Ecology of Southern California Island Sandy Beaches

Dale Straughan and Diane Hadley
Institute for Marine and Coastal Studies, University of Southern California, Los Angeles, California 90007

INTRODUCTION

In 1975 the Bureau of Land Management (BLM) initiated a series of marine studies in the southern California borderland (Straughan 1977b, 1978). These studies were to establish a baseline and to determine "areas of concern" prior to any expansion of the offshore petroleum industry. The baseline was to be one that accounted for natural variability in the region over a period of time so that it could be used to measure any impact of expansion of the petroleum industry. The "areas of concern" included those which have valuable marine resources and might therefore be excluded from larger areas that would be impacted by an increase in oil operations. The following data, concerning sandy beaches on some of the islands in the Southern California Bight, were collected as part of a program to achieve these goals.

The program was designed to establish the abiotic parameters and the distribution and abundance of the biota on the beaches. Surveys were conducted biannually and, at times, quarterly, in order to determine the variability in both abiotic and biotic components. The data were then analyzed to determine if there are correlations that would suggest possible cause-and-effect relationships.

The ultimate aim of the research is to define the physical habitat for each species. This would provide a certain degree of predictability of species distribution based on physical habitat data alone. The ultimate aim is to reach a point where distributional parameters can be extrapolated for nearly all beach areas. Interspecific and intraspecific variables operate within the framework. However, if a species cannot survive within the abiotic limitations in an area there can be no biotic interaction. In the relatively sparsely populated sandy beach habitat, we consider abiotic factors to be more important in limiting the distribution and abundance of species than biotic factors.

The BLM study also includes comparable surveys of mainland sandy beaches and sloughs. While these surveys are outside the scope of the present paper, reference will be made to these data for purposes of comparison.

Six sites were selected to account for many of the variables operating in the area (Table 1). The following factors were considered in selecting sites: (1) geographic variability; (2) the side of an island; (3) the presence of a mammal rookery; (4) exposure to wave action; and (5) disturbance by man.

Geographic variability could be a significant factor because the area is one which is impacted by cold-water currents (California Current) from the north, which flow south past San Miguel Island, and warm-water currents (Davidson Current) from the south. The intrusion of the currents into the Southern California Bight is variable and the current pattern is further complicated by periodic upwelling. However, it could be predicted that there might be a predominance of cold-water species on the more northern islands and a predominance of warm-water species on the more southern islands, with a gradation in between. Therefore, sites were selected ranging from Tyler Bight on San Miguel Island in the north to Dutch Harbor on San Nicolas Island and North West Cove on San Clemente Island in the south (Fig. 1).

The side of the island may be important in that there may be a difference in organisms on the Pacific Ocean side of the islands in comparison with the generally more sheltered mainland side.

TABLE 1. Characteristics of island sites.

Island site	Geographic location	Side of island	Exposure to waves	Mammal rookery	Manmade disturbances
San Miguel (Tyler Bight)	N	P	E	+	–
Santa Cruz (Black Point)	N	P	E	–	–
San Nicolas (Dutch Harbor)	S	P	E	–	–
San Clemente (North West Cove)	S	M	C	–	Military
Santa Catalina (the Isthmus)	S	M	E	–	Boating
Santa Catalina (Cat Harbor)	S	P	C	–	Boating

N= northern side of island. S= southern side of island.
P= Pacific Ocean side of island. M= mainland side of island.
E= exposed to wave action. C= cove sheltered from wave action.

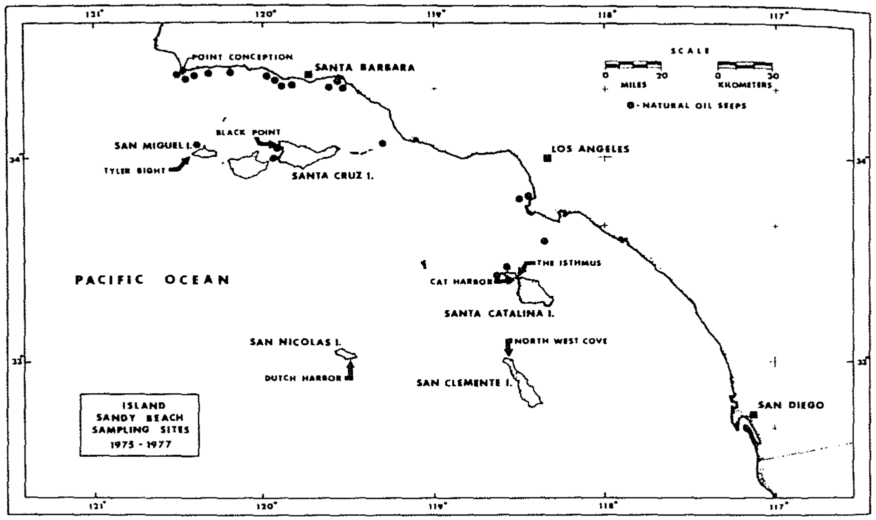

FIGURE 1. *Map of Southern California Bight showing location of island survey sites and recorded areas of natural oil and gas seepage.*

Exposure to wave action is usually related to the sediment parameters on the beach. In previous studies, sites exposed to wave action usually have shorter, more steeply sloping beaches and coarser sediment than sites which are sheltered from wave action. The exposed sites also usually have fewer species and fewer numbers of individuals collected than the sheltered sites.

The mammal rookeries on the islands are expanding. There are particularly large concentrations at the southern and western end of San Miguel Island which include California Sea Lions (*Zalophus californianus*) and Elephant Seals (*Mirounga angustirostris*). The animals traverse and frequently spend a considerable portion of their time in the intertidal areas. This could result in an increase in the organic content of the sediments, which, in turn, may influence the biota in the sand.

