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BIOTA OF A SHALLOW ESTUARINE HABITAT IN SAN FRANCISCO BAY

By

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INTRODUCTION

The information presented here is from a report prepared for the U. S. Navy that describes the biota in the vicinity of the breakwater at the Alameda Naval Station in San Francisco Bay. Although the work was done to provide a basis for an informed decision on closure of a gap in that breakwater, the data have broader interest as a detailed account of the biota in that part of the Bay. Because there is pressing need for biological data on San Francisco Bay, the results of that study are here made available.

STUDY AREA

Alameda Harbor and breakwater were constructed in an expansive shallow flat (maximum depth approximately 6m) that extends about 2 nautical miles from the eastern shore of south San Francisco Bay. The floor of these shallows is a composite of sand-silt and shell fragments (mostly fossilized oyster shells). Aside from the Harbor, which has been dredged to a depth of approximately 15m, there are no depths greater than about 5m within 1.5km of the breakwater gap.

The marine habitat at the study site has been strongly affected by tidal currents that funnel through the gap with exceptional force. These currents have scoured a channel that extends from the gap a short distance into the Bay shallows (Figure 1). The channel where it passes through the gap is about 12-13m deep on either side, but 8-10m deep in the middle. It appears that the current's scouring action removes finer sediments from the channel's edges and deposits them in the middle, thus accounting for the mid-channel ridge. As a result, the deeper areas on either side of the channel are floored with greatly increased proportions of the denser shell, while the midchannel ridge is composed of lighter sediments. (Sediment samples were taken and turned over to the Navy). The benthic habitats within the gap, therefore, are very different from those widespread in the surrounding area of the Bay.

Samples were taken by divers operating from a 21-ft boat. The water was extremely turbid during all of this work, which greatly increased the difficulty of mapping environmental features. Visibility was never more than 0.3m, this near the surface next to the breakwater, and generally was considerably less than this. In the gap channel visibility was zero, and the work had to be done in total absence of visible light.

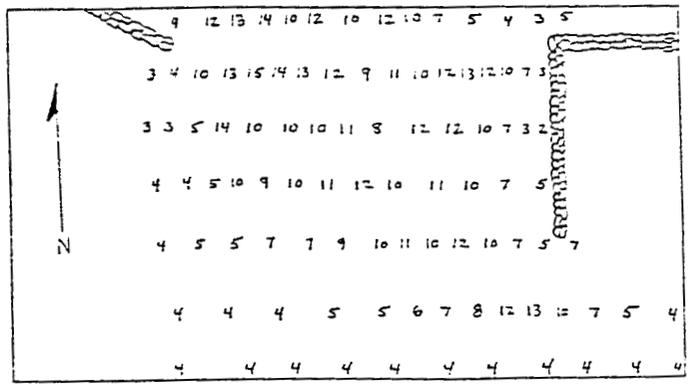
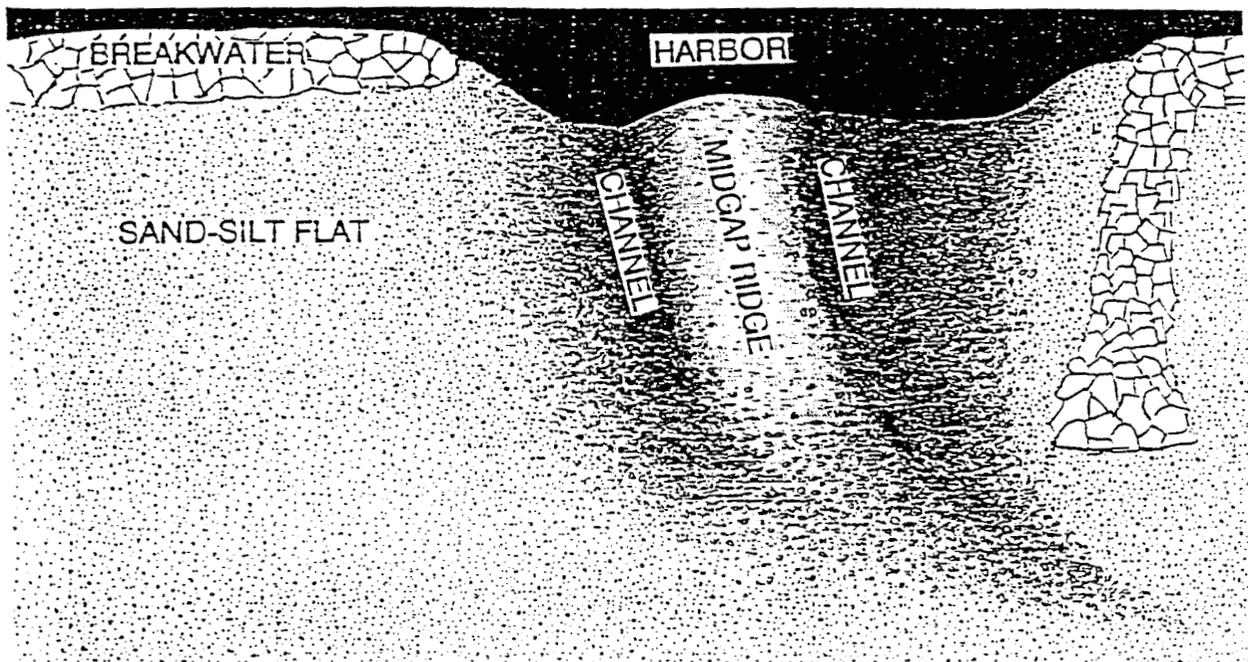


Figure 1. (Upper panel) Diagrammatic sketch of habitat features in vicinity of breakwater gap. (Lower panel) Depths in meters as determined by hydroacoustic transects using fathometer. These data are basis for mapping relative depths in upper panel.

