INVENTORY OF BENTHIC INVERTEBRATES IN SANDY INTERTIDAL AND BEACH HABITATS, OCEAN BEACH, SAN FRANCISCO, CA

Photo: Amphipods on kelp, D.Fong

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Introduction

The Golden Gate National Recreation Area (GOGA) is a coastal park in north-central California. This long, narrow park is divided by the Golden Gate entrance to San Francisco Bay, which separates the northern Marin County lands from the southern San Francisco and San Mateo County lands. GOGA was established in 1972 (PL 92-589) as part of the "parks to people" program, and the enabling legislation stated that the lands were founded "in order to preserve for public use and enjoyment certain areas of …possessing outstanding natural, historic, scenic and recreational values…"

The National Park Service's Natural Resources Management Guidelines (NPS-77) establishes 11 general objectives for the management of NPS's marine resources. The inventory and monitoring objectives for marine resources calls the Parks to:

- Inventory all ecosystem components,
- Determine limits of natural system variation (baseline conditions),
- Monitor system dynamics to detect abnormal changes in time to affect remedial actions.

Ocean Beach is our Park's most extensive sandy beach habitat, stretching five miles from the Cliff House in San Francisco to Fort Funston (Figure 1). Because of its importance to migratory shorebirds, especially the threatened snowy plover, *Charadrius alexandrinus*, an inventory was developed to focus on benthic invertebrates in the sandy beach and sandy intertidal habitats along Ocean Beach. The intent was to focus on habitats used by foraging shorebirds.

The specific objectives of the inventory program were as follows:

1) To establish a baseline species inventory of invertebrates associated with sandy beach and sandy intertidal habitats and organic debris at Ocean Beach.

2) To determine abundance and distribution of benthic invertebrates along longitudinal transects from the swash zone to the upper dunes at Ocean Beach.

3) To prepare a reference collection of benthic invertebrates for use in future monitoring programs.

The proposed activities are within the scope of an existing Golden Gate National Recreational Area (GOGA) Natural Resources Program Statement: *Monitor Intertidal Resources* (GOGA-N-025).

Background Shorebird Information

The threatened snowy plover, *Charadrius alexandrinus*, winters along Ocean Beach, San Francisco. The plovers are present for an extended period of the year, from early July through the end of May. However, numbers peak between January and March. Plovers are not uniformly distributed along Ocean Beach; rather, they tend to be concentrated in three sectors: between Lincoln and Judah Sts., between Noriega and Pacheco Sts., and between Pacheco and Rivera Sts (D. Hatch, NPS, unpublished data, 1995).

At beaches, it forages above and below the mean high-water line, gathering food from sand surface, kelp, marine mammal carcasses, or low foredune vegetation (Page *et al*., 1995). On Pacific coast beaches, plovers are thought to feed on mole crabs (*Emerita analoga*), crabs (*Pachygrapsus crassipes*), polychaetes, amphipods, sand hoppers (Orchestoidea), tanadacians (*Leptochelia dubia*), flies, beetles, clams, and ostracods (Page *et al.*, 1995).

Ocean Beach is also heavily used by migratory shorebirds as a stopover point during fall and spring migrations along the Pacific Flyway. Unfortunately, there are no published reports that describe times of peak occurrence of shorebirds at Ocean Beach. Furthermore, the times of peak occurrence for shorebirds is often staggered, depending upon the species (Recher 1966). During the fall migration, Page *et al.* (1979) found that September was the month of peak occurrence for sanderlings and least sandpipers and post-peak for willets and western sandpiper- species that are also common at Ocean Beach.

Past Work

To date, there has only been limited information collected regarding the sandy beach and sandy intertidal resources within GOGA. For Ocean Beach, *Orchestoidea* spp. have been recorded for upper beach and *Emerita analoga* and *Archaeomysis maculata* in the lower beach during August 1974 surveys (Chan 1974). Most recently, in 1992, a private consultant, Susan McCormick, collected benthic invertebrate and subtidal fish data to address the effects of sand disposal on Ocean Beach (McCormick 1992). Along Ocean Beach, the Park conducted yearly beach wrack surveys during the late-winter from 1996 to 1998.

Methods

Study Sites.