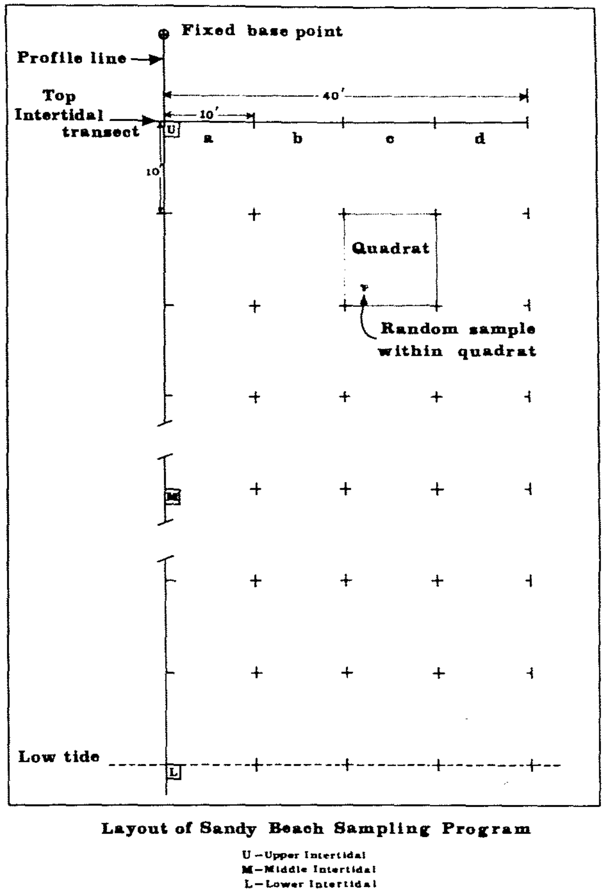

FIGURE 2. *Layout of sandy beach sampling techniques.*

Most of the islands are not heavily impacted by human activities. However, some of the sites are used by the military for training exercises. Massive beach disturbances have been observed at the site at North West Cove on San Clemente Island, for example. Santa Catalina Island is the only site readily accessible to the public. This is a favorite visiting place for the boating public and all areas are heavily used by boaters on fine summer weekends. Data collected at mussel communities on the mainland side of the island at the Isthmus suggested a slight contamination by fuel oil during the summer months, which is thought to be related to these activities (Straughan 1976).

METHODS

A stratified random quadrat method, which takes into account zonation and patchiness in distribution, was used to survey the beaches. Sampling was conducted by taking three cores (7.75 cm diameter and 20 cm deep) at a random point in stratified quadrats across the intertidal area from high tide to low tide level during low spring tides (Fig. 2). Cores were sieved through a 1.5-mm mesh screen; hence, these data include only macrobiota. The large screen size was

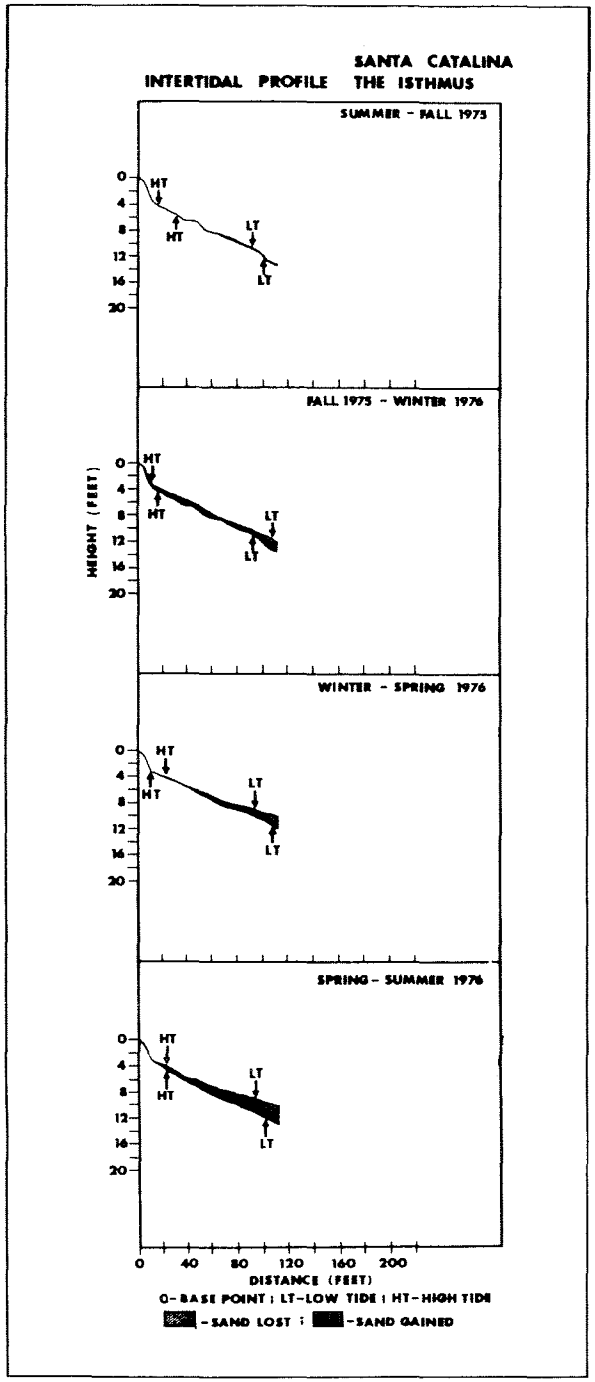

FIGURE 3. *Intertidal beach profiles recorded on quarterly surveys (summer 1975 to summer 1976) at the Isthmus, Santa Catalina Island.*

used so that large samples of sand could be rapidly sieved and large areas surveyed during a spring tide.

Sand samples were collected along the profile line of the grid for laboratory analysis. Grain size analysis was performed using an automatic settling tube (Folk 1968, Pettijohn 1957). Pipette analyses were conducted on a single set of samples from Cat Harbor to determine the amount of silts and clays present (Cook 1969, Gibbs 1974); however, the values were so low that this was discontinued. An Ohaus moisture meter (Model 6020 PG) was used to determine moisture and organic content. This organic content is not the same as total organic carbon (TOC) because it does not include organics incorporated into the sediments. Total organic carbon analyses were performed by Dr. W. E. Reed of the University of California at Los Angeles using the L.E.C.O. technique (Bandy and Kolpack 1963, Kolpack and Bell 1968).

Profiles were measured using an Emery stick method (Emery 1961), and all tar was collected within each sample and at each 10-ft (3.0 m) level down the grid. Temperatures were measured with a Yellow Springs Instrument Telethermometer, and salinity with a refractometer.