SAMPLING CONSIDERATIONS

Samples of the benthos (cores, air-lift and visual assessments, the latter sharply limited by turbidity of the water) were taken at three sites in the gap, which is considered the Project Area, and at two sites outside the breakwater 100 m to the west of the gap, which is considered the Control Area. The Project-Area sites were: 1) In the channel on the eastern side of the gap, 2) on the ridge of fine sediment at mid-gap, and 3) on the surface of the east breakwater facing the gap (Figure 1). The Control-Area sites were: 1) on the sand flat 10m from the breakwater, and 2) on the surface of the breakwater.

Samples of the fishes (gill net and trawl) were taken near the surface and near the bottom in both the Project Area (mid-gap) and Control Area (100 m to west of the gap, 10m outside the breakwater). Surface skims with a neuston net were also taken at both areas. See Appendix 1 (methods) for details.

Underwater visual assessments generally were impossible because turbidity of the water generally limited visibility to a few centimeters or less. This same limitation also precluded photographs. Several alternative methods were used to assess features that might otherwise have been measured visually. Hydroacoustic transects provided a basis for mapping the submarine topography (Figure 1), and airlift collections permitted assessing relative proportions of invertebrates on sections of the breakwater. Although it was not possible to get quantitative underwater assessments of the macroalgae, these relatively large, sessile organisms could be located visually and collected by hand for further study in the laboratory, and this combination permitted estimates of relative abundance.

RESULTS

Organisms that constitute the biota in each of the sites sampled are listed in Tables 1-8.

DISCUSSION

Despite what would seem major differences in environmental conditions, the data indicate few differences in benthic invertebrates between the Project Area and the Control Area (Tables 1 & 7). Moreover, those few differences that were evident can be explained. For example, the barnacle Balanus hesperius laevidomus was numerous in both the Control Area and gap channel, but was absent on the mid-gap ridge, a circumstance readily explained by the lack of hard substrata (a requirement of

barnacles) on the ridge. And the greater abundance of the bivalve mollusk Potamocorbula amurensis on the ridge, compared to the other sites, may indicate that it favors the fine sediments there. (This species is not a natural inhabitant of San Francisco Bay, however, as it was accidentally introduced from the Orient within recent years.) Finally, the much greater abundance of the terebellid polychaete Polycirrus sp. in the Control Area compared to the Project Area probably relates to differences in sediment composition, an important habitat variable for this burrowing species.

Other than these few exceptions, the benthic invertebrates occurred similarly in the two areas. That they demonstrate broad tolerances to varied conditions is not surprising, because as sessile inhabitants of temperate-zone shallows they must be adapted to major seasonal changes in their environment.

In contrast to the benthic invertebrates, many of the fishes showed major differences in distribution between the Control Area and the Project Area, with greater numbers in the Control Area in every such case (Tables 2-5). These results indicate that conditions in the Project Area are less favorable for the species involved. Considering that the Project Area is a small pocket of aberrant conditions, this result could have been expected. It can be assumed that species which occur here regularly are adapted to the conditions that prevail in this part of the Bay, and that they are likely to favor these conditions when presented with an alternative. Thus, the fishes by their greater numbers in the Control Area would seem to be demonstrating preferences for conditions there compared to the Project Area.

Although the limited visibility prevented visual assessments of organisms on the breakwater, the results of the airlift collections made there fail to show differences between the Control Area and the Project Area (Table 7). Thus, the greater current velocities along the breakwater in the Project Area does not seem to influence occurrences of benthic invertebrates on that structure. The macro algae on the breakwater, too, showed generally the same species composition in Project and Control Areas (Table 8), although one notable exception was Fucus distichus, which was the dominant intertidal form in the Project Area, but was absent in the Control Area.

Table 1. ORGANISMS SAMPLED WITH BENTHIC CORES

taxa	Control Area			Project Area		
	freq	x no. (95% CL)	n	freq	x no. (95% CL)	n
Cnidaria						
Obelia sp.	0.29	0.28 (0.18)	0.00	0.00	0.00	0.00
<u>Stylatula elongata</u>	0.00	0.00 - -	0.00	0.00	0.05 (0.47)	0.05
Actinaria						
Actinaria unid.	0.03	0.03 (0.32)	0.00	0.00	0.25 (1.40)	0.35
Nemertea						
Nemertea unid.	0.55	1.03 (2.44)	0.10	0.15 (1.02)	0.20 (1.53)	0.30
Nematoda						
Nematoda unid	0.33	0.65 (2.69)	0.40	1.05 (4.04)	0.20 (1.70)	0.35
Oligochaeta						
Oligochaeta unid.	0.68	1.73 (4.17)	0.80	1.90 (3.59)	0.60 (2.47)	1.15
Polychaeta						
Polychaeta unid.	0.45	0.83 (2.33)	0.15	0.15 (0.77)	0.40 (1.05)	0.40
Ampharetidae unid.	0.05	0.05 (0.45)	0.00	0.00	0.00	0.00
Capitellidae unid.	0.33	0.45 (1.51)	0.05	0.05 (0.47)	0.10 (0.64)	0.10
Cirratulidae unid.	0.13	0.13 (0.68)	0.15	0.15 (0.77)	0.20 (1.15)	0.25
Chrysopetalidae unid.	0.00	0.00 - -	0.00	0.00	0.10 (0.64)	0.10
Glyceridae						
<u>Glycer</u> sp.	0.03	0.03 (0.32)	0.10	0.10 (0.64)	0.00	0.00
Goniadidae						
Goniadidae unid.	0.08	0.08 (0.54)	0.00	0.00	0.05 (0.47)	0.05
<u>Goniada brunnea</u>	0.40	0.53 (1.45)	0.45	0.85 (2.38)	0.65 (1.20)	0.70
Maldanidae						
Maldanidae unid.	0.08	0.08 (0.54)	0.00	0.00	0.00	0.00
<u>Asychis elongata</u>	0.00	0.00 - -	0.05	0.05 (0.47)	0.00	0.00
Nephtyidae						