The Park's snowy plover monitoring program divided Ocean Beach into 4 general zones:

> Zone 1-Extends from the northern most end of Ocean Beach by the Cliff House to Stairwell #16 at middle Golden Gate Park.
>
> Zone 2-Extends from Lincoln Blvd to Judah St.

Zone 3-Extends from Noriega St. to Rivera St.

Zone 4-Extends from Rivera St. to Sloat Blvd.

Zone 1 has limited use by shorebirds, including plovers. This area is heavily used by visitors and is subjected to a variety of disturbances such as sand disposal and beach grooming. Zone 2 is a medium use area by snowy plovers. Zone 3 contains the area of highest use by snowy plovers. Zone 4 contains the medium use area for snowy plovers (primarily foraging). We selected 3 sites for benthic invertebrate sampling: midpoints of Zone 2 (Irving St.), Zone 3 (Pacheco St.), and Zone 4 (Taraval St.) (Figure 1).

Survey Period.

Samples were collected along Ocean Beach in the Fall of 1996 (October 12, 1996) and Winter-Spring of 1997 (January 25, 1997 and April 5, 1997).

Biological Measurements.

Sampling techniques were geared towards sampling features used by foraging shorebirds. These features included beach wrack (marine algae/seagrasses on the beach), sandy beach, and sandy intertidal areas. Sampling occurred at low tide. A variety of references were used to identify collected invertebrates in the laboratory (Banse and Hobson 1974; Bousfield 1959, 1973; Fauchald 1977; Kathman et al., 1986; Smith and Carlton 1989).

Sandy Beach and Sandy Intertidal. Sampling activities generally followed procedures developed by the Channel Islands National Park for monitoring abundance of amphipods (Dugan *et al.*, 1990). A random location was selected 50 m distance parallel along the beach (north-south orientation). A transect was stretched towards the ocean (east-west orientation). The transect extended from the crest of the beach to the swash zone (Figure 2).

Invertebrate samples from sandy areas along the transect were collected to a depth of 10 cm with 10 cm diameter cores made from PVC pipe. Our depth of coring reflected the foraging depth of the largest shorebird commonly seen on the beach. Of the larger shorebirds frequently seen at Ocean Beach, the marbled godwit, has an average bill length between 10 and 11.5 cm (Cogswell 1977).

The core samples were collected in two ways along the transects. Fall 1996 samples were collected every 4-5 m. Winter-Spring 1997 samples were collected from 3 general areas to represent the lower, middle and upper sections of the transect (Figure 2). Four, closely spaced replicate cores were taken from each section. Similar number of cores were taken during each sampling period (13 cores in Fall 1996 and 12 cores in Spring

1997).