In summary, the following abiotic data were obtained from each survey: (1) profile (intertidal height, beach slope); (2) temperature (air, ocean, sand surface, sand subsurface); (3) salinity (ocean, interstitial water); (4) sediment (grain size, moisture content, Ohaus organic content, TOC); and (5) weight of tar.

Ideally, all abiotic parameters should be measured at each sampling point. However, this is prohibitive in cost and time. Research over a nine-year period has indicated that the measurement of abiotic parameters along the profile line adequately reflects abiotic conditions on the 40-ft wide grid where biotic data are collected.

RESULTS

All sites were surveyed quarterly in 1975-76. In 1976-77, sites were surveyed only in summer and winter, except for San Nicolas Island which was surveyed quarterly. Therefore, the summarized data are based on six surveys of most sites and eight surveys at San Nicolas Island.

Tables 2 and 3 summarize the main abiotic characteristics of these island beaches. The water temperatures followed the predicted trend, with colder temperatures being recorded at the more northern sites (*e.g.*, San Miguel Island, 11.0°C to 17.5°C) and warmer temperatures at the more southern sites (*e.g.*, San Clemente Island, 14.0°C to 22°C).

The Isthmus site at Santa Catalina Island had the shortest, steepest beach (Fig. 3) with the coarsest sediment (average mean ϕ = 1.41), while the Cat Harbor site on the other side of the island had the longest and most gently sloping beach (Fig. 4) with the finest sediments (average mean ϕ = 2.05). The other four island sites fell in a group somewhat in the middle of these extremes. The beach slope and grain size (Table 2) varied more at Santa Cruz Island and San Nicolas Island than at San Miguel Island and San Clemente Island. The two sites with the greatest variability were more exposed to wave action than the other two sites. Wave action during winter storms at San Nicolas Island resulted in the loss of large amounts of sand from the intertidal area (Fig. 5). While a similar annual pattern of cut and fill was also recorded at San Miguel Island, the loss and gain of sand resulted in smaller changes than those recorded at San Nicolas Island (Fig. 6).

The moisture content of the sediment is related to grain size, intertidal height, and time above water level before samples are collected. The averaging of the data for a site-by-site study reduces the impact of the latter two parameters. Cat Harbor had the finest sediments and the greatest average moisture content (20.1 to 24.5 per cent). The Isthmus, on the other hand, had the coarsest sediments and the lowest average moisture content (9.0 to 15.9 per cent). The other beaches with intermediate grain size characteristics also had intermediate moisture content characteristics.

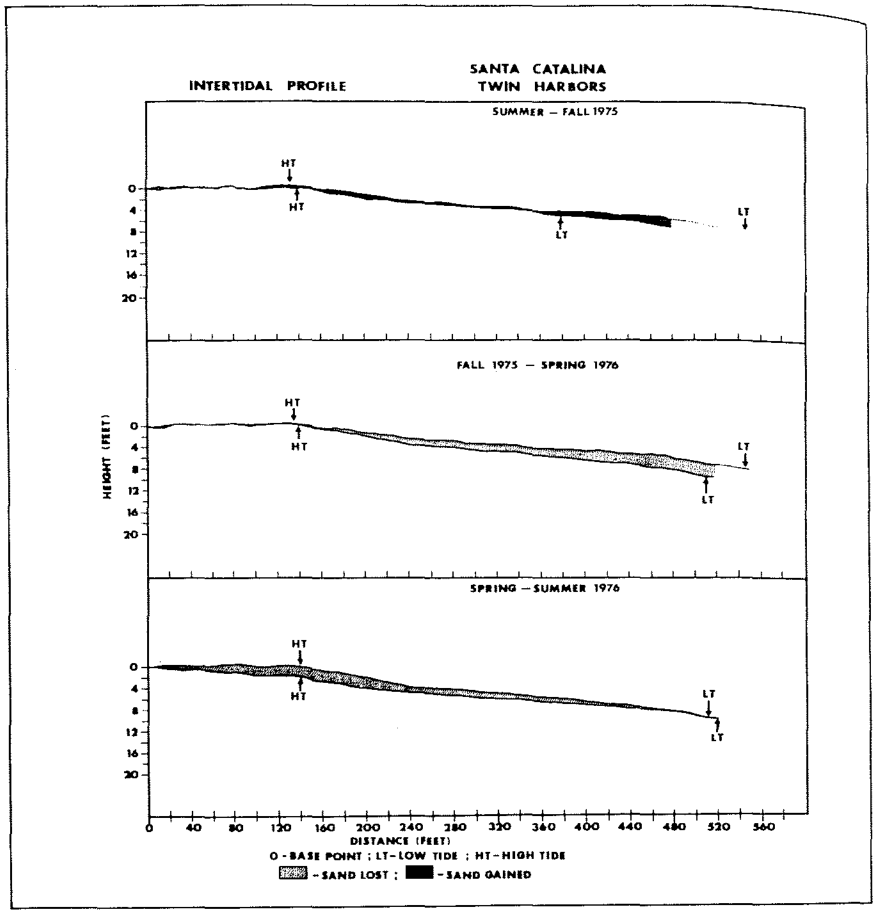

FIGURE 4. *Intertidal profiles recorded on surveys in 1975 and 1976 at Cat Harbor, Santa Catalina Island. (Note: this is referred to as the Twin Harbors site on this figure and in the Bureau of Land Management reports.)*

The Ohaus organic content, which measures plant and waste materials mixed in the sand but not organics incorporated in the sediments, was variable. The highest values were recorded at Tyler Bight on San Miguel Island (Tables 2 and 3). This is the site populated by elephant seals. The highest total organic carbon (6.5 per cent) and Ohaus organic carbon values (0.64 per cent) were also recorded at this site. The survey area is in the sheltered end of the cove and these organic values are interpreted as being waste products from the elephant seal colony.