(CON'T 2 of 4)

taxa	Control Area				Project Area							
	Sand Flat n=40				Mid-Gap Ridge n=20				Gap Channel n=20			
	freq	x no. (95% CL)	freq	x no. (95% CL)	freq	x no. (95% CL)	freq	x no. (95% CL)	freq	x no. (95% CL)	freq	x no. (95% CL)
Nephtyidae unid.	0.00	0.00 - -	0.00P	0.00 - -	0.05P	0.05 (0.47)	0.05P	0.05 (0.47)	0.05P	0.05 (0.47)	0.05P	0.05 (0.47)
<u>Nephtys caecoides</u>	0.00	0.00 - -	0.10	0.10 (0.64)	0.05	0.05 (0.47)	0.05	0.05 (0.47)	0.05	0.05 (0.47)	0.05	0.05 (0.47)
Nereidae												
Nereidae unid.	0.03	0.03 (0.34)	0.00	0.00 - -	0.00	0.00 - -	0.00	0.00 - -	0.00	0.00 - -	0.00	0.00 - -
<u>Cheilonereis cyclurus</u>	0.05	0.05 (0.45)	0.00	0.00 - -	0.00	0.00 - -	0.00	0.00 - -	0.00	0.00 - -	0.00	0.00 - -
Opheliidae												
<u>Armandia brevis</u>	0.03	0.03 (0.32)	0.00	0.00 - -	0.20	0.20 (1.37)	0.20	0.20 (1.37)	0.20	0.20 (1.37)	0.20	0.20 (1.37)
Orbiniidae												
(c.f. <u>Haploscoloplos elongatus</u>)	0.10	0.13 (0.82)	0.40	0.75 (2.95)	0.50	0.95 (2.30)	0.50	0.95 (2.30)	0.50	0.95 (2.30)	0.50	0.95 (2.30)
Polynoidae unid.	0.68	1.63 (3.62)	0.20	0.35 (1.56)	0.50	1.05 (3.36)	0.50	1.05 (3.36)	0.50	1.05 (3.36)	0.50	1.05 (3.36)
Sabellidae unid.	0.33	0.40 (1.28)	0.35	0.80 (2.59)	0.70	1.70 (4.30)	0.70	1.70 (4.30)	0.70	1.70 (4.30)	0.70	1.70 (4.30)
Spionidae												
Spionidae unid.	0.50	0.80 (3.21)	0.35	0.55 (2.40)	0.40	0.55 (1.59)	0.40	0.55 (1.59)	0.40	0.55 (1.59)	0.40	0.55 (1.59)
<u>Polydora brachycephala</u>	0.28	0.33 (1.16)	0.30	0.60 (2.66)	0.30	0.70 (2.89)	0.30	0.70 (2.89)	0.30	0.70 (2.89)	0.30	0.70 (2.89)
<u>Polydora limicola</u>	0.00	0.00 - -	0.15	0.40 (2.49)	0.05	0.05 (0.47)	0.05	0.05 (0.47)	0.05	0.05 (0.47)	0.05	0.05 (0.47)
<u>Polydora sp.</u>	0.20	0.25 (1.10)	0.15	0.35 (2.07)	0.00	0.00 - -	0.00	0.00 - -	0.00	0.00 - -	0.00	0.00 - -
<u>Streblospio benedicti</u>	0.00	0.00 - -	0.05	0.05 (0.47)	0.00	0.00 - -	0.00	0.00 - -	0.00	0.00 - -	0.00	0.00 - -
spionid A	0.00	0.00 - -	0.00	0.00 - -	0.15	0.45 (2.40)	0.15	0.45 (2.40)	0.15	0.45 (2.40)	0.15	0.45 (2.40)
Syllidae												
Syllidae unid.	0.40	0.93 (2.98)	0.40	0.60 (2.08)	0.65	1.05 (2.30)	0.65	1.05 (2.30)	0.65	1.05 (2.30)	0.65	1.05 (2.30)
<u>Exogone laurei</u>	1.00	23.28 (38.36)	0.85	5.75 (10.67)	1.00	16.60 (44.10)	1.00	16.60 (44.10)	1.00	16.60 (44.10)	1.00	16.60 (44.10)
Terebellidae												
Terebellidae unid.	0.63	4.43 (20.95)	0.25	0.25 (0.93)	0.20	0.45 (2.49)	0.20	0.45 (2.49)	0.20	0.45 (2.49)	0.20	0.45 (2.49)
<u>Amaena occidentalis</u>	0.05	0.08 (0.71)	0.35	0.50 (1.59)	0.15	0.25 (1.34)	0.15	0.25 (1.34)	0.15	0.25 (1.34)	0.15	0.25 (1.34)
<u>Polycirrus sp.</u>	0.98	13.13 (24.87)	0.05	0.05 (0.47)	0.55	1.10 (2.79)	0.55	1.10 (2.79)	0.55	1.10 (2.79)	0.55	1.10 (2.79)
Bivalvia												
Bivalvia unid.	0.08	0.10 (0.77)	0.05	0.05 (0.47)	0.10	0.10 (0.64)	0.10	0.10 (0.64)	0.10	0.10 (0.64)	0.10	0.10 (0.64)
<u>Clinocardium nuttalli</u>	0.00	0.00 - -	0.05	0.05 (0.47)	0.00	0.00 - -	0.00	0.00 - -	0.00	0.00 - -	0.00	0.00 - -

