM analysis of these areas is presented in Table 4. Plot mean areas were lowest (44.4 m^2) in April and were significantly higher (90.0 m^2) in October. Plot sizes were significantly different by zones also, and varied from a mean of 56.6 m^2 in zone 5 to 77.0 m^2 in zone 1.

Arithmetic mean number of debris items per 100 m^2 is presented by zone, year and month in Table 5. Zone, year and month had significant effects on number of debris items per 100 m^2 (Table 6). The year (1987) with the fewest number (78) of random plots sampled had the highest mean number of items per 100 m^2 (72.7). The lowest mean number of items per 100 m^2 (32.0) occurred in 1989. With respect to sampling zone, uncleaned zone 3 had the highest number of items per 100 m^2 (104.6) and uncleaned zone 6 the fewest (33.1). The average number of debris items per 100 m^2 was lowest in the winter months, November through February (16.2 - 34.2), rose in April and May and peaked in August (155.6).

Mean weight of debris items collected per 100 m^2 is presented by year, month and zone in Table 7. A GLM analysis of debris weights (Table 8) indicated a significant difference in average kilograms per 100 m^2 for month and sample zones. Weights were lowest in winter months November, December, January and February (0.143 - 0.246) and peaked in May (1.121 kgs per 100 m^2). Uncleaned zone 3 had the highest average weights per 100 m^2 (1.461) while cleaned zone 4 had the lowest (0.158).

When numbers and weights of debris items from uncleaned zones were compared to those from cleaned zones, the mean number of debris items per 100 m^2 was reduced (64.6 to 49.2) but the difference was not significant. There was, however, a significant reduction in mean weight per 100 m^2 (0.514 kgs from uncleaned zones to 0.243 kgs from cleaned zones).

Areas of fixed foreshore and backshore plots are presented in tables 9 and 10 respectively. Results of a GLM analysis of plot area for fixed foreshore and fixed backshore plots are presented in tables 11 and 12. There was no difference in foreshore plot sizes by year, zone or plots within zones. There was a difference based on month of the year where plot areas varied from a low 50.9 m^2 in April to a high of 99.5 m^2 in November (Table 11).

The areas of fixed backshore plots varied significantly only by sampling zone. Plot area was lowest (41.4 m^2) in zone 3 and highest (119.4 m^2) in zone 1.

When examined by year or location, no differences were detected in rate (number or weight) of debris accumulation in fixed foreshore or backshore plots. When examined by month of the year (Table 13) there was no difference in the number of items that accumulated per day, in foreshore or backshore plots. In May, June and July, however, foreshore plots accumulated significantly higher weights (0.094 - 0.305 kg/100 m^2/day) of marine debris. The rate of debris accumulation by weight in these plots was lowest in November (0.003 kg/100 m^2/day). There was no difference in mean weight accumulation by month in backshore plots (Table 13).

Tarballs had the highest percentages by number per 100 m^2 among the nine major debris categories (Figure 6) in cleaned (47.9%) and uncleaned (73.9%) zones, followed by plastic (25.2% and 14.4%, respectively).

Dominant debris types, in percentages by weight per 100 m^2, varied between cleaned and uncleaned zones (Figure 6). In the cleaned zones miscellaneous items (70.7%) dominated, followed by plastic (9.4%). In uncleaned zones wooden items (69.8%) replaced miscellaneous items as the dominant debris type, but were followed by plastic (15.3%).

When examined by sampling zone (Table 14), tar balls and plastic items ranked first and second respectively in number of items collected in every zone except zone 6. In this zone the two categories ranked second and first respectively. Styrofoam™ and glass items alternated among zones for the third and fourth most frequently collected item.

Despite the fact that tar balls were the most frequently collected debris item, their average weight (1.7 g per item) was next to the lowest average weight (Table 15). Styrofoam™ had the lowest average weights (1.6 g per item) of all debris categories. The heaviest items were wood (919.8 g per item) followed by miscellaneous (241.3 g per item) and rubber (143.3 g per item). The high average weights for miscellaneous items were attributed to asphalt, tile, concrete and brick collected primarily from cleaned zones 4 and 5.

Strandings

During STSSN surveys conducted from June 1987 through September 1989 in marine debris survey zones 1-6, 171 stranded sea turtles were found (Table 16). Most of the strandings occurred in study zones 4 and 5 (49 and 57 respectively). The smallest number of strandings was recorded in zone 3 (12).

Nine of the 171 strandings were live strandings (Table 17). Of the 162 carcasses that remained 32 have been analyzed for gastrointestinal tract contents. Seventy three were too decomposed for gut content analysis and 57 are awaiting examination. Nineteen of the 32 thus far examined contained ingested marine debris (Table 18). Ingested materials were of many types but plastics were dominant. None of the ingested materials were judged to have caused the sea turtle's demise.

Six of the 171 stranded sea turtles were entangled in man-made materials (Table 19). No entangling events were recorded in study zones 2 or 6. One each was recorded in zones 1 and 3 while zones 4 and 5 each had 2 entanglements. Two of the 6 entanglements (1 in zone 4, 1 in zone 5) involved discarded ropes. Both of these turtles were dead when found. It was not possible to attribute either death to entanglement. The remaining 4 entanglements involved live animals, entangled one each in a shredded plastic bag, monofilament fishing line, a fish hook and the intake screen of an electrical power plant.

Tables 20 and 21 summarize strandings along surveyed beaches in zones 1-6 from June 1987-September 1989, by year and month. Stranding levels remained relatively stable from year to year (Table 20). May was the peak month for strandings, but a minor secondary peak occurred in August (Table 21). By species, loggerheads (Caretta caretta) and kemp's ridleys (Lepidochelys kempi) dominated the strandings (Table 20). Other stranded turtles included leatherbacks (Dermochelys coriacea) greens (Chelonia mydas) and hawksbills (Eretomochelys imbricata).

Nine of the total strandings documented in the study were live-strandings (Table 22). One animal was released immediately. A second turtle required flipper amputation and can never exist in the wild. Two died in captivity after attempts at rehabilitation failed. The five remaining live stranded animals were all released back into the wild after 0.5 to 10 months of rehabilitation.

SUMMARY AND DISCUSSION

Strandings of hundreds of sea turtles on beaches bordering the northwestern Gulf of Mexico each year are symptomatic of something radically wrong in the coastal ecosystem of which sea turtles are a part. Either man's at-sea activities or major changes in the biotic and abiotic conditions within the sea turtles's natural environment or both are stressing sea turtles and causing their mortalities.

Several causes for these mortalities have been identified including shrimping activity, offshore petroleum operations, natural causes and ingestion of or entanglement in man-made marine debris. By-catch in shrimp trawls has been reported to be the major cause of sea turtle mortalities (Liner, 1954; Cox and Mauermann, 1976; Magnuson et al., 1990). The extent of involvement of the remaining causes has not been well defined. This study was undertaken to quantify the number of sea turtle deaths caused by man-made marine debris and describe the amount, type and variability of this debris in a specific locale.

Width of individual marine debris sample plots were constant but lengths, hence areas sampled, varied because of differences in tide stage at the time of sampling. Mean areas sampled were significantly higher in the winter months (Table 4). This was expected as lower tides are more frequent in wintertime, caused by an increase in the number and strength of northerly winds. There was no significant difference in mean area of sample plots between years. Because sample area was not constant debris items were examined in terms of number and weight per 100 m^2 sampled.