The Ohaus organic and TOC values for Black Point on Santa Cruz Island and Dutch Harbor on San Nicolas Island are interpreted to mean that organic material such as kelp is mixed with the sand on the beach but very little organic material is incorporated in the sediments. The data at North West Cove suggest relatively higher incorporation of organics in sediments and less organic material mixed with the sediments. Both sites at Santa Catalina Island have relatively

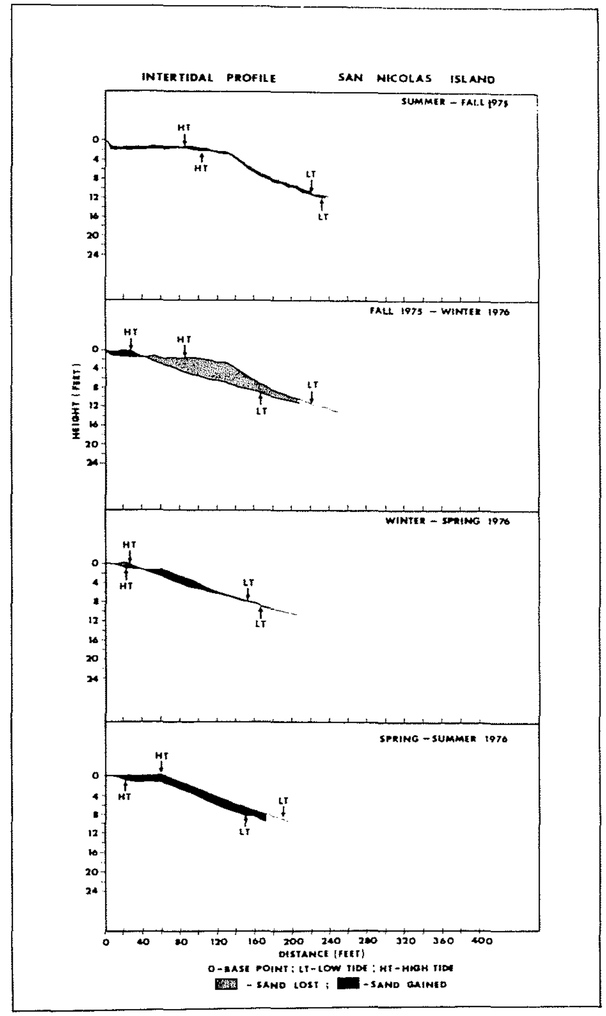

FIGURE 5. *Intertidal profiles recorded on San Nicolas Island (summer 1975 to summer 1976).*

high amounts of organics mixed with, as well as incorporated in, the sediments.

The calcium carbonate data indicate large amounts of shell in the sand at Tyler Bight, Dutch Harbor, North West Cove, and the Isthmus (mean = 10.60 to 13.89 per cent), and very low amounts of shell at Cat Harbor and Black Point (mean = 0.46 and 0.52 per cent, respectively).

No tar was recorded at San Miguel Island or San Clemente Island. Large amounts (an average of 733.95 g per survey) were recorded at the Cat Harbor site. It appeared that, once tar entered the area, ocean currents were not strong enough to move it out of the cove and/or break it into smaller pieces. Small amounts of tar were recorded at the other three sites.

Table 4 shows the number of species recorded at each site for two survey years and Appendix 1 lists all the species recorded at each site. This includes incomplete identifications due to missing taxonomic characters on specimens. It should again be noted that all sites were

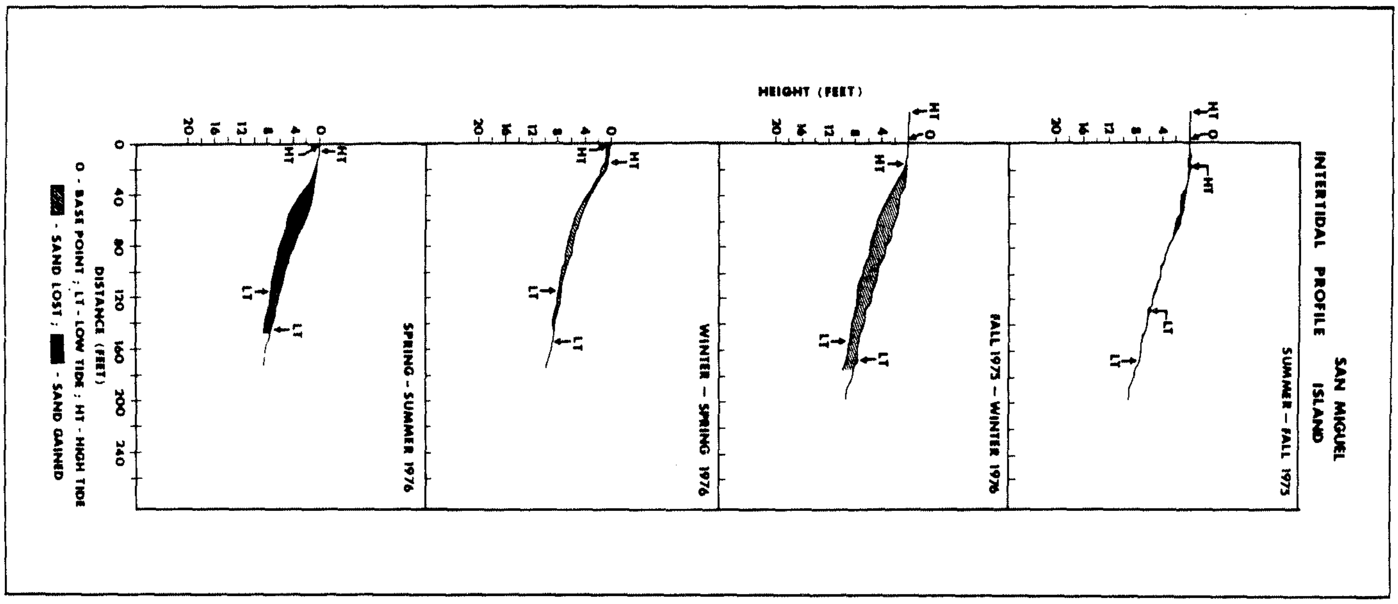

FIGURE 6. *Intertidal profiles at Tyler Bight on San Miguel Island (summer 1975 to summer 1976).*

TABLE 2. Abiotic characteristics measured at island sites, 1975-1977.