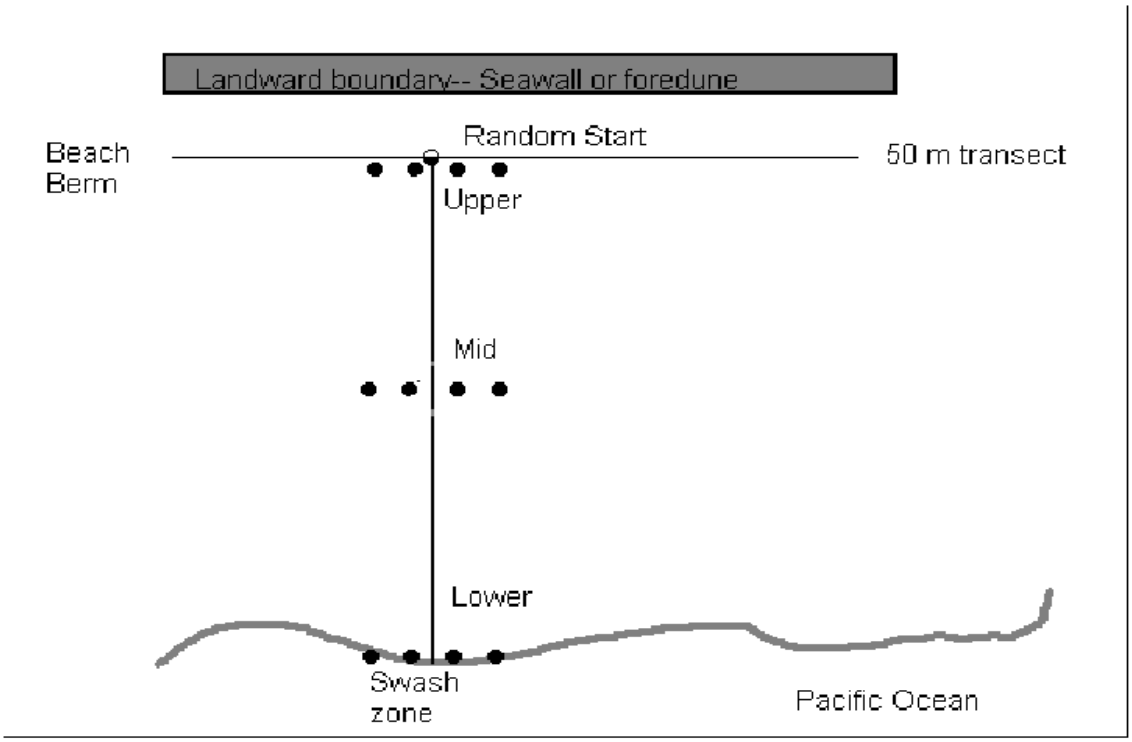


FIGURE 2: GENERALIZED INVERTEBRATE SAMPLING LOCATIONS FOR WINTER-SPRING 1997 ON OCEAN BEACH, CA.

Cores were wet sieved in the field (0.5 mm mesh) to reduce bulk, placed in a 500 ml Nalgene bottle, and preserved in a 10% formalin solution. Even with wet sieving, large amounts of sand were present in preserved samples.

Beach wrack/Carcasses. We surveyed a 50 m wide area that extended from the beach berm to the swash zone which enclosed the transect. All wracks and carcasses greater than hand-size were counted.

For each zone up to four wracks were sampled and retained for lab processing. In zones with more than four wracks/carcasses, all wracks were flagged and four wracks were selected at random. Selected wracks were washed with seawater and the wash water sieved to collect invertebrates. A single core was also taken directly below the selected wrack. Descriptive information regarding the relative age and taxa of the beach wrack were recorded. Shriveled, lightweight, bleached wracks were classified as old. Recent wracks were characterized by a general fleshy appearance and retention of some of their

natural color.

Results/Discussion

A total of 17 species from 16 genera were collected and identified (Table 1). A reference collection has been placed into the Park archives. Several specimens were unidentified, largely because pieces of specimens, and not entire individuals were available. A recent survey at Ocean Beach in 1991 and 1992 by McCormick (1992) found 8 taxa in the sandy intertidal area (near Sloat Blvd), 5 of which were not identified in the current survey (Table 1).

The greater number of species observed by McCormick might be explained by differences with our sampling technique. McCormick used a 1/3 sq. meter quadrat to sample on two occasions (3 replicates at 6 stations) for a total of 12 square meters of sampled habitat. While we collected 90 core samples, the small surface area per core resulted in a total sampled surface area of just 0.7 square meters.

One collected taxon, *Archaeomysis grebnitzkii,* is typically associated with the water column. We used ocean water to assist in the field wet sieving. Although the ocean water was filtered through a 0.5 mm screen, it may have been possible for them to squeeze through the mesh.

Excluding dogs and humans, there are potentially two other non-indigenous animals on Ocean Beach. Our species list (Table 1) was compared with a recent study on non-indigenous aquatic species of the San Francisco Bay-Estuary (Cohen and Carlton 1995). *Synidotea laticauda* (syn. *Synidotea laevidorsalis*) is a widely distributed species thought to originate from Asia hitch-hiking with hydroids and bryozoans fouling the hulls of ships (Cohen and Carlton 1995). Another potential non-indigenous species*, Jassa marmorata*, a transplant from the Atlantic coast, might also be present on Ocean Beach. We found a single individual that we were only able to identify to genus. Neither of these two taxa were recorded by a prior study at Ocean Beach (McCormick 1992).