Samples of marine debris and all dead or live stranded sea turtles were collected over a 28 month period from 6 designated beaches. Debris was categorized by type and amount present and sea turtles were examined for any involvement with marine debris. Sea turtle carcasses reported by the general public were also examined by investigators and analyzed in conjunction with those found on routine surveys. It was felt that the combination would more accurately represent total mortalities and increase the chances of identifying marine debris related deaths.

The significant difference detected in mean number of debris items between years cannot be explained by this data. The difference may be real or an artifact from sampling one entire year and only parts of two others. This would have to be resolved by an extended sampling period covering several years. The warmer summer months were also significantly higher in mean number of debris items. This can be accounted for if one assumes a higher degree of outdoor, marine related activity by the general public in the warmer months of the year. This higher activity level would generate increased levels of waste and result in more debris on the beaches.

The mean number of debris items between zones ranged from 33 to 104 per 100 m^2, with two uncleaned zones, 3 and 6, accounting for both the highest and the lowest mean numbers (Table 6). Surprisingly, when cleaned and uncleaned zones were grouped and compared to each other there was a reduction, from uncleaned to cleaned, in mean number of debris items but not a significant reduction. Mean weights, however, were significantly reduced (Table 8). These findings could be the result of two factors. First of all, debris surveyors collected, counted and weighed all debris found which often resulted in large numbers of very small and lightweight items (Tables 14-15). Secondly it is entirely possible that cleaning crews, who generally work from tractors, tend to remove only the unsightly, but larger and heavier items from the beach. These factors combined would tend to minimally affect a difference in numbers of items between the two zone types but could dramatically affect mean weights.

When comparing rates of accumulation of man-made marine debris, from fixed foreshore plots, (Table 13), rates were higher in the warmer months of the year, May through August. Significant increases were observed in weights of debris. This is in agreement with the concept of higher levels of outdoor human activity during this time of year. Rates of accumulation in fixed backshore plots were variable with no significant differences observed.

Marine debris and its detrimental effect on sea turtles can be divided into two categories, entanglement and ingestion. Only 6 (3.5%; Table 19) of all stranded animals documented in the study were entangled or externally associated with man-made materials. Even though the loss of one endangered or threatened animal is unacceptable, possibly affecting the species' ultimate survival, this percentage cannot be viewed as very high. On the other hand, 59.4% of all carcasses that could be examined (Table 18) had gastrointestinal contents that included some type of man-made marine debris. It could not be determined if the ingested materials caused the deaths or strandings. The amounts, types and possible effects of these ingested materials is the subject of another report in preparation.

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Table 1. Temporal-spatial sampling of marine debris from June 1987 through September 1989[a].

		Zones																						
		Uncleaned												Cleaned						Uncleaned				
		1				2				3				4			5			6				No. of plots sampled
Year	Month	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	1	2	3	1	2	3	4	
1987	Jun	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	22
	Jul	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	22
	Aug	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	22
	Sep	S	S	S	S	S	S	S	S	S	N	S	S	N	N	N	N	N	N	N	N	N	N	11
	Oct	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	N	N	N	S	19
	Nov	S	S	S	S	S	S	S	S	S	S	S	S	S	S*	S	S	S	S	S	S	N	N	20
	Dec	S	N	S	S	S	S	N	N	S	S	S	S	N	N	N	N	N	N	N	N	N	N	9
Subtotal of samples		7	6	7	7	7	7	6	6	7	6	7	7	5	5	5	5	5	5	4	4	3	4	125

Table 1. (continued)

		Zones																						
		Uncleaned												Cleaned						Uncleaned				
		1				2				3				4			5			6				No. of plots
Year	Month	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	1	2	3	1	2	3	4	sampled
1988	Jan	S*	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	N	N	N	19
	Feb	S	N	S	S	N	S	S	S	S	N	N	N	S	S	S	N	N	N	N	N	N	N	11
	Mar	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	N	N	N	N	18
	Apr	S	S	N	S	S	S	S	S	S	S	S	S	N	N	N	N	N	N	N	N	N	N	11
	May	S	S	S	S	S	N	S	S	S	S	S	S	S	S	S	N	N	N	N	N	N	N	14
	Jun	S	S	S	S	S	S	S	S	S	S	S	S	N	N	N	N	N	N	N	N	N	N	12
	Jul	S	S	S	S	S	S	S	S	S	S	S	S	N	N	N	N	N	N	N	N	N	N	12
	Aug	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	22
	Sep	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	22
	Oct	S	S	S	S	S	S	S	S	N	N	N	N	S	S	S	S	S	S	S	S	S	S	18
	Nov	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	22
	Dec	S	S	S	S	S	S	S	S	N	N	N	N	S	S	S	N	N	N	S	S	S	S	15
Subtotal of samples		12	11	11	12	12	11	12	12	10	9	9	9	9	9	9	6	6	6	6	5	5	5	196

Table 1. (continued)

		Zones																					
		Uncleaned												Cleaned						Uncleaned				
		1				2				3				4			5			6				No. of plots
Year	Month	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	1	2	3	1	2	3	4	sampled
1989	Jan	S	S	S	S	S	S	N	N	S	S	S	N	S	S	S	S	S	S	S	S*	S*	S	19
	Feb	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S*	S	S	S	S	S	S	22
	Mar	S	S	S	S	S	S	N	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	21
	Apr	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	22
	May	N	N	N	N	N	N	N	N	N	N	N	N	S	S	S	S	S	S	S	S	S	S	10
	Jun	N	N	N	N	N	N	N	N	N	N	N	N	S	S	S	N	N	N	S	S	N	N	5
	Jul	S	N	S	S	S	S	S	S	S	S	S	S	N	N	N	S	S	S	N	N	N	N	14
	Aug	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	N	N	20
	Sep	S	S	S	S	S	S	S	S	S	S	S	S	N	N	N	S	S	S	S	S	S	S	19
Subtotal of samples		7	6	7	7	7	7	5	6	7	7	7	6	7	7	7	8	8	8	8	8	6	6	152
Grand Total		26	24	25	26	26	25	23	24	24	22	23	22	21	21	21	19	19	19	18	17	14	15	473

[a] Plots 1 and 2 in Zones 1-6 were randomly located foreshore plots; plot 3 in Zones 4-5 was a randomly located foreshore plot; plot 3 in Zones 1-3 and 6 was a fixed foreshore plot; and plot 4 was a fixed backshore plot landward of plot 3 in Zones 1-3 and 6. S = sampled; N = not sampled; and * = no debris in sample.

Table 2. Lengths of zones[a] (or strata) surveyed for sea turtle strandings and entanglement on the upper Texas and southwestern Louisiana coasts from June 1987 through September 1989.

Zone[a]	Total length km	Length of surveyed beach km	Percent
1	38.34	38.34	100
2	41.20	38.14	92.6
3	20.00	19.15	95.8
4	68.51	66.67	97.3
5	99.83	75.8	75.9
6	49.44	43.13	87.2
Total	327.64	281.23	85.84

[a] These zones are the same as those in which debris sampling plots, both random and fixed, were established.

Table 3. Mean area (in 100 m^2 units) randomly located foreshore plots from June 1987 through September 1989.