Island site	Water temperature (°C)	Salinity range (°/oo)	Grain size* (mean ϕ)	Moisture* (%)	Ohaus organic* (%)	Tar g†
San Miguel (Tyler Bight)	11.0-17.5	32,35	1.72-2.11	14.6-21.0	0.31-0.86	
			1.93	17.90	0.54	0.0
Santa Cruz (Black Point)	13.0-19.0	32,35	1.33-2.45	13.5-21.4	0.17-0.42	0.0-112.5
			1.95	17.70	0.29	22.43
San Nicolas (Dutch Harbor)	13.0-20.0	32,35	1.63-2.14	15.2-17.9	0.27-0.64	0.0-0.2
			1.77	15.90	0.45	0.05
San Clemente (North West Cove)	14.0-22.0	34,35	1.73-2.03	14.7-19.6	0.14-0.53	
			1.89	17.70	0.32	0.0
Santa Catalina (the Isthmus)	14.5-19.0	33,35	1.05-1.60	9.0-15.9	0.29-0.71	0.0-24.5
			1.10	13.05	0.47	9.25
Santa Catalina (Cat Harbor)	17.0-21.0	34,35	1.97-2.08	20.1-24.5	0.39-1.56	545.3-1761.5
			2.05	21.40	0.63	733.95

* Range of average value for each survey and overall average value.
† Range of total amount of tar collected on the survey grid per survey, and average value.

TABLE 3. Organic characteristics measured at island sites, 1976-1977 (range and average values).

Island site	Tar (g)	Ohaus organic (%)	Total carbon (%)	Total inorganic carbon (%)	Total organic carbon (%)	$CaCO_3$ (%)
San Miguel (Tyler Bight)	0.0	0.66-0.86	5.24-9.79	5.12-8.30	0.05-1.59	9.36-17.66
		0.76	6.50	5.86	0.64	13.43
Santa Cruz (Black Point)	4.5-17.6	0.37-0.42	0.07-0.20	0.03-0.16	0.02-0.10	0.29-1.36
	11.0	0.40	0.10	0.06	0.05	0.52
San Nicolas (Dutch Harbor)	0.0	0.27-0.64	1.44-2.20	1.32-2.04	0.03-0.32	10.96-17.03
		0.45	1.78	1.67	0.11	13.89
San Clemente (North West Cove)	0.0	0.14-0.53	1.49-3.25	1.12-2.12	0.10-1.12	9.36-17.66
		0.34	1.88	1.61	0.27	13.89
Santa Catalina (the Isthmus)	0.0-2.0	0.31-0.71	0.63-2.05	0.48-1.84	0.12-0.33	3.98-15.36
	1.0	0.51	1.49	1.28	0.21	10.69
Santa Catalina (Cat Harbor)	545.3-1114.5	0.44-1.56	0.18-0.51	0.04-0.10	0.14-0.46	0.30-0.84
	829.9	0.50	0.32	0.06	0.26	0.46

TABLE 4. Number of species collected at each site.

Island	1975-1976	1976-1977	1975-1977
San Miguel	33	18	33
Santa Cruz	18	20	25
San Nicolas	26	20	26
San Clemente	18	16	24
Santa Catalina (the Isthmus)	9	7	10
Santa Catalina (Cat Harbor)	121	82	127

surveyed four times in the first year and that only San Nicolas was surveyed four times in the second year. All other sites were surveyed only in the summer and winter of the second year. The most species (127) were recorded at the Cat Harbor site. This was the site with the finest sediments, highest moisture content, and longest, most gradually sloping beach. The fewest species (10) were recorded at the Isthmus, which had the coarsest sediments, lowest moisture content, and the shortest, steepest beach. Ohaus organic content and TOC content were variable but generally high at these sites. The other four sites, which had intermediate abiotic parameters, also had intermediate species numbers (24, 25, 26, and 33), although these were more similar to those recorded at the Isthmus than at Cat Harbor.

During the first survey year, 47 species were collected on the islands and 53 species were collected on the mainland beaches (Straughan 1977b). This number excludes Cat Harbor, where 107 species were collected, of which more than 45 were unique to the site.

Table 5 shows which species were consistently recorded in all surveys at a particular site. Cat Harbor had the largest number of consistently occurring species (13); nine of these are polychaetes. This is also the only site where molluscan species were consistently recorded. All the other sites had only two, three, or four species consistently recorded. Crustacea were found at most sites. Polychaetes were found at all but the coarsest sediment sites, while molluscs occurred only at the finer sediment sites.

Data in Tables 4 and 5 also show that, while each site had specific characteristics, there was a large variability in species occurrence at each site. It should be added that no single species was recorded at all sites.

Most of the island sandy beaches can be characterized by the consistent presence of a crustacean species, which in some instances is the sand crab *Emerita analoga*, sometimes the isopod *Excirolana chiltoni*, and sometimes a beach hopper, *Orchestoidea* sp. San Miguel Island is characterized by the polychaetes *Lumbrineris zonata* and *Nerinides acuta*; Santa Cruz is characterized by the blood worm *Euzonus mucronata*; no polychaete is characteristic of San Nicolas Island; *Hemipodus borealis* is characteristic of the Isthmus site; and *Euzonus dillonensis* is characteristic of San Clemente. The remaining site at Cat Harbor is characterized by a large number of polychaetes and the molluscs *Tagelus californianus* and *Transennella tantilla*.

The biotic characteristics, in terms of numbers of species and numbers of specimens collected, were compared with the abiotic characteristics using the Spearman rank correlation coefficient (Table 6). When $n = 6$, r_s was significant at the 0.05 level when equal to 0.829. The correlation coefficient approached this level of significance with grain size and was significant when the biotic parameters were compared with moisture. Multiple discriminant analyses of data by survey (Straughan 1977b, 1978) showed that the grain size and moisture content explained most of the variation associated with changes in the distribution and abundance of species.

Data in Table 7 show details in the abundance of dominant species at Cat Harbor and further emphasize the variability of each site. However, it should be noted that there are preliminary indications that at least some of the changes at Cat Harbor may be due to contamination by fresh, wet tar in the spring of 1976 (Fig. 7). For example, there was almost a sixfold increase in the population of the polychaete *Capitella capitata* when fresh tar was found at the site. Grassle and Grassle (1974) have recorded large increases in capitellids during the recovery phase following an oil spill. Other abundance patterns which may be influenced by the presence of petroleum include an apparent temporary reduction in numbers of the polychaete *Lumbrineris zonata* and the drastic reduction of the population of the bivalve *Transennella tantilla*. Further analyses over a longer time are required to determine if these are petroleum impacts and, if so, the duration of the impacts. The source of the petroleum is unknown. However, there appears to be a background level of at least 500 g of dry tar in the survey area. This harbor is sheltered so it

TABLE 5. Species found on all surveys at island sandy beach sites.

