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BIOTA OF A SHALLOW ESTUARINE  
HABITAT IN SAN FRANCISCO BAY

By

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Brian Jarvis, Carol Reilly, and Wayne Samiere

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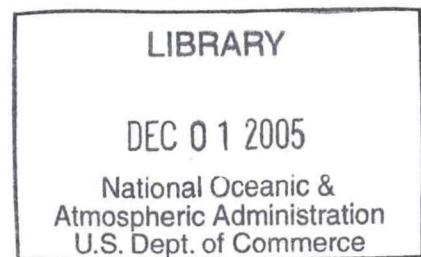


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## INTRODUCTION

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.

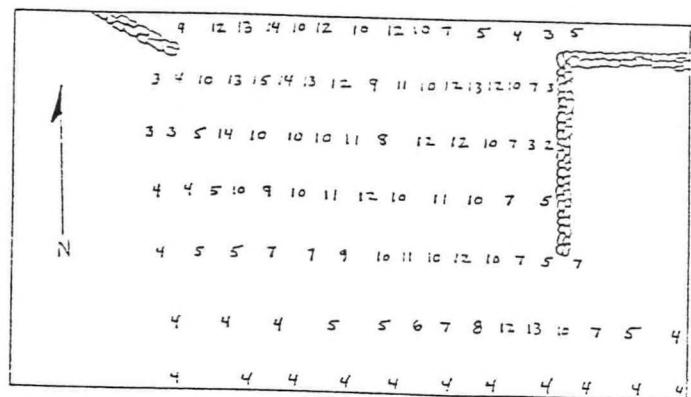
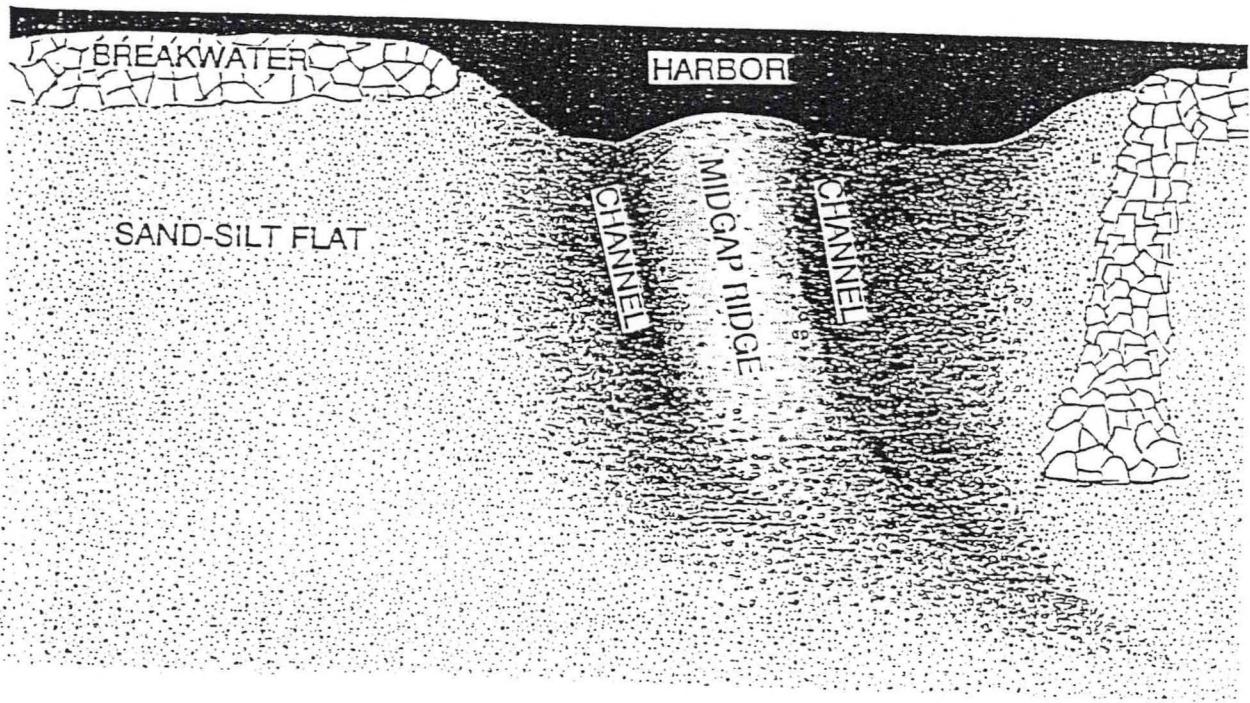


Figure 1. (Upper panel) Diagrammatic sketch of habitat features in vicinity of breakwater gap. (Lower panel) Depths in meters as determined by hydroacoustic transects using fathometer. These data are basis for mapping relative depths in upper panel.