		Zones					
		Uncleaned			Cleaned		Uncleaned
		1	2	3	4	5	6
Year	Month						
1987	Jun	1.07	0.76	0.53	0.46	0.43	0.57
	Jul	0.77	0.52	0.52	0.26	0.12	0.52
	Aug	0.83	0.76	0.66	0.64	0.18	0.49
	Sep	0.78	0.85	0.65*	N	N	N
	Oct	0.92	1.14	1.06	1.24	0.53	N
	Nov	1.15	0.87	1.50	0.50	0.92	0.46
	Dec	1.06*	0.83	0.81	N	N	N
1988	Jan	0.63	0.62	0.33	1.10	0.59	1.72*
	Feb	0.77*	0.64	0.29*	0.62	N	N
	Mar	0.52	0.50	0.37	0.53	0.61	N
	Apr	0.50	0.45	0.41	N	N	N
	May	0.59	0.39*	0.89	0.57	N	N
	Jun	0.48	0.39	0.63	N	N	N
	Jul	0.71	0.55	0.51	N	N	N
	Aug	0.33	0.66	0.68	0.50	0.34	0.86
	Sep	1.71	1.16	0.61	0.83	0.71	0.56

Table 3 (cont'd)

		Zones					
		Uncleaned			Cleaned		Uncleaned
		1	2	3	4	5	6
Year	Month						
1988	Oct	0.48	0.62	N	1.11	0.53	1.09
	Nov	0.57	0.57	0.91	0.82	0.50	0.68
	Dec	0.61	0.48	N	0.91	N	0.82
1989	Jan	0.96	0.74	0.86	0.87	0.66	0.48
	Feb	1.54	0.53	0.73	0.50	1.16	0.49
	Mar	0.76	0.42	0.39	0.57	0.84	0.73
	Apr	0.43	0.59	0.47	0.51	0.37	0.45
	May	N	N	N	0.41	0.38	0.78
	Jun	N	N	N	0.82	N	0.79
	Jul	0.64*	0.58	0.75	N	0.68	N
	Aug	0.28	0.77	0.71	0.49	0.70	0.81
	Sep	0.82	0.64	0.55	N	0.61	0.93

* Indicates only one sample plot represented; otherwise means for zones 1, 2, 3 and 6 are for two sample plots; and means for zones 4 and 5 are for three sample plots.
N Indicates no sample taken.

Table 4. Results of general linear models (GLM) analysis of mean area (in 100 m^2 units) for randomly located foreshore sample plots.

A Type IV GLM analysis[a]

Source of variation	Degrees of freedom	Mean square	F
Year	2	0.156	2.05
Month	11	0.453	5.94*
Zone	5	0.226	2.96*
Plots within zones	8	0.066	0.86
Residual	274	0.076	
Total	300		

B Least-Squares Means

Month	Number of plots	Debris Items, No/100 m^2	Zone	Number of plots	Area in 100 m^2 units
Jan	27	0.775	1	49	0.770
Feb	21	0.745	2	51	0.666
Mar	26	0.588	3	46	0.694
Apr	20	0.444	4	63	0.681
May	16	0.571	5	57	0.566
Jun	25	0.619	6	35	0.697
Jul	28	0.525			
Aug	42	0.583			
Sep	30	0.820			
Oct	24	0.900			
Nov	28	0.798			
Dec	14	0.781			

[a] Milliken and Johnson (1984).
* Indicates significant difference from zero at $P < 0.05$.

Table 5. Mean number of debris items per 100 m^2 in randomly located foreshore plots.

		Zones					
		Uncleaned			Cleaned		Uncleaned
		1	2	3	4	5	6
Year	Month						
1987	Jun	29	450	651	289	84	60
	Jul	79	153	25	540	42	212
	Aug	182	352	258	132	246	28
	Sep	59	185	91*	N	N	N
	Oct	18	98	287	82	43	N
	Nov	30	42	37	7	14	93
	Dec	2*	35	56	N	N	N
1988	Jan	13	69	79	86	41	20*
	Feb	19*	42	59*	15	N	N
	Mar	245	30	48	45	70	N
	Apr	62	37	125	N	N	N
	May	69	109*	512	131	N	N
	Jun	73	71	73	N	N	N
	Jul	236	298	503	N	N	N
	Aug	985	1086	1821	459	119	85
	Sep	128	49	21	47	104	16

Table 5. (cont'd).

		Zones					
		Uncleaned			Cleaned		Uncleaned
		1	2	3	4	5	6
Year	Month						
1988	Oct	148	44	N	74	57	15
	Nov	8	19	72	4	102	6
	Dec	23	9	N	15	N	97
1989	Jan	10	4	250	13	48	1
	Feb	37	44	57	53	5	21
	Mar	73	15	79	44	20	15
	Apr	379	154	225	29	52	43
	May	N	N	N	55	40	96
	Jun	N	N	N	24	N	33
	Jul	47*	43	74	N	27	N
	Aug	152	57	49	31	38	64
	Sep	13	34	108	N	95	15

* Indicates only one sample represented; otherwise means for zones 1, 2, 3 and 6 are means of two samples; zones 4 and 5 are means of three samples.
N Indicates no sample taken.

Table 6. Results of general linear models (GLM) analysis of transformed number of marine debris items per 100 m^2, for randomly located foreshore sample plots.

A Type IV GLM analysis[a]

Source of variation	Degrees of freedom	Mean square	F
Year	2	15.005	10.73*
Month	11	12.455	8.91*
Zone	5	5.836	4.17*
Plots within zones	8	1.533	1.10
Residual	274	1.398	
Total	300		

B Detransformed Least-Squares Means[b]

Year	Number of plots	No. of Debris items per 100 m^2
1987	78	72.7
1988	121	69.5
1989	102	32.0

Zone	Number of plots	No. of debris items per 100 m^2
1	49	56.0
2	51	60.0
3	46	104.6
4	63	47.6
5	57	47.4
6	35	33.1

Month	Number of plots	No. of Debris items per 100 m^2
Jan	27	32.6
Feb	21	34.2
Mar	26	51.4
Apr	20	100.2
May	16	114.4
Jun	25	92.2
Jul	28	94.7
Aug	42	155.6
Sep	30	52.2
Oct	24	49.0
Nov	28	16.2
Dec	14	17.8

[a] Milliken and Johnson (1984).
[b] Antilog of (LSM-1).
* Indicates significant difference from zero at P <0.05.

Table 7. Mean weight (kg) of debris items per 100 m^2, in randomly located foreshore plots.

		Zones					
		Uncleaned			Cleaned		Uncleaned
		1	2	3	4	5	6
Year	Month						
1987	Jun	0.13	0.69	2.07	0.40	0.03	0.30
	Jul	0.06	0.37	0.10	1.56	0.53	1.36
	Aug	0.44	5.48	2.72	0.25	0.24	0.25
	Sep	0.03	1.85	3.14*	N	N	N
	Oct	0.13	5.85	5.61	0.43	0.68	N
	Nov	0.20	0.79	3.64	0.03	0.38	0.42
	Dec	0.00*	0.67	1.25	N	N	N
1988	Jan	0.03	3.22	1.99	0.91	0.88	0.21
	Feb	0.01*	2.80	9.77*	0.03	N	N
	Mar	1.75	7.87	0.54	0.27	2.13	N
	Apr	0.07	0.15	15.61	N	N	N
	May	1.11	9.34*	13.89	0.09	N	N
	Jun	0.53	0.58	0.71	N	N	N
	Jul	0.78	2.29	2.24	N	N	N
	Aug	2.60	2.31	12.33	0.80	0.60	0.40
	Sep	0.36	1.15	0.17	0.25	0.99	1.45

Table 7 (cont'd)

		Zones					
		Uncleaned			Cleaned		Uncleaned
		1	2	3	4	5	6
Year	Month						
1988	Oct	2.44	2.34	N	0.37	1.36	0.27
	Nov	0.04	0.16	0.36	0.36	3.32	0.12
	Dec	0.08	3.28	N	0.12	N	0.12
1989	Jan	0.23	0.31	1.05	0.05	1.21	0.07
	Feb	2.13	3.95	0.29	0.51	0.05	0.01
	Mar	1.32	3.58	0.99	1.95	0.68	0.81
	Apr	0.41	5.04	5.75	0.02	0.74	0.25
	May	N	N	N	2.17	0.30	2.59
	Jun	N	N	N	0.14	N	0.70
	Jul	0.30*	0.67	0.52	N	3.97	N
	Aug	0.35	1.04	2.54	1.27	1.03	0.77
	Sep	0.28	3.07	21.10	N	2.50	0.07

* Indicates only one sample represented; otherwise means for zones 1, 2, 3 and 6 are means of two samples; zones 4 and 5 are means of three samples.
N Indicates no sample taken.