Species	San Miguel (6)	Santa Cruz (6)	San Nicolas (8)	Santa Catalina, the Isthmus (6)	Santa Catalina, Cat Harbor (6)	San Clemente (6)
Boccardia hamata					+	
Capitella capitata					+	
Euzonus dillonensis						+
Euzonus mucronata		+				
Hemipodus borealis				+		
Lumbrineridae	+					
Lumbrineris zonata	+				+	
Marphysa sanguinea					+	
Neanthes acuminata					+	
Nemertean sp. B					+	
Nothria stigmatus					+	
Notomastus tenuis					+	
Pseudopolydora paucibranchiata					+	
Scolelepis squamata	+					
Callianassa spp.					+	
Emerita analoga	+	+				
Excirolana chiltoni			+			+
Orchestoidea corniculata				+	+	
Orchestoidea juvenile			+	+		
Orchestoidea minor			+			
Tagelus californicus					+	
Transennella tantilla					+	

( ) = number of surveys at site.

TABLE 6. Comparison of biotic and abiotic data using Spearman rank correlation coefficient (r_s).

Island site	Ranking* of data: Grain size	Moisture	Tar	Ohaus organic	TIC	TOC	$CaCO_3$	Numbers of species and specimens†
San Miguel (Tyler Bight)	4	5	1.5	6	6	6	4.5	5
Santa Cruz (Black Point)	5	4	4	2	1.5	1	2	3
San Nicolas (Dutch Harbor)	2	2	3	3	5	2	6	4
San Clemente (North West Cove)	3	3	1.5	1	4	5	4.5	2
Santa Catalina (the Isthmus)	1	1	5	4	3	3	3	1
Santa Catalina (Cat Harbor)	6	6	6	5	1.5	4	1	6
r_s with numbers	0.76	0.83	0.13	0.60	0.39	0.26	−0.16	

* Lowest value = 1.

† Same ranking for both variables.

Table 7. Number of more abundant species collected on surveys at Cat Harbor, Santa Catalina Island.

Species	1975 Summer	1975 Fall	1976 Winter	1976 Spring	1976 Summer	1977 Winter
Boccardia hamata	3	16	12	6	2	33
Boccardia proboscidae	2	1	16	57	3	0
Capitella capitata	126	159	53	180	54	96
Lumbrineris zonata	73	80	64	57	27	57
Marphysa sanguinea	16	5	5	9	0	6
Neanthes acuminata	6	9	6	6	1	15
Nothria stigmatus	19	14	13	6	7	1
Notomastus tenuis	7	15	22	23	18	8
Paraeurythoe californica	0	0	10	0	2	17
Prionospio nr. *malmgreni*	0	2	6	4	1	7
Pseudopolydora paucibranchiata	66	1	129	74	40	11
Scyphoproctus oculatus	0	10	16	10	8	0
Callianassa spp.	8	36	49	4	14	29
Hemigrapsus oregonensis	1	2	0	0	4	0
Orchestia georgiana	3	11	0	0	1,340	0
Orchestoidea benedicti	4	2	0	0	1	0
Orchestoidea corniculata	37	29	14	10	19	7
Tylos punctatus	3	2	5	5	5	0
Cryptomya californica	0	0	0	0	2	9
Nassarius tegula	12	10	13	21	27	0
Tagelus californianus	0	2	6	5	3	3
Transennella tantilla	575	271	456	190	71	10

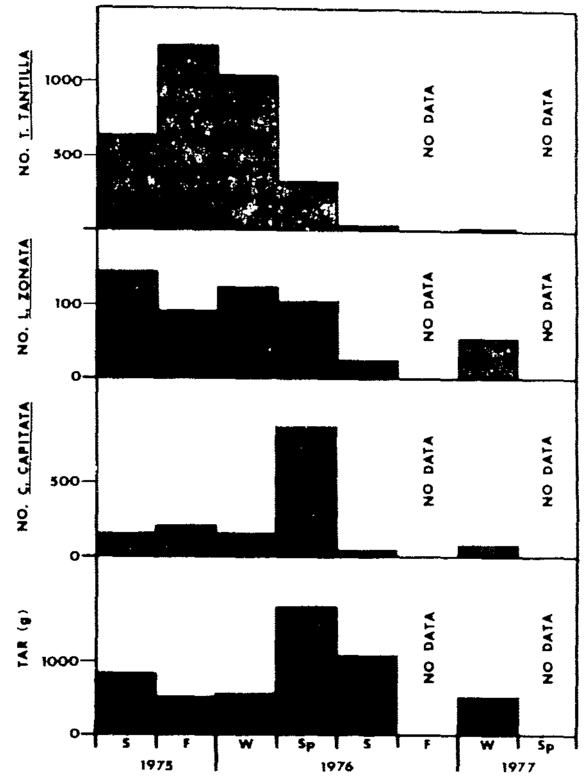

Figure 7. *Weight of tar (g), number of* Capitella capitata, *number of* Lumbrineris zonata, *and number of* Transennella tantilla *recorded on quarterly surveys at Cat Harbor, Santa Catalina Island. There were no surveys in fall 1976 or spring 1977.*

is not surprising that when petroleum enters it is not as readily washed away as occurs on the open coast sandy beaches.

DISCUSSION

Distribution and abundance of species are influenced by both abiotic and biotic factors. However, sandy beach populations, which are sparse in comparison with other types of intertidal areas (*e.g.*, rocky shore populations), and which are exposed to large and rapid fluctuations in abiotic parameters, may show primary responses to abiotic changes (*e.g.*, sediment parameters) and secondary responses to biotic changes (interspecific and intraspecific interactions). Such responses are contrasted between the studies of marginal species subject to large climatic changes (Andrewartha and Birch 1954) and studies in dense populations maintained under relatively constant climatic conditions (Nicholson 1957). There have been many attempts to provide a single overall theory which would explain all population regulation. However, regulation of populations both in terms of distribution and abundance will be dominated by different factors under different conditions. Kikkawa (1977) recently demonstrated this ecological problem with reference to terrestrial species. Studies in the marine environment in recent years have concentrated on the biotic interactions either within or at the edge of communities, such as in the case of starfish predation of mussels (Landenberger 1968, 1969) and interspecific competition in barnacles (Connell 1961), giving rise to the general premise that the biotic interactions are paramount in governing the distribution and abundance of marine species.