Mean invertebrate densities were typically higher for the same locales during the Winter-Spring sampling events versus the Fall (Table 2, Figure 3). However, we were not able to test whether such differences were significant because our Spring 1997 invertebrate data were pooled when tabulated. It is likely that the differences in mean densities would not be significant because of expected high variability in the number of invertebrates per core. For example, the coefficient of variation (std. dev./mean*100) for 1997 invertebrate densities at Irving, Pacheco, and Taraval locations were 131, 325, and 170%, respectively. Such high variability may result from the small sample area per core (0.008 sq. m) and patchiness of invertebrates.

Table 1: Composite taxa list for sandy intertidal and beach habitat at Ocean Beach (List derived from specimens collected October 12, 1996, January 25, 1997 and April 5, 1997 in this study and from McCormick 1992).

Taxonomic Grouping		Species
Crustacea	Amphipoda	*Atylus levidensus*
		Eogammarus confervicolus
		Ericthonius hunteri
		Eohaustorius spp. (1a)
		Haploops tubicola
		Jassa spp.
		Mandibulophoxus gilesi (1a)
		Megalorchestia pugettensis
		Megalorchestia columbiana
		Megalorchestiodea californiana (1a)
		Oligochinus lighti
		Orchestoidea benedicti (1a)
		Paramoera serrata
		Unidentified
	Copepoda	Unidentified
	Decapoda, Anomura	*Emerita analoga (1b)*
	Isopoda	*Excirolana linguifrons (1b)*
		Excirolana vancouverensis
		Lironeca vulgaris
		Synidotea laticauda
		Unidentified
	Cumacea	*Diastylopsis dawsoni*
	Mysida	*Archaeomysis grebnitzkii (1b)*
		Unidentified
Insecta	juvenile / adult	Unidentified
	larvae	Unidentified
	Staphylinidae (1a)	
Annelida	Polychaeta	*Pherusa plumosa*
		Unidentified
	Oligochaeta	Unidentified
Nemertea		Unidentified

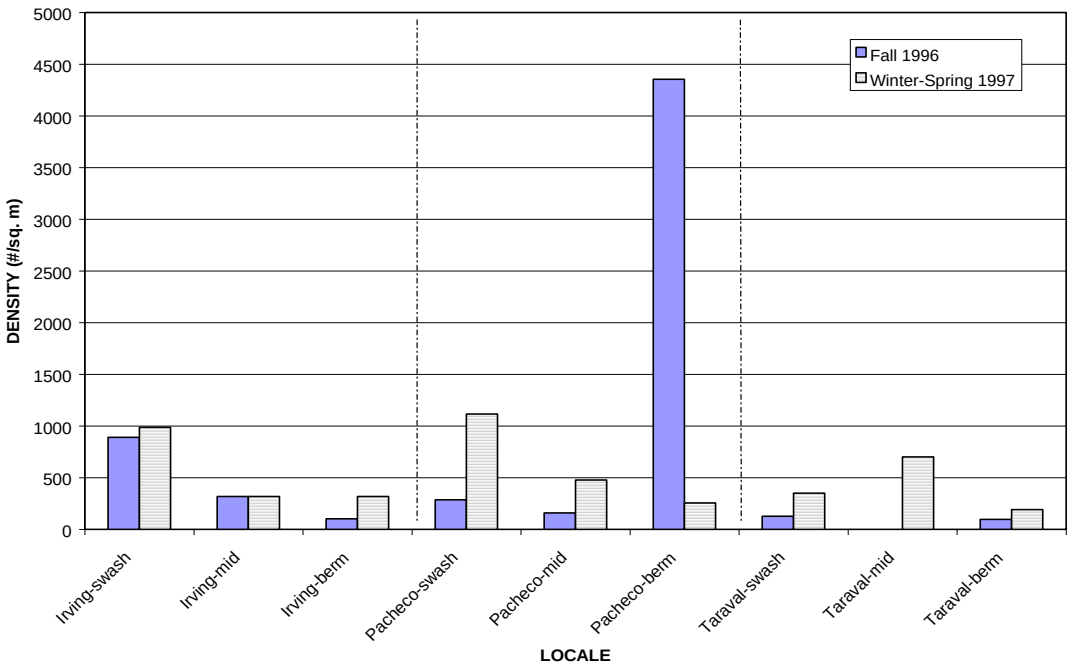
KEY: 1a – Specimens collected only from McCormick (1992) samples, 1b – Specimens collected from both current study and McCormick (1992).