Table 8. Results of general linear models (GLM) analysis of transformed kilograms of marine debris per 100 m^2, in randomly located foreshore sample plots.

A Type IV GLM analysis [a]

Source of variation	Degrees of freedom	Mean square	F
Year	2	2.674	0.72
Month	11	8.598	2.30*
Zone	5	43.329	11.61*
Plots within zones	8	6.633	1.78
Residual	274	3.733	
Total	300		

B Detransformed Least-Squares Means[b]

Month	Number of Plots	Weight (kg) of debris items per 100 m^2
Jan	27	0.246
Feb	21	0.194
Mar	26	0.724
Apr	20	0.278
May	16	1.121
Jun	25	0.320
Jul	28	0.404
Aug	42	0.551
Sep	30	0.390
Oct	24	0.876
Nov	28	0.190
Dec	14	0.143

Zone	Number of Plots	Weight (kg) of debris items per 100^2
1	49	0.184
2	51	1.016
3	46	1.461
4	63	0.158
5	57	0.307
6	35	0.200

[a] Milliken and Johnson (1984).
[b] Antilog of (LSM-1).
* Indicates significant difference from zero at $P < 0.05$

Table 9. Area in 100 m^2 units of fixed foreshore plots from June 1987 through September 1989. Each month and zone is represented by one sample plot.

		Uncleaned zones			
		1	2	3	6
Year	Month				
1987	Jun	1.04	0.58	0.72	0.93
	Jul	0.50	0.68	0.54	0.46
	Aug	0.46	0.75	0.74	0.73
	Sep	0.64	0.85	0.64	N
	Oct	1.03	1.14	1.09	N
	Nov	0.71	1.00	1.85	N
	Dec	0.84	N	0.96	N
1988	Jan	0.62	1.00	0.49	N
	Feb	0.97	0.63	N	N
	Mar	0.57	0.48	0.54	N
	Apr	N	0.38	0.42	N
	May	0.36	0.70	0.66	N
	Jun	0.35	0.40	0.58	N
	Jul	0.73	0.80	0.54	N
	Aug	0.34	0.64	0.51	0.82
	Sep	1.48	0.68	0.52	0.53
	Oct	0.85	0.71	N	0.92
	Nov	0.65	0.60	1.07	1.17
	Dec	0.56	0.57	N	1.10

Table 9 (cont'd).

Year	Month	Uncleaned zones 1	2	3	6
1989	Jan	0.69	N	0.91	0.35
	Feb	0.84	0.53	0.70	0.39
	Mar	0.67	N	0.51	0.79
	Apr	0.49	0.62	0.45	0.41
	May	N	N	N	0.77
	Jun	N	N	N	N
	Jul	0.42	0.54	0.74	N
	Aug	0.27	0.50	0.59	N
	Sep	0.89	0.59	0.56	0.85

N Indicates no sample taken.

Table 10. Area in 100 m^2 units of fixed backshore plots, from June 1987 through September 1989. Each month and zone is represented by one sample plot.

		Uncleaned zones			
		1	2	3	6
Year	Month				
1987	Jun	1.27	0.65	0.22	1.34
	Jul	1.43	0.81	0.73	1.01
	Aug	1.53	1.07	0.74	1.61
	Sep	1.60	0.63	0.63	N
	Oct	0.89	0.78	0.29	0.98
	Nov	1.24	0.96	0.44	N
	Dec	0.77	N	0.39	N
1988	Jan	1.27	0.48	0.55	N
	Feb	0.83	0.12	N	N
	Mar	1.04	0.43	0.51	N
	Apr	0.99	0.68	0.41	N
	May	1.50	0.60	0.43	N
	Jun	1.30	0.57	0.38	N
	Jul	1.33	0.25	0.26	N
	Aug	1.77	0.85	0.46	0.62
	Sep	1.19	1.28	1.26	0.59
	Oct	1.16	1.09	N	0.52
	Nov	1.13	1.11	0.32	0.67
	Dec	1.34	1.44	N	0.70

N Indicates no sample taken.

Table 10 (cont'd)

		Uncleaned zones			
		1	2	3	6
Year	Month				
1989	Jan	0.97	N	N	0.98
	Feb	0.82	0.90	0.21	1.78
	Mar	1.12	0.69	0.37	0.99
	Apr	0.43	0.31	0.13	0.83
	May	N	N	N	0.99
	Jun	N	N	N	N
	Jul	1.23	0.94	0.10	N
	Aug	1.77	0.69	0.64	N
	Sep	1.27	1.25	0.08	0.66

* Indicates no sample taken.

Table 11. Results of general linear models (GLM) analysis of area (in 100 m^2 units) for fixed foreshore sample plots.

A Type IV GLM analysis[a]

Source of variation	Degrees of freedom	Mean square	F
Year	2	0.120	2.32
Month	11	0.137	2.64*
Zone	3	0.024	0.46
Plots within zones	0		
Residual	68	0.052	
Total	84		

B Least-Squares Means

Month	Number of plots	Area in 100 m^2 units
Jan	6	0.722
Feb	6	0.734
Mar	6	0.642
Apr	6	0.509
May	4	0.669
Jun	7	0.629
Jul	10	0.593
Aug	11	0.576
Sep	11	0.760
Oct	6	0.942
Nov	7	0.995
Dec	5	0.804

[a] Milliken and Johnson (1984).
* Indicates significant difference from zero at $P < 0.05$.

Table 12. Results of general linear models (GLM) analysis of area (in 100 m^2 units) for fixed backshore sample plots.

A Type IV GLM analysis[a]

Source of variation	Degrees of freedom	Mean square	F
Year	2	0.047	0.49
Month	11	0.126	1.31
Zone	3	2.466	25.67*
Plots within zones	0		
Residual	70	.096	
Total	86		

B Least-Squares Means

Zone	Number of plots	Area in 100 m^2 units
1	26	1.194
2	24	0.769
3	22	0.414
6	15	0.940

[a] Milliken and Johnson (1984).
* Indicates significant difference from zero at $P < 0.05$.

Table 13. Least-squares means, accumulation rates of marine debris, in permanently located foreshore and backshore plots.