Connell (1975) documented that competition can occur only where predation and harsh physical conditions are not limiting. However, in a recent article on niche shifts and interspecific competition, Diamond (1978) concedes that the next step in the development of competition theory involves further study of the resources (abiotic parameters) in order to remove the "overwhelming" but sometimes "circumstantial" evidence of interspecific competition as a controlling factor in the distribution and abundance of species.

Sandy beach species are generally sparse in their overall distribution and, as a group, appear to have greater mobility than other marine benthic groups. This overall mobility is demonstrated in their response to changing sediment parameters on a beach. In general, the distribution of the more common species within their intertidal range correlates well with the sediment parameters of the beach. If these species were not mobile they would die off when there was a change in sediment parameters and, because species that otherwise would thrive under the new conditions would not be undergoing larval settlement at the time, there would be no invertebrates on the beach. Therefore, there should be records of relatively fine sand grain beaches, which normally contain most sandy beach organisms, with very few or no organisms. In nine years of surveys of sandy beaches from all latitudes and many parts of the world we have no such records from unpolluted areas. The more abundant and dominant sandy beach species, therefore, must be mobile even after larval settlement and must be able to respond to changes in sediments. Whether this mobility is due to the efforts of the organism, simple transport with the sediments and currents, or a combination of these factors will vary with the species.

Numbers of species and specimens are correlated with the grain size and moisture content of the sediments of sites; these are predictable relationships. Straughan (1975, 1977a, 1977b) has already demonstrated the relationships between some of the more abundant species and these parameters as well as organic content of sediments.

The lack of correlations with organic values, either in terms of Ohaus organics or TOC values, was unpredicted but suggests that grain size and moisture content of sediments may be limiting any response of species to an enriched organic environment, such as at San Miguel Island. However, organic values as a whole fluctuated at each site and it is possible that some species fluctuation will be detected when the data are examined in more detail.

The closeness in overall organic values at the two sites on Santa Catalina Island was not predicted. The Cat Harbor site is a sheltered site with finer grain size and is frequently visited by buffalo. The Isthmus site is exposed with coarser sediments. The reasons for these unpredicted high values are not known.

The data for the island sandy beaches have been compared with the data from the mainland sandy beaches and there is no division between the mainland and island sites (Straughan 1977b, 1978). In both instances, changes in species distribution on each survey correlate with abiotic factors measured on the survey and not with geographic factors in terms of north-south distribution and island-mainland distribution.

The species composition recorded at Cat Harbor differs from that found at the other island sites. The site most similar to it is one inside King Harbor. This is a low, gently sloping, sheltered intertidal area with fine sediments (Straughan 1977a). In other words, again the species distributions are related to abiotic parameters. Wicksten (1980) has also reported similar observations in some groups of Crustacea in that their distribution was related to grain size parameters, not to geography, in the Southern California Bight.

While most species and specimens were consistently recorded at Cat Harbor, this site is the only one to be consistently exposed to large amounts of petroleum. Although this petroleum is mainly dry tar, the area was contaminated by a large volume of fresh tar between winter and spring surveys in 1976. No chemical analyses were performed, so it is not known if this tar is from natural seepage or pollution sources. There are large areas of intermittent natural seepage of oil and gas offshore in southern California (Fig. 1). The nearest documented area of natural oil seepage is several miles to the west of the tip of Santa Catalina Island, which could be a source of the tar in Cat Harbor. While some surveys along mainland sandy beaches have established that most of the stranded tar is of natural seep origin (Allen 1971, Straughan 1973), no similar surveys have been conducted at island sites.

SUMMARY

Sandy beaches on San Miguel Island, Santa Cruz Island, San Nicolas Island, San Clemente Island, and Santa Catalina Island were surveyed at least twice a year, from summer 1975 through summer 1977. Comparable surveys were conducted on mainland beaches. The surveys were designed to collect macrofauna from the sand in a series of randomly selected cores within a grid of quadrats extending across the beach from high tide to low tide. Physical characteristics of the sites at the time of the biotic collections were recorded in the field (*e.g.*, temperatures, salinities, and beach profile). Samples of sediment and tar were also collected in order to determine such characteristics as sediment grain size, moisture and organic content of sediments, and weight of visible tár present in the survey area. The data do not show overall distinctions between the biota at mainland and island sites.

The island sandy beach macrofaunas follow predictable trends of increasing abundance with increasing stability of habitat (finer sediments, more sheltered conditions). There may be some impact of petroleum at the Cat Harbor site, Santa Catalina Island.

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APPENDIX 1. List of species on island sandy beaches.

	San Miguel	Santa Cruz	San Nicolas	San Clemente	Santa Catalina, Cat Harbor	Santa Catalina, the Isthmus
COELENTERATA						
Anthozoa?					+	
NEMERTEA						
Nemertea sp.	+				+	
Nemertea sp. A	+				+	
Nemertea sp. B				+		
Nemertea sp. C					+	
Nemertea sp. D					+	
NEMATODA						
Unidentified sp.						+
ANNELIDA						
OLIGOCHAETA						
Unidentified sp.		+			+	
ANNELIDA						
POLYCHAETA						
Amphinomidae					+	
Boccardia hamata					+	
Boccardia proboscidea					+	
Boccardia sp.					+	
Boccardia truncata					+	
Branchiomaldane vincentii					+	
Capitella capitata					+	
Capitellidae					+	
Cirratulidae					+	

Appendix 1. (Cont.)