TABLE 2: Density of invertebrates from cores and wrack samples

LOCALE	FALL 1996 BEACH CORE n	Core Mean (invert/ sq. m)	WRACK n (# wracks /acre)	WRACK Mean (invert/ sq. m) 1996	WINTER - SPRING 1997 BEACH CORE n	Core Mean (invert /sq. m)	WRACK n (# wracks /acre)	WRACK Mean (invert /sq. m)	WRACK + CORE Mean (invert/sq. m)
IRVING			4 (51)	177			0 (0)*	N.A.	N.A.
--swash	4	891			4*	987	N.S.**		
--middle	4	318			4*	318			
--berm	5	102			4*	318			
PACHECO			3 (24)	350			0 (0)*		
--swash	4	286			4**	1115	4 (69)**	53	243
--middle	4	159			4**	478			
--berm	5	4354			4**	255			
TARAVAL			4 (59)	169			0 (0)*		
--swash	4	127			4**	350	4 (126)**	20	498
--middle	4	0			4**	701			
--berm	4	96			4**	191			

KEY: * April 5, 1997, ** Jan 25, 1997, N.S.-not sampled

Figure 3: Mean invertebrate density of sandy intertidal cores, Ocean Beach, CA



One of the project objectives was to determine the abundance and distribution of benthic invertebrates along longitudinal transects from the swash zone to the upper dunes at Ocean Beach. In terms of total abundance, amphipods and insects (larvae and adults) were the most commonly collected taxa groups for both the sandy beach cores as well as the wrack samples. For Fall 1996, the high density of invertebrates at the berm locale at Pacheco St. was due entirely to the presence of insect larvae (Figure 3).

The abundance and distribution of common invertebrates from our Ocean Beach sampling differed from McCormick's data. The Sloat Blvd. site sampled twice by McCormick was dominated by isopod (*Excirolana linguifrons)* and mole crab (*Emerita analoga*)---representing 80% and 5% of the total abundance in Nov 1991 and 8% and 94% in March 1992 (McCormick 1992). Both species were just minor occurrences for us. Excirolana spp. and Emerita analoga accounted for 3-6% and <1-9%, respectively, of total abundance for Fall 1996 and Spring 1997 sampling event.

There is some local information that we can use to compare our densities of sandy intertidal invertebrates. Our grand mean densities of invertebrates in sandy beach habitats were higher than those reported in two recent studies. We had a grand mean of 614 invertebrates per square meter for all sampling locales and dates. By comparison, using

the sampling area and total invertebrate data provided in McCormick (1992), we calculated mean invertebrate densities of 41.8 (November 1991) and 18.7 individuals per square meter of sandy intertidal habitat (March 1992). Comparisons with McCormick's data may not be entirely appropriate because of substantial differences in sampling technique. For his study area in Bodega Bay, Sonoma Co., mean invertebrate densities in open sandy beach areas averaged 220 invertebrates per square meter over the entire sampling period (Yaninek 1980) using similar sampling techniques as this study.

Our sampled beach wrack contained fewer invertebrates by several orders of magnitude. We recorded a grand mean of 154 invertebrates per sq. m. of wrack. By comparison, wrack invertebrate densities from Bodega Bay averaged 38,000 individuals per sq. meter (ranging from 4,700 to 72,000 per sq. meter) (Yaninek 1980). The techniques used to sample and estimate wrack invertebrate densities were unclear, however.

The relatively low densities of invertebrates per wrack area may be partly explained by differences in sampling technique. Yaninek (1980) did not explain his methods for sampling and estimating wrack invertebrate densities. Our field sampling procedures likely missed a substantial number of mobile invertebrates initially present on the wracks. The process of lifting wracks and placing them in buckets of seawater may have caused many invertebrates to drop off and scurry merrily away from the humans. Berzins (1985) placed plastic bags over wracks in order to capture adult flies that may be associated with wracks. Similar modifications could be done in the future to maximize the collection of invertebrates associated with wrack.