	Foreshore		Backshore	
Month	No. of debris items per $100m^2$ per day	Weight (kg) of debris items per $100m^2$ per day	No. of debris items per $100m^2$ per day	Weight (kg) of debris items per $100m^2$ per day
January	0.8	0.040	91.3	0.043
February	2.0	0.020	5.6	0.260
March	0.5	0.087	9.7	0.094
April	3.8	0.008	5.9	-0.061
May	9.3	0.276*	8.9	-0.134
June	9.6	0.305*	10.4	-0.220
July	23.7	0.094*	15.8	0.992
August	15.2	0.032	6.8	0.203
September	3.8	0.035	8.6	0.181
October	0.5	0.045	0.9	0.066
November	-1.7	0.003	2.1	0.272
December	-0.7	0.029	4.3	-0.030

* Indicates significant difference from zero at $P < 0.05$.

Table 14. Total number of marine debris items per 100 m^2 in randomly located foreshore plots, by zone and marine debris category, June 1987 through September 1989.

	Zones					
Debris Type	1	2	3	4	5	6
Tar Balls	7282	7036	8062	4410	1662	885
Plastic	1135	925	1711	1678	1520	909
Styrofoam	559	670	585	399	346	240
Glass	83	202	889	422	918	50
Wood	66	74	157	52	93	38
Paper	28	32	61	143	62	88
Rubber	26	43	50	38	87	17
Metal	25	52	175	93	126	32
Miscellaneous	10	22	190	65	563	54

Table 15. Average weight (g) per item of marine debris collected in randomly located foreshore plots, June 1987 through September 1989.

Debris Category	Weight (gm)per item
Wood	919.8
Miscellaneous	241.3
Rubber	143.3
Metal	42.6
Plastic	19.1
Glass	17.0
Paper	7.6
Tar balls	1.7
Styrofoam	1.6

Table 16. Total number of sea turtles stranded on the upper Texas and southwestern Louisiana coasts from June 1987 through september 1989, by species and zone. The number of carcasses found on routine surveys is enclosed in parentheses.

	Zones						
Species	1	2	3	4	5	6	**Total**
Kemp's ridley	6 (6)	5 (2)	5 (3)	13	24 (2)	12 (9)	65 (22)
Loggerheads	8 (8)	5 (5)	2 (1)	30 (4)	21 (4)	3 (3)	69 (25)
Green	1			4 (1)	1		6 (1)
Leatherback			3 (3)	2	6 (2)		11 (5)
Hawksbill	1 (1)		1				2 (1)
Unknown	3	8	1		5	1 (1)	18 (1)
Total	19 (15)	18 (7)	12 (7)	49 (5)	57 (8)	16 (13)	171 (55)

Table 17. Number of live stranded sea turtles that stranded on the upper Texas and southwestern Louisiana coasts from June 1987 through September 1989, by species and zone.

	Zones						
Species	1	2	3	4	5	6	Total
Kemp's ridley			1	2	1		4
Loggerheads				2			2
Hawksbill	1		1				2
Unknown					1		1
Total	1		2	4	2		9

Table 18. Number of gastrointestinal tracts that contained marine debris/ and number of tracts analyzed, from sea turtles that stranded on the upper Texas and southwestern Louisiana coasts from June, 1987 through September, 1989 by species and study zone. Parentheses indicate number of carcasses too decomposed for gastrointestinal tract analysis.

	Zones						
Species	1	2	3	4	5	6	**Total**
Kemp's ridley	0/1	1/1 (2)	0/1 (2)	1/3 (4)	3/5 (8)	(10)	5/11 (30)
Loggerheads	1/2 (2)	1/1 (1)	(1)	5/8 (7)	6/8 (6)	(3)	13/19 (22)
Green	(1)			1/1 (2)			1/1 (3)
Leatherback			(2)	(1)	(5)	(2)	
Hawksbill							(2)
Unknown	(3)	0/1 (7)	(1)		(4)	(1)	0/1 (17)
Total	1/3 (6)	2/3 (10)	0/1 (6)	7/12 (14)	9/13 (23)	(14)	19/32 (73)

Table 19. Numbers of sea turtles found entangled on beaches of the upper Texas and southwestern Louisiana coasts from June 1987 through September 1989, by entangling material and zone.

	Zones						
Entanglement	1	2	3	4	5	6	**Total**
Fish hook				1*			1
Monofilament			1*				1
Plastic bag	1*						1
Rope				1	1		2
Intake screen					1*		1
None	19	19	11	47	53	16	165
Total	20	19	12	49	55	16	171

* Indicates an entangled sea turtle that was alive when found.

Table 20. Sea turtle strandings on beaches of the upper Texas and southwestern Louisiana coasts from June 1987 through September 1989, by species and year.

Species	1987	1988	1989	Total
Loggerhead	22	22	25	69
Kemp's Ridley	21	25	19	65
Green	1		5	6
Leatherback	1	7	3	11
Hawksbill	1		1	2
Unknown	12	4	2	18
Total	58	58	55	171

Table 21. Sea turtle strandings on beaches of the upper Texas and southwestern Louisiana coasts from June 1987 through September 1989, by species and month.

	Species						
Month	Loggerhead	Kemp's Ridley	Green	Leatherback	Hawksbill	Unknown	Total
January	4					1	5
February	1		1				2
March	5	2	1				8
April	5	13		1		2	21
May	12	9	2	3		1	27
June	5	5		1	1		13
July	7	4	1		1	4	17
August	7	8	1	1		6	23
September	9	8				2	19
October	4	4		2		1	11
November	8	7		3			18
December	2	5					7
Total	69	65	6	11	2	18	171

Table 22. Disposition of sea turtles found live-stranded on beaches of the upper Texas and southwestern Louisiana coasts from June 1987 to September 1989.

Species	Released immediately	Released after rehab.	Permanent captive	Died in captivity	Total
Kemp's ridley		3		1	4
Hawksbill		1	1		2
Loggerhead		1		1	2
Unknown	1				1
Total	1	5	1	2	9