## 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					
	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)
Cnidaria									
<u>Obelia</u> 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	- -	0.05	0.05 ( 0.47 )		
Actinaria									
Actinaria unid.	0.03	0.03 ( 0.32 )	0.00	0.00	- -	0.25	0.35 ( 1.40 )		
Nemertea									
Nemertea unid.	0.55	1.03 ( 2.44 )	0.10	0.15 ( 1.02 )		0.20	0.30 ( 1.53 )		
Nematoda									
Nematoda unid	0.33	0.65 ( 2.69 )	0.40	1.05 ( 4.04 )		0.20	0.35 ( 1.70 )		
Oligochaeta									
Oligochaeta unid.	0.68	1.73 ( 4.17 )	0.80	1.90 ( 3.59 )		0.60	1.15 ( 2.47 )		
Polychaeta									
Polychaeta unid.	0.45	0.83 ( 2.33 )	0.15	0.15 ( 0.77 )		0.40	0.40 ( 1.05 )		
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	0.10 ( 0.64 )		
Cirratulidae unid.	0.13	0.13 ( 0.68 )	0.15	0.15 ( 0.77 )		0.20	0.25 ( 1.15 )		
Chrysopetalidae unid.	0.00	0.00	- -	0.00	- -	0.10	0.10 ( 0.64 )		
Glyceridae									
<u>Glycera</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	0.05 ( 0.47 )		
<u>Goniada brunnea</u>	0.40	0.53 ( 1.45 )	0.45	0.85 ( 2.38 )		0.65	0.70 ( 1.20 )		
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	0.47 )	0.00	0.00	- -	
Nephtyidae									

## (CON'T 2 of 4)

## Control Area

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

(CONT' 3 of 4)

## Control Area

## Project Area

taxa	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	x no. (95% CL)
<u>Gemma gemma</u>	0.05	0.05 ( 0.45)		0.10	0.10 ( 0.64)		0.00	0.00		0.00
<u>Macoma</u> sp.	0.00	0.00 -		0.20	1.05 ( 5.58)		0.15	0.25	( 1.50)	- -
<u>Modiolus rectus</u>	0.08	0.10 ( 0.77)		0.00	0.00 -		0.00	0.00		- -
<u>Musculus senhousia</u>	0.65	1.40 ( 3.48)		0.30	0.40 ( 1.58)		0.35	0.40	( 1.25)	
<u>Mya arenaria</u>	0.08	0.08 ( 0.54)		0.00	0.00 -		0.00	0.00		- -
<u>Mytilus edulis</u>	0.15	0.20 ( 1.04)		0.00	0.00 -		0.00	0.00		- -
<u>Potamocorbula amurensis</u>	0.05	0.05 ( 0.45)		0.55	3.80 (11.91)		0.35	0.40	( 1.25)	
<u>Tapes japonica</u>	0.53	0.85 ( 2.07)		0.05	0.05 ( 0.47)		0.15	0.25	( 1.50)	
<u>Tellina</u> sp.	0.05	0.05 ( 0.45)		0.10	0.10 ( 0.64)		0.00	0.00		- -
<u>Siliqua lucida</u>	0.00	0.00 --		0.20	0.20 ( 0.86)		0.05	0.05	( 0.47)	
<u>Solen sicarius</u>	0.00	0.00 --		0.15	0.30 ( 1.53)		0.00	0.00	- -	
<u>Zirphaea pilosryi</u>	0.00	0.00 --		0.00	0.00 -		0.05	0.05	( 0.47)	

## Gastropoda

<u>Turbonilla</u> sp.	0.33	0.48 ( 1.58)		0.00	0.00 -		0.00	0.00		- -
<u>Okenia plana</u>	0.00	0.00 -		0.00	0.00 -		0.25	0.35	( 1.40)	
<u>Epitonium tintillum</u>	0.03	0.03 ( 0.32)		0.00	0.00 -		0.00	0.00		- -

## Ostracoda

<u>Sarssiella zostericola</u>	0.30	0.38 ( 1.35)		0.35	0.70 ( 2.46)		0.80	1.35	( 2.18)
Harpacticoida unid.	0.00	0.00 --		0.00	0.00 -		0.05	0.05	( 0.47)

## cirripedia

<u>Balanus hesperius</u>	0.90	15.30 (30.12)		0.00	0.00 -		0.85	19.85	(49.31)
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## Cumacea

Cumacea unid.	0.00	0.00 -		0.25	0.45 ( 2.40)		0.00	0.00	
<u>Leucon</u> sp.	0.00	0.00 -		0.35	1.95 ( 6.53)		0.40	0.75	( 3.32)

## Tanaidacea

<u>Leptocheilia dubia</u>	0.95	18.00 (32.01)		0.05	0.05 ( 0.47)		0.55	1.15	( 2.90)
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(CONT'N 4 of 4)