(CON'T 4 of 4)

taxa	Control Area			Project Area					
	Sand flat			Mid-Gap Ridge			Gap Channel		
	freq	x no. (95% CL)	n=40	freq	x no. (95% CL)	n=20	freq	x no. (95% CL)	n=20
Amphipoda									
Gammaridea									
Gammaridea unid.	0.20	0.25 (1.08)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ampelisca abdita	0.68	1.78 (3.82)	0.15	0.20 (1.09)	0.20	0.20 (0.86)	0.20	0.20 (0.86)	0.20
Corophium ascherusicum	0.18	0.40 (2.09)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corophium alienense	0.00	- -	0.10	0.10 (0.64)	0.00	0.00	0.00	0.00	0.00
Corophium insidiosum	0.00	- -	0.00	0.00	0.05	0.05 (0.47)	0.05	0.05 (0.47)	0.05
Corophium sp.	0.03	0.03 (0.32)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Microdeutopus schmitti	0.15	0.25 (1.50)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Photis sp.	0.03	0.03 (0.32)	0.00	0.00	0.05	0.05 (0.47)	0.05	0.05 (0.47)	0.05
Phoxocephalidae unid.	0.00	- -	0.05	0.05 (0.47)	0.05	0.05 (0.47)	0.05	0.05 (0.47)	0.05
Decapoda									
Upogebia pugettensis	0.13	0.13 (0.68)	0.00	0.00	0.00	0.00	0.25	0.25 (0.93)	0.25
Crangon sp.	0.00	- -	0.05	0.05 (0.47)	0.05	0.05 (0.47)	0.05	0.05 (0.47)	0.05
Pycnogonida unid.	0.00	- -	0.00	0.00	0.00	0.00	0.05	0.05 (0.47)	0.05
Phoronida									
Phoronis pallida	0.15	0.50 (2.75)	0.00	0.00	0.00	0.00	0.25	1.30 (7.95)	1.30
Ectoprocta									
Alcyonidium sp.	0.00	- -	0.00	0.00	0.00	0.00	0.15	0.45 (2.30)	0.45
Fish eggs unid.	0.00	- -	0.00	0.00	0.00	0.00	0.05	0.15 (1.40)	0.15

Table 2. FISHES SAMPLED WITH GILLNET DURING THE DAY
Control Area Project Area

taxa	Control Area				Project Area					
	freq	x NO.	x SL ¹	MIN	MAX	freq	x NO.	x SL ¹	MIN	MAX
TRIAKIDAE (Smoothhounds)										
<u>Mustelus henlei</u>	0.00	0.00	--	--	--	1.00	0.75	191.00	38	270
<u>Triakis semifasciata</u>	0.25	0.25	660.00	660	660	0.00	0.00	--	--	--
MYLIOBATIDAE (Eagle Rays)										
<u>Myliobatis californica</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
CLUPEIDAE (Herrings)										
<u>Clupea harengus pallasii</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
ENGRAULIDAE (Anchovies)										
<u>Engraulis mordax</u>	0.50	2.25	101.33	81	110	0.25	3.00	107.42	95	142
OSMERIDAE (Smelts)										
<u>Spirinchus starksi</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
BATRACHOIDIDAE (Toadfishes)										
<u>Porichthys notatus</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
SCORPAENIDAE (Rockfishes)										
<u>Sebastes auriculatus</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
COTTIDAE (Sculpins)										
<u>Artedius notospilotus</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<u>Leptocottus armatus</u>	0.00	0.00	--	--	--	0.25	0.50	88.50	85	92
SCIAENIDAE (Croakers)										
<u>Genyonemus lineatus</u>	0.00	0.00	--	--	--	0.25	0.50	163.56	85	223
EMBIOTOCIDAE (Surfperches)										
<u>Amphistichus argenteus</u>	0.50	0.50	202.50	195	210	0.00	0.00	--	--	--
<u>Cymatogaster aggregata</u>	0.25	0.25	65.00	65	65	0.00	0.00	--	--	--
<u>Damalichthys vacca</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<u>Embiotoca jacksoni</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<u>Hyperpropon argenteum</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<u>Micrometrus minimus</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
GOBIIDAE (Gobies)										
<u>Lepidogobius lepidus</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<u>Acanthogobius flavimanus</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<u>Tridentiger trigonocephalus</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--

(CON'T 2 of 2)

taxa	Control Area				Project Area			
	freq	x NO.	x SL ¹	MIN MAX	freq	x NO.	x SL ¹	MIN MAX
BOTHIDAE (Lefteye Flatfishes)								
<u>Citharichthys stigmaeus</u>	0.00	0.00	--	--	0.00	0.00	--	--
<u>Paralichthys californicus</u>	0.00	0.00	--	--	0.00	0.00	--	--
PLEURONECTIDAE (Righteye Flatfishes)								
<u>Hypsopsetta guttulata</u>	0.50	0.50	222.50	175 270	0.00	0.00	--	--
<u>Parophyrus vetulus</u>	0.00	0.00	--	--	0.00	0.00	--	--
<u>Pleuronichthys decurrens</u>	0.00	0.00	--	--	0.00	0.00	--	--
CYNOGLOSSIDAE (Tonguefishes)								
<u>Symphurus atricauda</u>	0.00	0.00	--	--	0.00	0.00	--	--