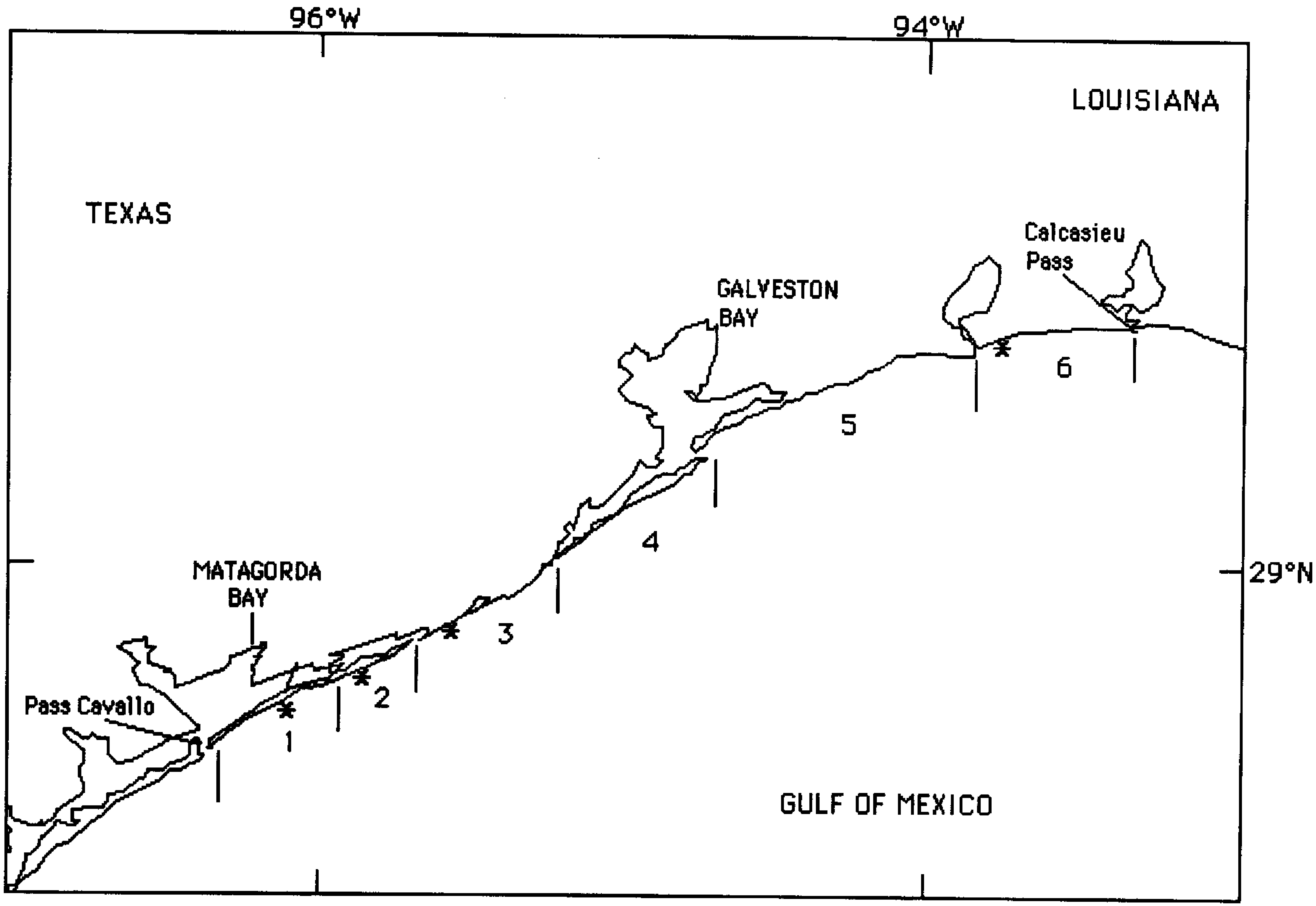

Figure 1. Geographic location of marine debris and sea turtle stranding and salvage sampling zones. Asterisks (*) mark the location of permanent debris sampling plots.

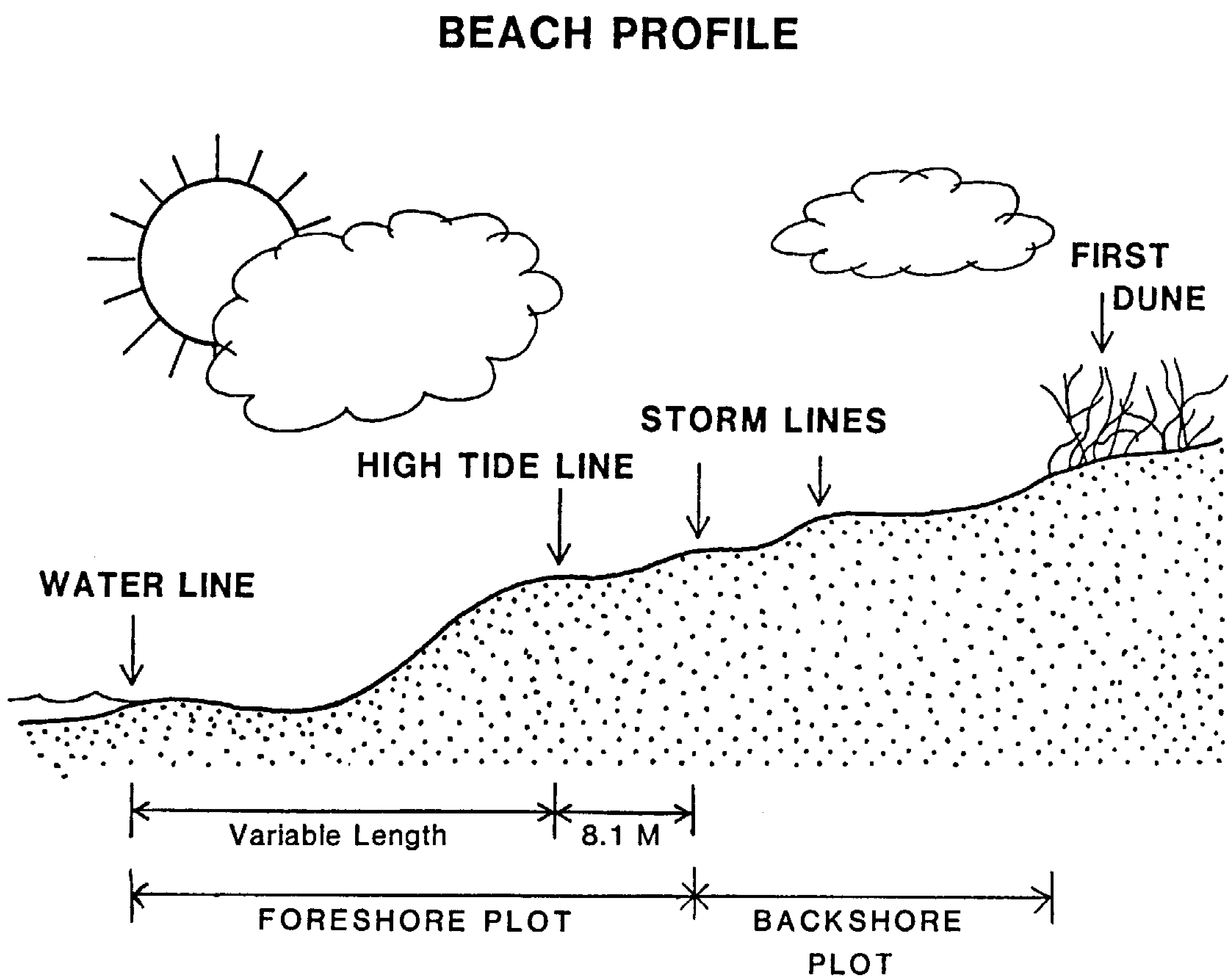

Figure 2. Diagrammatic profile (cross-section) of coastal beach (adapted from American Littoral Society, unpublished).