We also had differences from Yaninek's study in terms of the abundance of invertebrates found directly under beach wrack. The grand mean densities of invertebrates from the sand cores underneath the beach wracks had similar or lower densities than our open sand cores. By comparison, Yaninek (1980) found that beach cores associated with wracks averaged 173 times greater invertebrate densities than nearby open beach areas.

Because of the high variability (both spatially and seasonally) in invertebrate abundance and the large commitment of field and laboratory time, it is unlikely that the methodology used in this study would be suitable for a long-term monitoring program which focuses on invertebrate abundance. However, periodic inventories of the sandy beach habitat will be invaluable for documenting taxa changes over time (e.g., introductions of non-indigenous species). To ensure a higher probability of detection, the current sampled area should be increased by increasing the number of samples or increasing the surface area for individual samples.

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APPENDIX I: NPS Ocean Beach -- Fall 1996 Sampling Summary

Taxonomic Grouping		Species	Irving zone 2	Pacheco zone 3	Taraval zone 4
Crustacea	Amphipoda	*Atylus levidensus*	19	1	0
		Eogammarus confervicolus	0	2	0
		Ericthonius hunteri	0	1	0
		Haploops tubicola	0	1	0
		Jassa spp.	1	0	0
		Megalorchestia pugettensis	1	0	0
		Megalorchestia columbiana	8	20	1
		Oligochinus lighti	0	1	0
		Paramoera serrata	0	2	0
		unidentified	0	2	0
	Copepoda	unidentified	1	0	1
	Decapoda, Anomura	*Emerita analoga*	1	2	0
	Isopoda	*Excirolana linguifrons*	8	0	3
		Excirolana vancouverensis	0	3	0
		Lironeca vulgaris	0	1	0
		Synidotea laticauda	0	1	0
		unidentified	0	1	0
	Mysida	*Archaeomysis grebnitzkii*	1	16	0
		crustacean subtotal	40	54	5
Insecta	juvenile / adult	unidentified	18	91	10
	larvae	unidentified	9	230	1
		insect subtotal	27	321	11
Annelida	Polychaeta	*Pherusa plumosa*	0	1	0
		unidentified	0	0	1
	Oligochaeta	unidentified	0	0	1
Nemertea		unidentified	0	0	0
		worm subtotal	0	1	2
		Totals	**67**	**376**	**18**

APPENDIX II: NPS Ocean Beach -- Spring 1997 Sampling Summary

Taxonomic Grouping		Species	Irving zone 2	Pacheco zone 3	Taraval zone 4
Crustacea	Amphipoda	*Atylus levidensus*	21	23	21
		Megalorchestia columbiana	0	6	3
		unidentified	0	1	0
	Copepoda	unidentified	0	7	6
	Decapoda, Anomura	*Emerita analoga*	1	3	15
	Isopoda	*Excirolana linguifrons*	8	1	3
	Cumacea	*Diastylopsis dawsoni*	0	1	0
		unidentified	0	1	0
	Mysida	*Archaeomysis grebnitzkii*	20	0	1
		unidentified	1	5	1
		crustacean subtotal	50	43	49
Insecta	juvenile / adult	unidentified	0	11	4
	larvae	unidentified	0	30	5
		insect subtotal	0	41	9
Annelida	Polychaeta	unidentified	0	1	0
	Oligochaeta	unidentified	0	2	1
Nemertea		unidentified	0	8	7
		worm subtotal	0	11	8
		Totals	**51**	**100**	**67**

APPENDIX III: NPS Ocean Beach Fall 1996 Sampling
Irving (Site 1, zone 2)

Vial Label	Samp Locat'n (m from berm)	Nemertea / Annelida	Other Crustacea	Insecta juv / adult	Insecta larvae	Mysida	Isopoda	Amphipoda	Parts Worm	Parts Crustacean	Parts Arthropod
33	0			1							6
28	5										
27	10 *			1					38		1
26	15			1				1	4	2	13
25	20										
24	25		1					1	4		
23	30						2	2	2		
22	35										1
21	40			2				2	1		1
20	45			1	2		2		1		
19	50						2			1	2
18	55		1	1	3			11			3
17	58						2	3		6	
29	wrack #2			3	2						
30	wrack #30			4	2			5		31	1
31	wrack #3			4		1		3			9
32	wrack #35							1		1	22
	Totals	0	2	18	9	1	8	29	50	41	59