¹ Standard Length

Table 3. FISHES SAMPLED WITH GILLNET DURING THE NIGHT

taxa	Control Area n=4				Project Area n=4				
	freq	x NO.	x SL ¹	MIN MAX	freq	x NO.	x SL ¹	MIN MAX	
TRIAKIDIDAE (Smoothhounds)									
<u>Mustelus henlei</u>	1.00	4.25	404.10	200 750	1.00	1.25	556.00	400 760	
<u>Triakis semifasciata</u>	0.25	0.25	1000.00	1000 1000	0.00	0.00	--	--	--
MYLIOBATIDIDAE (Eagle Rays)									
<u>Myliobatis californica</u>	0.00	0.00	00	--	0.00	0.00	--	--	--
CLUPEIDAE (Herrings)									
<u>Clupea harengus pallasi</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
ENGRAULIDIDAE (Anchovies)									
<u>Engraulis mordax</u>	0.25	0.25	120.00	120 120	0.00	0.00	--	--	--
OSMERIDAE (Smelts)									
<u>Spirinchus starksi</u>	0.25	0.25	106.00	106 106	0.25	0.25	90.00	90 90	
BATRACHOIDIDAE (Toadfishes)									
<u>Porichthys notatus</u>	0.25	0.25	150.00	150 150	0.00	0.00	--	--	--
SCORPAENIDAE (Rockfishes)									
<u>Sebastes auriculatus</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
COTTIDAE (Sculpins)									
<u>Artedius notospilotus</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
<u>Leptocottus armatus</u>	0.25	0.25	120.00	120 120	0.00	0.00	--	--	--
SCIAENIDAE (Croakers)									
<u>Genyonemus lineatus</u>	0.25	0.25	180.00	180 180	0.00	0.00	--	--	--
EMBIOTOCIDAE (Surfperches)									
<u>Amphistichus argenteus</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
<u>Cymatogaster aggregata</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
<u>Damalichthys vacca</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
<u>Embiotoca jacksoni</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
<u>Hyperprosopon argenteum</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
<u>Micrometrus minimus</u>	0.00	0.00	--	--	0.00	0.00	--	--	--

(CON'T 2 of 2)

taxa	Control Area				Project Area				
	freq	x NO.	x SL ¹	MIN MAX	freq	x NO.	x SL ¹	MIN MAX	
GOBIIDAE (Gobies)									
<u>Lepidogobius lepidus</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
<u>Acanthogobius flavimanus</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
<u>Tridentiger trigonocephalus</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
BOTHIDAE (Lefteye Flatfishes)									
<u>Citharichthys stigmaeus</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
<u>Paralichthys californicus</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
PLEURONECTIDAE (Righteye Flatfishes)									
<u>Hypsopsetta guttulata</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
<u>Parophyrus vetulus</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
<u>Pleuronichthys decurrens</u>	0.00	0.00	--	--	0.00	0.00	--	--	--
CYNOGLOSSIDAE (Tonguefishes)									
<u>Symphurus atricauda</u>	0.00	0.00	--	--	0.00	0.00	--	--	--

¹ Standard Length

Table 4. FISHES SAMPLED WITH TRAWL DURING THE DAY

taxa	Control Area				Project Area			
	freq	x NO.	x SL ¹	MIN MAX	freq	x NO.	x SL ¹	MIN MAX
<u>Mustelus henlei</u>	0.25	0.25	265.00	265 265	0.50	1.50	258.83	235 270
<u>Triakis semifasciata</u>	0.00	0.00	--	-- --	0.00	0.00	--	-- --
MYLIOBATIDAE (Eagle Rays)								
<u>Myliobatis californica</u>	0.25	0.25	500.00	500 500	0.00	0.00	--	-- --
CLUPEIDAE (Herrings)								
<u>Clupea harengus pallasii</u>	0.25	0.75	51.33	48 56	0.00	0.00	--	-- --
ENGRAULIDAE (Anchovies)								
<u>Engraulis mordax</u>	1.00	33.00	65.18	49 92	1.00	5.00	75.28	55 100
OSMERIDAE (Smelts)								
<u>Spirinchus starksi</u>	0.50	0.50	36.00	35 37	0.00	0.00	--	-- --
BATRACHOIDIDAE (Toadfishes)								
<u>Porichthys notatus</u>	1.00	3.25	69.08	22 173	0.50	20.25	30.34	20 190
SCORPAENIDAE (Rockfishes)								
<u>Sebastes auriculatus</u>	0.50	0.50	64.00	48 80	0.50	3.00	74.58	40 100
COTTIDAE (Sculpins)								
<u>Artedius notospilotus</u>	0.25	0.50	49.50	44 55	0.00	0.00	--	-- --
<u>Leptocottus armatus</u>	0.75	9.00	84.75	61 112	1.00	10.75	88.76	67 115
SCIAENIDAE (Croakers)								
<u>Genyonemus lineatus</u>	0.50	1.00	56.75	47 67	0.75	5.75	133.50	67 186
EMBIOTOCIDAE (Surfperches)								
<u>Amphistichus argenteus</u>	0.00	0.00	--	-- --	0.00	0.00	--	-- --
<u>Cymatogaster aggregata</u>	0.75	7.25	65.52	43 100	1.00	1.00	66.50	46 95
<u>Damalichthys vacca</u>	1.00	2.75	97.18	52 180	0.00	0.00	--	-- --
<u>Embiotoca jacksoni</u>	0.50	0.50	75.00	65 85	0.00	0.00	--	-- --
<u>Hyperprosopon argenteum</u>	0.00	0.00	--	-- --	0.50	0.50	62.50	62 63
<u>Micrometrus minimus</u>	0.00	0.00	--	-- --	0.00	0.00	--	-- --
GobiIDAE (Gobies)								
<u>Lepidogobius lepidus</u>	0.75	24.50	55.64	41 72	1.00	27.00	58.75	40 74
<u>Acanthogobius flavimanus</u>	0.00	0.00	--	-- --	0.00	0.00	--	-- --
<u>Tridentiger trigonocephalus</u>	0.75	4.00	48.94	39 65	0.50	0.50	49.00	48 50

(CON'T 2 of 2)

taxa	Control Area				Project Area					
	freq	x NO.	x SL ¹	MIN	MAX	freq	x NO.	x SL ¹	MIN	MAX
BOTHIDAE (Lefteye Flatfishes)										
<u>Citharichthys stigmaeus</u>	1.00	48.00	53.15	32	70	1.00	13.50	55.43	25	84
<u>Paralichthys californicus</u>	0.25	0.25	280.00	280	280	0.25	0.25	680.00	680	680
PLEURONECTIDAE (Righteye Flatfishes)										
<u>Hypsopsetta guttulata</u>	0.25	0.25	168.00	168	168	0.25	0.25	100.00	100	100
<u>Parophyrus vetulus</u>	1.00	36.75	55.16	33	81	1.00	3.75	62.07	43	75
<u>Pleuronichthys decurrens</u>	0.25	0.25	55.00	55	55	0.00	0.00	--	--	--
CYNOGLOSSIDAE (Tonguefishes)										
<u>Symphurus atricauda</u>	0.75	0.25	85.50	73	95	0.50	3.75	78.50	77	80