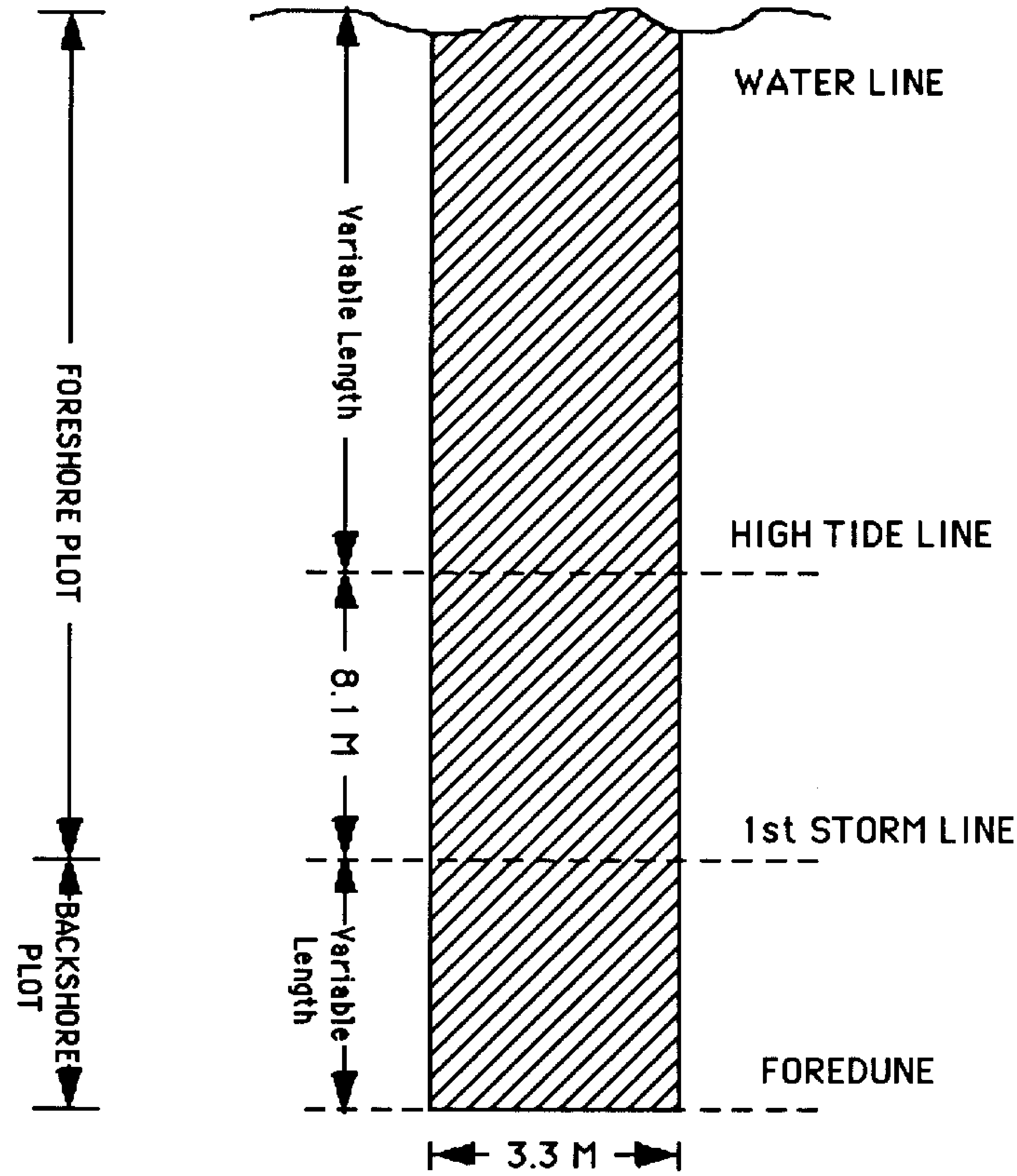

Figure 3. Diagram (plan view) of marine debris survey plot (adapted from American Littoral Society, unpublished).

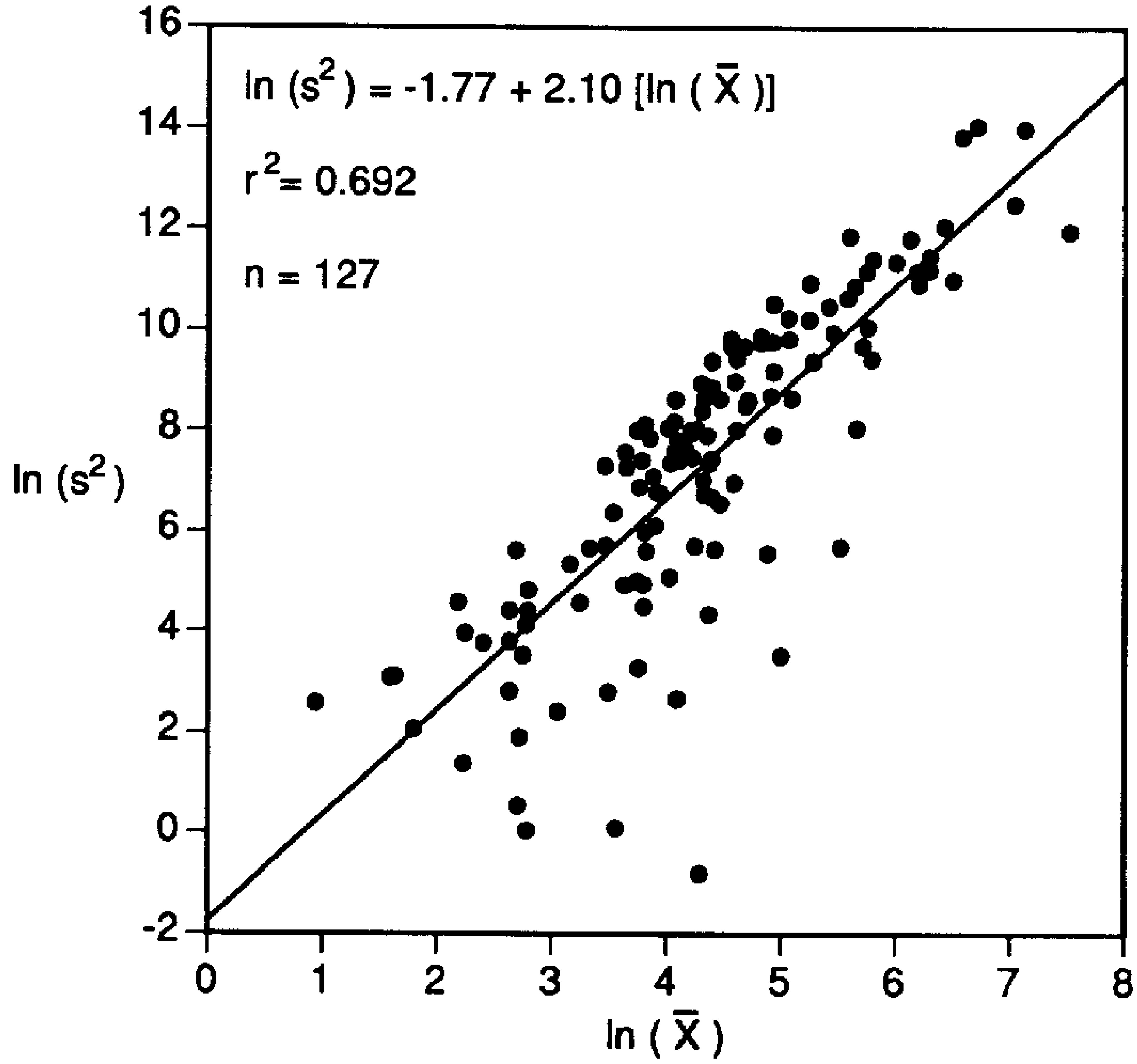

Figure 4. Plot of natural log variance vs. natural log mean for number of debris items per 100 square meters of beach sampled. Data are from randomly located foreshore plots only, sampled from June 1987 through September 1989.