APPENDIX IV: NPS Ocean Beach Fall 1996 Sampling

Pacheco (Site 2, zone 3)

Vial Label	Samp Locat'n (m from berm)	Nemertea / Annelida	Other Crustacea	Insecta juv / adult	Insecta larvae	Mysida	Isopoda	Amphipoda	Parts Worm	Parts Crustacean	Parts Arthropod
13	0				166		1	1	1		
12	4					1				1	
11	8										
10	12										
9	16					2					
8	20					0				1	
7	24					2					
6	28					1					
5	32						1	1		1	
4	36					1		1			
3	40	1	2								
2	44					2	1				
1	48					1			1		1
14	wrack #1			64	47	4		11			5
15	wrack #2			12	4	1				2	14
16	wrack #3	2		15	13	1	3	16			

	Totals	3	2	91	230	16	6	30	2	5	20

APPENDIX V: NPS Ocean Beach Fall 1996 Sampling
Taraval (Site 3, zone 4)

Vial Label	Samp Locat'n (m from berm)	Nemertea / Annelida	Other Crustacea	Insecta juv / adult	Insecta larvae	Mysida	Isopoda	Amphipoda	Parts Worm	Parts Crustacean	Parts Arthropod
45	0										
44	4	1 (oligoch)									
43	8	1 (polych)		1							
42	12										
41	16										
40	20 *										
39	24										
38	28										
37	32										
36	36										12
35	40						3				
34	44			1							
46	wrack #1										
47	wrack #2										
48	wrack #3			1	1					5	4
49	wrack #4			7				1		6	
	Totals	2	0	10	1	0	3	1	0	11	16

APPENDIX VI: NPS Ocean Beach Spring 1997 Sampling

Irving (Site 1, zone 2)

Vial Label	Sample Location	Nemertea / Annelida	Other Crustacea	Insecta juv / adult	Insecta larvae	Mysida	Isopoda	Amphipoda	Parts Worm	Parts Crustacean	Parts Arthropod
1.A	at water					19		12	1		
1.B	middle		1			2		7		1	
1.C	at berm						8	2			
	Totals	0	1	0	0	21	8	21	1	1	0

APPENDIX VII: NPS Ocean Beach Spring 1997 Sampling
Pacheco (Site 2, zone 3)

Vial Label	Sample Location	Nemertea / Annelida	Other Crustacea	Insecta juv / adult	Insecta larvae	Mysida	Isopoda	Amphipoda	Parts Worm	Parts Crustacean	Parts Arthropod
2.A	at water	2 / 1 +,**	8 *			5		18	1		
2.B	middle	6 / 0	2	1			1	5			
2.C	at berm	0 / 1 oligo	1	2				4			
2.W.1	wrack #1							1			
2.W.2	wrack #2		1 *		12			2			4
2.W.3	wrack #3			2	5					2	
2.W.4	wrack #4	0 / 1 poly		5	8				1		
2.WC.1	wrack core 1										
2.WC.2	wrack core 2										
2.WC.3	wrack core 3				1						
2.WC.4	wrack core 4			1	4				1		
	Totals	11	12	11	30	5	1	30	3	2	4

* 1 cumacean
+ 1 unidentified capitellid oligochaete (Capitella?)
** 2 planktonic chaetognaths (not included in this count)

APPENDIX VIII: NPS Ocean Beach Spring 1997 Sampling

Taraval (Site 3, zone 4)

Vial Label	Sample Location	Nemertea / Annelida	Other Crustacea	Insecta juv / adult	Insecta larvae	Mysida	Isopoda	Amphipoda	Parts Worm	Parts Crustacean	Parts Arthropod
3.A	at water	3 / 1 oligo	4	1	1	1			2	1	
3.B	middle	4 / 0	14				3	1			
3.C	at berm		3			1		2			
3.W.1	wrack #1				1						
3.W.2	wrack #2							1		1	
3.W.3	wrack #3										
3.W.4	wrack #4			3	3			5			
3.WC.1	wrack core 1							15			
3.WC.2	wrack core 2										
3.WC.3	wrack core 3										
3.WC.4	wrack core 4										
	Totals	8	21	4	5	2	3	24	2	2	0