¹ Standard Length

Table 5. FISHES SAMPLED WITH TRAWL DURING THE NIGHT
Control Area Project Area

taxa	Control Area				Project Area			
	freq	x NO.	x SL ¹	MIN MAX	freq	x NO.	x SL ¹	MIN MAX
TRIAKIDIDAE (Smoothhounds)								
<u>Mustelus henlei</u>	0.75	1.50	260.00	247 274	1.00	1.25	234.20	185 264
<u>Triakis semifasciata</u>	0.00	0.00	--	-- --	0.00	0.00	--	-- --
MYLIOBATIDIDAE (Eagle Rays)								
<u>Myliobatis californica</u>	0.25	0.25	550.00	550 550	0.00	0.00	--	-- --
CLUPEIDAE (Herrings)								
<u>Clupea harengus pallasi</u>	0.00	0.00	--	-- --	0.00	0.00	--	-- --
ENGRAULIDIDAE (Anchovies)								
<u>Engraulis mordax</u>	1.00	21.50	82.95	55 125	1.00	8.25	94.67	55 139
OSMERIDAE (Smelts)								
<u>Spirinchus starksi</u>	0.50	1.25	35.00	31 39	0.00	0.00	--	-- --
BATRACHOIDIDAE (Toadfishes)								
<u>Porichthys notatus</u>	1.00	17.50	32.90	20 218	1.00	5.75	32.35	19 142
SCORPAENIDAE (Rockfishes)								
<u>Sebastes auriculatus</u>	0.25	.25	100.00	100 100	1.00	6.00	61.50	37 105
COTTIDAE (Sculpins)								
<u>Artedius notospilotus</u>	0.00	0.00	--	-- --	0.00	0.00	--	-- --
<u>Leptocottus armatus</u>	1.00	14.50	87.12	61 108	0.50	0.75	89.00	65 115
SCIAENIDAE (Croakers)								
<u>Genyonemus lineatus</u>	1.00	10.25	134.54	36 230	0.75	4.00	126.50	48 193
EMBIOTOCIDAE (Surfperches)								
<u>Amphistichus argenteus</u>	0.25	0.25	230.00	230 230	0.00	0.00	--	-- --
<u>Cymatogaster aggregata</u>	1.00	4.00	65.06	51 89	0.75	2.25	72.00	59 117
<u>Damalichthys vacca</u>	0.00	0.00	--	-- --	0.25	0.25	92.00	92 92
<u>Embiotoca jacksoni</u>	0.50	0.50	62.50	62 63	0.00	0.00	--	-- --
<u>Hyperprosopon argenteum</u>	0.00	0.00	--	-- --	0.00	0.00	--	-- --
<u>Micrometrus minimus</u>	0.25	1.00	44.75	39 48	0.25	0.25	53.00	53 53
GOBIIDAE (Gobies)								
<u>Lepidogobius lepidus</u>	1.00	11.50	56.88	44 69	0.75	1.50	57.83	54 63
<u>Acanthogobius flavimanus</u>	0.25	0.25	74.00	74 74	0.00	0.00	--	-- --
<u>Tridentiger trigonocephalus</u>	0.25	0.50	44.00	41 47	0.25	0.25	45.00	45 45

(CON'T 2 of 2)

taxa	Control Area				Project Area					
	freq	x NO.	x SL ¹	MIN	MAX	freq	x NO.	x SL ¹	MIN	MAX
BOTHIDAE (Lefteye Flatfishes)										
<u>Citharichthys stigmatæus</u>	1.00	48.75	57.81	35	83	1.00	9.00	59.11	34	95
<u>Paralichthys californicus</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
PLEURONECTIDAE (Righteye Flatfishes)										
<u>Hypsopsetta guttulata</u>	0.50	1.50	169.83	152	195	0.25	0.25	223.00	223	223
<u>Parophyrus vetulus</u>	0.75	11.75	53.69	50	81	0.75	1.50	64.50	59	69
<u>Pleuronichthys decurrens</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
CYNOGLOSSIDAE (Tonguefishes)										
<u>Symphurus atricauda</u>	0.50	1.75	76.00	65	80	0.25	0.25	82.00	82	82

¹ Standard Length

TABLE 6. FISHES AND FISH EGGS SAMPLED WITH NEUSTON NET

	CONTROL AREA				PROJECT AREA			
	Day		Night		Day		Night	
	7/18	7/20	7/18	7/20	7/18	7/20	7/18	7/20
<u>Atherinopsis californicus</u> larvae	48	44	26	5	9	2	9	2
Unidentified fish larvae	0	0	4	2	0	0	0	2
<u>Engraulis mordax</u> eggs	90	74	70	410	15	31	190	84
Unidentified fish eggs	0	22	11	18	0	4	11	6