	San Miguel	Santa Cruz	San Nicolas	San Clemente	Santa Catalina, Cat Harbor	Santa Catalina, the Isthmus
ANNELIDA						
POLYCHAETA						
Eteone dilatae					+	
Eteone pacifica					+	
Eunicidae					+	
Euzonus dillonensis	+	+	+	+		
Euzonus mucronata	+	+	+			
Exogone lourei					+	
Fabricia sp.					+	
Glycera tenuis					+	
Glyceridae					+	+
Hemipodus borealis	+				+	+
Leitoscoloplos elongatus					+	
Lumbrineridae	+	+	+		+	
Lumbrineris sp. A	+				+	
Lumbrineris sp. B					+	
Lumbrineris zonata	+	+	+		+	
Malmgrenia sp.					+	
Marphysa sanguinea					+	
Mediomastus sp.					+	
Megalomma pigmentum					+	
Neanthes acuminata					+	
Nephtyidae		+	+		+	
Nephtys caecoides					+	
Nephtys californiensis		+	+			

	San Miguel	Santa Cruz	San Nicolas	San Clemente	Santa Catalina, Cat Harbor	Santa Catalina, the Isthmus
ANNELIDA						
POLYCHAETA						
Nereidae					+	
Nerinides sp.					+	
Nothria iridescens					+	
Nothria stigmatis					+	
Notomastus lineatus					+	
Notomastus magnus					+	
Notomastus precocis					+	
Notomastus tenuis					+	
Onuphidae					+	
Opheliidae	+				+	
Orbiniidae	+			+		
Paraonella platybranchia					+	
Paraeurythoe californica					+	
Pherusa capulata					+	
Phyllodocidae					+	
Polydora socialis					+	
Polyopthalmus pictus					+	
Prionospio nr. *malmgreni*					+	
Prionospio sp.					+	
Pseudomalacoceros maculata					+	
Pseudopolydora paucibranchiata					+	
Scolelepis squamata	+		+	+	+	
Scoloplos acmeceps	+		+	+	+	
Scoloplos armiger	+		+	+		
Scyphoproctus oculatus					+	

APPENDIX 1. (Cont.)

	San Miguel	Santa Cruz	San Nicolas	San Clemente	Santa Catalina, Cat Harbor	Santa Catalina, the Isthmus
ANNELIDA						
POLYCHAETA						
Sigalionidae					+	
Spionidae	+			+	+	
Spio filicornis					+	
Sthenelais verruculosa					+	
Terebellidae					+	
Tharyx sp.					+	
ARTHROPODA						
CRUSTACEA						
Alloniscus perconvexus			+		+	+
Ampithoe pollex					+	
Ampithoe sp.					+	
Anatanais sp.					+	
Archaeomysis grebnitzki	+		+			
Archaeomysis sp. ?	+					
Atylus tridens				+		
Betaeus harrimani					+	
Blepharipoda occidentalis		+	+	+		
Callianassa californiensis					+	
Callianassa juvenile					+	
Callianassa longimana					+	
Callianassa sp.					+	
Cancer anthonyi					+	
Corophium sp.					+	
Crustacean eggs					+	
Emerita analoga	+	+	+	+		
Eohaustorius washingtonianus			+	+		
Excirolana chiltoni	+	+	+	+	+	+
Exosphaeroma inornata	+	+	+	+		+
Hemigrapsus oregonensis					+	
Heterophoxus cf. *oculatus*					+	
Idotea cf. *rufescens*					+	
Lepidopa californica		+				
Leptochelia dubia					+	
Mandibulophoxus gilesi	+					
Mysidacea	+					
Orchestia georgiana					+	
Orchestia juvenile		+				
Orchestia traskiana				+		
Orchestoidea benedicti	+	+	+	+	+	+
Orchestoidea californiana		+				
Orchestoidea columbiana			+			
Orchestoidea cf. *columbiana*			+			
Orchestoidea corniculata	+	+	+	+	+	+
Orchestoidea juvenile	+	+	+	+	+	+
Orchestoidea minor			+			
Paranthura elegans					+	
Paraphoxus cf. *calcaratus*					+	
Paraphoxus lucubrans	+					
Paraphoxus sp.	+					
Proharpinia sp.					+	
Pugettia dalli					+	
Tylos punctatus		+	+		+	
Unidentifiable	+			+		

APPENDIX 1. (Cont.)

	San Miguel	Santa Cruz	San Nicolas	San Clemente	Santa Catalina, Cat Harbor	Santa Catalina, the Isthmus
ARTHROPODA						
INSECTA/ARACHNIDA						
Alleculinae larvae				+	+	
Amphidora nigropilosa					+	
Anthomyiidae					+	
Bledius sp.					+	
Cafius lithocharinus			+			
Cercyon luniger	+					
Cercyon sp. larvae					+	
Chilopoda					+	
Coelopa vanduzeei pupae			+			
Corixidae nymph					+	
Cryptadius inflatus		+				
Cyclorrhapha larvae	+		+			
Cyclorrhapha pupae	+				+	
Dolichopodidae larvae		+			+	
Eumolpinae					+	
Forcula auricularia					+	
Fucellia rufitibia		+				
Geophiloidea					+	
Gnaphosa maritima immature					+	
Histeridae larvae		+			+	
Leptus sp.		+				
Myrmeleontidae						+
Oxytelinae		+				
Paraclunio alaskensis	+					
Sarcophagidae	+					
Staphylinidae		+	+		+	
Staphylinidae larvae					+	
Tenebrionidae larvae					+	

	San Miguel	Santa Cruz	San Nicolas	San Clemente	Santa Catalina, Cat Harbor	Santa Catalina, the Isthmus
MOLLUSCA						
GASTROPODA						
Acteocina culcitella					+	
Acteocina incluta					+	
Caecum californicum					+	
Littorina scutulata					+	
Nassarius tegula					+	
Norrisia norrisi					+	
Olivella biplicata					+	
Tegula eiseni					+	
MOLLUSCA						
PELECYPODA						
Chione undatella					+	
Cryptomya californica					+	
Cumingia californica					+	
Leporimetis obesa					+	
Macoma nasuta					+	
Parvilucina tenuisculpta					+	
Pelecypoda unidentified					+	
Protothaca staminea	+			+		
Tagelus californianus					+	
Transennella tantilla					+	
ECHINODERMATA						
OPHIUROIDEA						
Amphipholis squamata					+	
PISCES						
Clevelandia ios					+	
Gobiidae					+	
Ilypnus gilberti					+	
Quietula y-cauda					+	