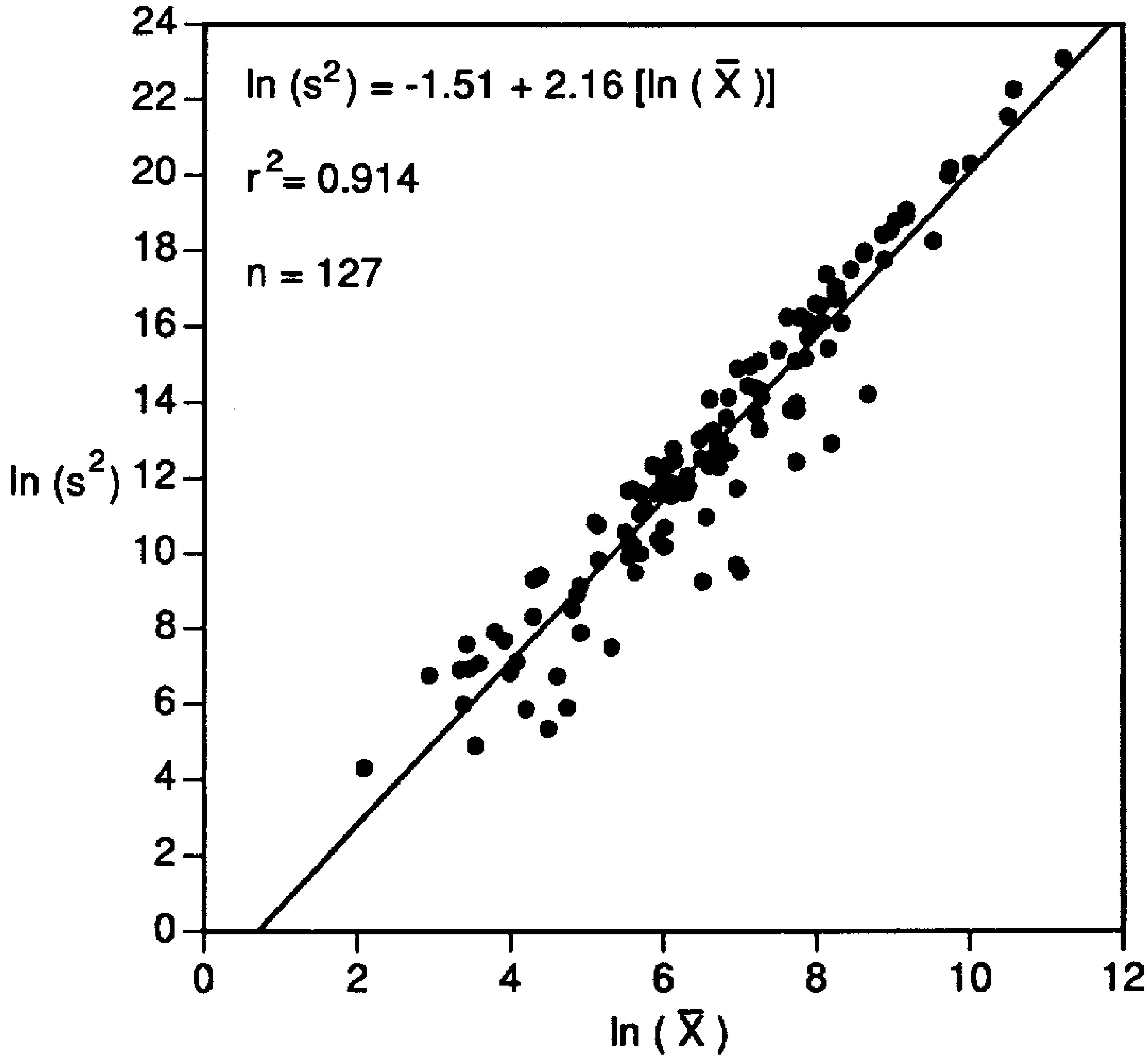

Figure 5. Plot of natural log variance vs. natural log mean for weight of debris items per 100 square meters of beach sampled. Data are from randomly located foreshore plots only, sampled from June 1987 through September 1989.

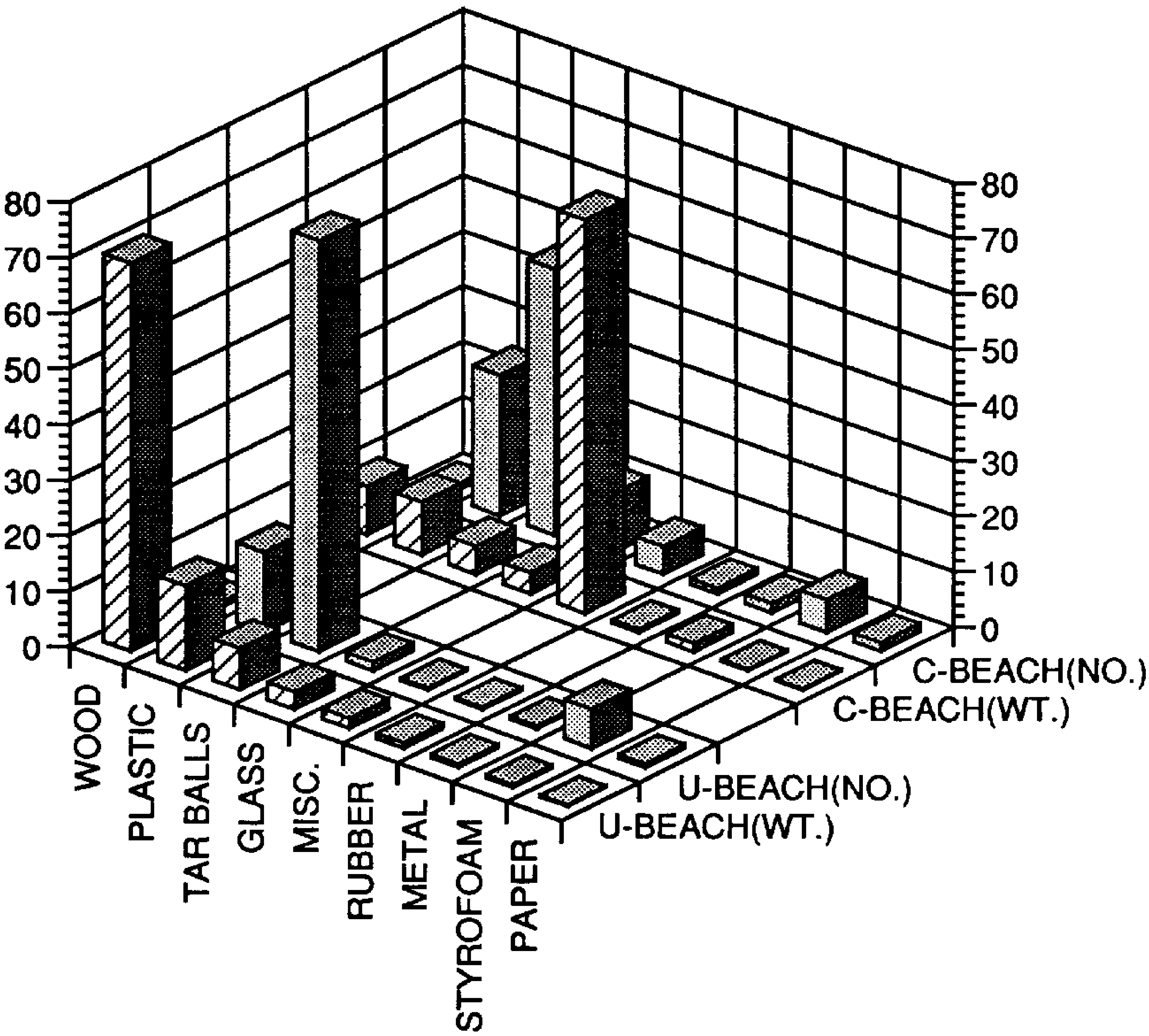

Figure 6. Percentages, by marine debris category, of number and weights of items per 100 square meters of beach sampled in cleaned (c-beach) and uncleaned (u-beach) sampling areas. Data are from randomly located foreshore plots only, sampled from June 1987 through September 1989.

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