Table 7. BREAKWATER ORGANISMS SAMPLED WITH AIRLIFT

taxa	Control Area n=2			Project Area n=1		
	\bar{x}	Volume	Size (mm) min max	\bar{x}	Volume	Size (mm) min max
Porifera						
<u>Lucilla nuttingi</u>	1.0	0.1	- -	0.0	-	- -
Hydrozoa						
Hydrozoans unid.	P	0.1	- -	0.0	-	- -
<u>Obelia</u> sp.	P	0.1	- -	P	0.1	- -
Nemertea						
Nemertea unid.	0.5	0.1	- 13.0	10.0	0.1	- 7.0
Oligochaeta						
Oligochaeta unid.	2.0	0.1	4.0 5.0	0.0	-	- -
Sipunculida						
<u>Themiste</u> sp.	0.0	-	- -	10.0	0.1	- 8.0
Polychaeta						
Polychaeta unid.	1.0	0.1	4.0 10.0	10.0	0.1	- 5.0
Cirratulidae unid.	1.0	0.1	- 6.0	0.0	-	- -
Goniadidae unid.	2.5	0.1	3.0 6.0	10.0	0.1	- 7.0
Nereidae						
Nereidae unid.	5.0	0.1	4.0 15.0	0.0	-	- -
<u>Cheilonereis cyclurus</u>	2.5	1.0	20.0 45.0	0.0	-	- -
Opheliidae						
<u>Armandia brevis</u>	1.5	0.1	- 10.0	30.0	0.1	6.0 12.0
Orbiniidae unid.						
(c.f. <u>Haploscoloplos elongatus</u>)	0.0	-	- -	10.0	0.1	- 11.0
Polynoidae unid.	315.0	1.0	2.0 14.0	510.0	0.1	2.0 12.0
Sabelliidae unid.	5.0	0.1	- 4.0	10.0	0.1	- 5.0

(CON'T 2 of 4)

taxa	Control Area n=2				Project Area n=1				
	\bar{x}	Volume	Size (mm)		\bar{x}	Volume	Size (mm)		
			min	max			min	max	
Spionidae									
<u>Polydora sp.</u>	1.0	0.1	-	6.0	0.0	-	-	-	-
Syllidae									
Syllidae unid.	15.0	0.1	2.0	7.0	10.0	0.1	-	5.0	5.0
<u>Exogone laurei</u>	750.0	1.0	2.0	4.5	480.0	0.1	3.0	4.5	4.5
Bivalvia									
Bivalvia unid.	3.0	0.1	-	2.0	0.0	-	-	-	-
<u>Hiatella arctica</u>	4.0	0.1	-	2.0	0.0	-	-	-	-
<u>Modiolus rectus</u>	25.0	0.1	1.5	3.0	50.0	0.1	2.5	11.0	11.0
<u>Musculus senhousia</u>	50.0	0.1	1.2	5.0	80.0	0.1	1.8	6.8	6.8
<u>Mytilus edulis</u>	50.0	0.1	1.5	5.0	60.0	0.1	1.5	5.0	5.0
<u>Tapes japonica</u>	0.5	0.1	-	12.0	0.0	-	-	-	-
Gastropoda									
<u>Alia carinata</u>	0.0	-	-	-	10.0	0.1	-	9.0	9.0
<u>Alvinia compacta</u>	45.0	0.1	1.5	2.5	60.0	0.1	-	2.0	2.0
<u>Lacuna marmorata</u>	1.0	0.1	-	2.0	0.0	-	-	-	-
Ostracoda									
Podocopids unid.	90.0	0.1	0.6	1.0	60.0	0.1	-	0.6	0.6
<u>Sarsiella zostericola</u>	10.0	0.1	1.0	1.3	10.0	0.1	-	1.2	1.2
Copepoda									
Harpacticoida unid.	7.5	0.1	0.8	1.0	0.0	-	-	-	-
Cirripedia									
<u>Balanus hesperius</u>	0.0	-	-	-	20.0	0.1	3.0	5.0	5.0
<u>laevidomus</u>									

(CON'T 3 of 4)

taxa	Control Area n=2				Project Area n=1				
	\bar{x}	Volume	Size (mm) min max	\bar{x}	Volume	Size (mm) min max	\bar{x}	Volume	Size (mm) min max
Tanaidacea									
<u>Leptocheilia dubia</u>	245.0	5.5	1.5 6.0	280.0	0.1	2.0 6.0	280.0	0.1	2.0 6.0
Isopoda									
Anthuridae unid.	5.0	0.1	4.0 8.0	0.0	-	-	0.0	-	-
Amphipoda									
Gammaridea									
Gammaridea unid.	0.0	-	-	20.0	0.1	2.0	20.0	0.1	2.0 3.0
Ampelisca sp.	1.0	0.1	2.0 4.0	0.0	-	-	0.0	-	-
<u>Corophium ascherusicum</u>	22.0	0.1	2.0 4.0	0.0	-	-	0.0	-	-
<u>Corophium baconi</u>	0.0	-	-	20.0	0.1	-	20.0	0.1	3.0
<u>Jassa falcata</u>	10.0	0.1	3.0	0.0	-	-	0.0	-	-
<u>Microdeutopus schmitti</u>	0.0	-	-	10.0	0.1	-	10.0	0.1	8.0
Pleustidae unid.	25.0	0.1	2.0 6.0	30.0	0.1	2.0	30.0	0.1	2.0 5.0
<u>Podocerus brasiliensis</u>	45.0	0.1	2.0 4.0	40.0	0.1	2.5	40.0	0.1	2.5 4.0
<u>Pontogenia rostrata</u>	22.5	0.1	3.0 5.0	20.0	0.1	2.0	20.0	0.1	2.0 6.0
Stenothoidae unid.	5.0	0.1	2.0 3.0	10.0	0.1	-	10.0	0.1	3.0
Caprellidea									
<u>Caprella californica</u>	255.0	1.0	3.0 14.0	270.0	0.1	5.0	270.0	0.1	5.0 12.0
<u>Caprella incisa</u>	1.0	0.1	7.0	0.0	-	-	0.0	-	-
<u>Caprella mutica</u>	52.5	0.1	7.0	0.0	-	-	0.0	-	-
<u>Caprella verrucosa</u>	6.0	0.1	2.5 5.0	0.0	-	-	0.0	-	-
<u>Caprella</u> sp.	0.0	-	-	130.0	0.1	5.0	130.0	0.1	5.0 8.0
Decapoda									
<u>Petrolisthes</u> sp.	0.5	0.1	4.0	0.0	-	-	0.0	-	-
Pycnogonida unid.	15.0	0.1	5.0 20.0	0.0	-	-	0.0	-	-

(CON'T 4 of 4)

taxa	Control Area n=2			Project Area n=1		
	\bar{x}	vol.	Size (mm) min max	\bar{x}	Volume	Size (mm) min max
Bryozoa						
Bryozoa unid.	P	0.1	-	P	0.1	-
<u>Aeverillia</u> sp.	P	0.1	-	NP	-	-
<u>Alcyonidium</u> sp.	P	3.0	-	NP	-	-
<u>Bowerbankia</u> sp.	P	0.1	-	NP	-	-
<u>Bugula pacifica</u>	P	3.0	-	P	1.0	-
<u>Bugula</u> sp.	P	0.1	-	NP	-	-
<u>Crisia</u> sp.	P	0.1	-	P	0.1	-
<u>Filicrisia geniculata</u>	P	0.1	-	P	0.1	-
<u>Scrupocellaria diegensis</u>	P	89.0	-	P	95.0	-
Ascidians unid.	15.0	0.1	1.0 3.0	30.0	1.0	1.0 3.0
Fishes						
<u>Tridentiger</u>	0.0	-	-	1.0	0.1	-
<u>trigonocephalus</u>						54.0

TABLE 8. MACRO ALGAE ON BREAKWATER¹

taxa	Estimated Rank ² in Relative Abundance			
	Intertidal		Subtidal	
	Control	Project	Control	Project
CHLOROPHYTA				
<u>Enteromorpha intestinalis</u>	6	5	-	-
<u>Ulva lobata</u>	1	2	-	-
PHAEOPHYTA				
<u>Fucus distichus</u>	-	1	-	-
<u>Sargassum muticum</u>	-	-	1	1
RHODOPHYTA				
<u>Porphyra lanceolata</u>	2	6	-	-
<u>Porphyra sp.</u>	-	-	7	-
<u>Gelidium pusillum</u>	5	7	-	-
<u>Gigartina agardhii</u>	4	4	-	-
<u>G. exasperata</u>	-	-	4	2
<u>G. papillata</u>	3	3	-	-
<u>Rhodoglossum roseum</u>	-	-	3	-
<u>Iridaea cordata</u>	7	8	-	-
<u>I. flaccida</u>	-	-	-	5
<u>Gastroclonium coulteri</u>	-	-	2	6
<u>Ceramium sp.</u>	-	-	-	8
<u>Cryptopleura violacea</u>	-	-	6	4
<u>Polysiphonia sp.</u>	-	-	8	7
<u>Polyneura latissima</u>	-	-	5	3
Crustose corallines	8	-	-	-

¹ Values in this table are estimated rank, based on visual assessments. Approximate wet weights of a algae taken incidentally in air-lift collections were: Control Area 956.0 g/m²
Project Area 916.4 g/m²

² Top eight species ranked

APPENDIX 1 METHODS

Sampling Benthic Invertebrates

1. Benthic Cores.

Core specifications

Vented, capped tube of ABS Pipe.

Diameter: 10cm

Sampling Method.

Benthic cores were taken during mid-morning on 26 and 27 April, 1989. On each of these days 24 cores (replicate groups of 12) were taken along transects in the Control Area, and 24 along transects in the Project Area (12 from the gap channel, and 12 from the mid-gap ridge). From each group of 12 samples, 2 were preserved and set aside for possible future use by the U. S. Navy. Each group of 12 cores consisted of samples taken 1m apart, with the core inserted approximately 13cm into the sediment, thus taking one liter of sediment.

Sampling the fishes

1. Gill Nets

Net Specifications.

depth: 8 ft.

width: 150 ft (6-25ft. panels).

mesh: variable stretch mesh of 5 sizes, 1/2" to 3".

material: monofilament

Sampling method.

The gill-net collections consisted of two day-night series in both the Control Area and the Project Area, one series on 18 July, the other on 20 July. Each series included two daytime sets and two nighttime sets at each site, with each set lasting about one hour. The daytime sets were between 1145 and 1330 hr, the nighttime sets between 2210 and 2350 hr. Of the two sets in a series at the Project Area, one sampled the upper part of the water column, the other the lower. In the Control Area, however, all sets were from the bottom because the depth was not great enough to benefit from two-depth settings.

Sampling the fishes (continued)

2. Trawl

Trawl Specifications

Type: 16 ft. semi-balloon otter trawl
Mesh: body — 1 1/2in stretch mesh
cod end — 1 1/4in " "
liner — 1/2in " "

Sampling method

Trawl collections were made after each gill-net set, and thus followed the schedule presented above, except being about one hour later. Each collection lasted 10 minutes, with the boat motor maintained at 800 rpm, and sampled along the bottom.

3. Neuston Net ("Surface Skim")

Net specifications

Neuston net on 86 x 15.5cm rectangular frame
Mesh: 0.335mm nitex

Sampling method

The Neuston net sampled the water's surface layer to a depth of approximately 8cm. One neuston sample was taken after the second trawl collection in each segment of the day-night series described above. Net was deployed from an outrigger to one side of the boat, and towed for 10 min at 600 rpm within the gap and adjacent area (traversing a distance of approximately 300m, and filtering approximately 20m³ of water).

Assessments of Breakwater Organisms

With underwater visual assessments impossible because of the turbidity, an air-lift was used to assess organisms on the breakwater. Samples were taken from rock surfaces of the breakwater at three sites, one in the Project Area, the other two in the control Area. Each collection sampled approximately one-quarter meter of rock surface, taken as a narrow strip (the diameter of the air-lift intake) from just below the water's surface to near the base of the breakwater, a depth that varied from 2 to 5m.