## Control Area

Sand flat  
n=40Project Area  
Mid-Gap Ridge  
n=20

taxa	freq	x no. (95% CL)	freq	x no. (95% CL)						
<b>Amphipoda</b>										
<i>Gammaridea</i> unid.	0.20	0.25 ( 1.08 )	0.00	0.00	—	—	0.00	0.00	0.00	—
<i>Ampelisca abdita</i>	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	0.20 ( 0.86 )
<i>Corophium ascherusicum</i>	0.18	0.40 ( 2.09 )	0.00	0.00	—	—	0.00	0.00	0.00	—
<i>Corophium alienense</i>	0.00	—	0.10	0.10 ( 0.64 )	0.00	0.00	0.00	0.00	0.00	—
<i>Corophium insidiosum</i>	0.00	—	0.00	0.00	—	—	0.05	0.05	0.05	( 0.47 )
<i>Corophium</i> sp.	0.03	0.03 ( 0.32 )	0.00	0.00	—	—	0.00	0.00	0.00	—
<i>Microdeutopus schmitti</i>	0.15	0.25 ( 1.50 )	0.00	0.00	—	—	0.00	0.00	0.00	—
<i>Photis</i> sp.	0.03	0.03 ( 0.32 )	0.00	0.00	—	—	0.05	0.05	0.05	( 0.47 )
<i>Phoxocephalidae</i> unid.	0.00	—	0.05	0.05 ( 0.47 )	0.05	0.05 ( 0.47 )	0.05	0.05 ( 0.47 )	0.05	( 0.47 )
<b>Decapoda</b>										
<i>Upogebia pugettensis</i>	0.13	0.13 ( 0.68 )	0.00	0.00	—	—	0.25	0.25 ( 0.93 )	0.05	0.05 ( 0.47 )
<i>Crangon</i> sp.	0.00	—	0.05	0.05 ( 0.47 )	0.05	0.05 ( 0.47 )	0.05	0.05 ( 0.47 )	0.05	0.05 ( 0.47 )
<b>Pycnogonida</b>										
<i>Phoronida</i> unid.	0.00	0.00	—	0.00	0.00	—	0.05	0.05	0.05	( 0.47 )
<i>Phoronis pallida</i>	0.15	0.50 ( 2.75 )	0.00	0.00	—	—	0.25	1.30 ( 7.95 )	1.30 ( 7.95 )	
<b>Ectoprocta</b>										
<i>Alcyonium</i> sp.	0.00	0.00	—	0.00	0.00	—	0.15	0.45	0.45	( 2.30 )
Fish eggs unid.	0.00	0.00	—	0.00	0.00	—	0.05	0.15	0.15	( 1.40 )

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

taxa	n=4						n=4						
	freq	x	NO.	x	SL <sup>1</sup>	MIN	MAX	freq	x	NO.	x	SL <sup>1</sup>	MIN
<b>TRIAKIDIDAE</b> (Smoothhounds)													
<i>Mustelus henlei</i>	0.00	0.00	--	--	--	--	--	1.00	0.75	191.00	38	270	
<i>Triakis semifasciata</i>	0.25	0.25	660.00	660	660	0.00	0.00	--	--	--	--	--	
<b>MYLIOBATIDAE</b> (Eagle Rays)													
<i>Myliobatis californica</i>	0.00	0.00	--	--	--	0.00	0.00	--	--	--	--	--	
<b>CLUPEIDAE</b> (Herrings)													
<i>Clupea harengus pallasi</i>	0.00	0.00	--	--	--	0.00	0.00	--	--	--	--	--	
<b>ENGRAULIDAE</b> (Anchoovies)													
<i>Engraulis mordax</i>	0.50	2.25	101.33	81	110	0.25	3.00	107.42	95	142			
<b>OSMERIDAE</b> (Smelts)													
<i>Spirinchus starksii</i>	0.00	0.00	--	--	--	0.00	0.00	--	--	--	--	--	
<b>BATRACHOIDIDAE</b> (Toadfishes)													
<i>Porichthys notatus</i>	0.00	0.00	--	--	--	0.00	0.00	--	--	--	--	--	
<b>SCORPAENIDAE</b> (Rockfishes)													
<i>Sebastodes auriculatus</i>	0.00	0.00	--	--	--	0.00	0.00	--	--	--	--	--	
<b>COTTIDAE</b> (Sculpins)													
<i>Artedius notospilotus</i>	0.00	0.00	--	--	--	0.00	0.00	--	--	--	--	--	
<i>Leptocottus armatus</i>	0.00	0.00	--	--	--	0.25	0.50	88.50	85	92			
<b>SCIACENIDAE</b> (Croakers)													
<i>Gennonemus lineatus</i>	0.00	0.00	--	--	--	0.25	0.50	163.56	85	223			
<b>EMBIOTOCIDAE</b> (Surfperches)													
<i>Amphistichus argenteus</i>	0.50	0.50	202.50	195	210	0.00	0.00	--	--	--	--	--	
<i>Cymatogaster aggregata</i>	0.25	0.25	65.00	65	65	0.00	0.00	--	--	--	--	--	
<i>Damalichthys vacca</i>	0.00	0.00	--	--	--	0.00	0.00	--	--	--	--	--	
<i>Embiotoca jacksoni</i>	0.00	0.00	--	--	--	0.00	0.00	--	--	--	--	--	
<i>Hyperprosopon argenteum</i>	0.00	0.00	--	--	--	0.00	0.00	--	--	--	--	--	
<i>Micrometrus minimus</i>	0.00	0.00	--	--	--	0.00	0.00	--	--	--	--	--	
<b>GOBIIDAE</b> (Gobies)													
<i>Lepidogobius lepidus</i>	0.00	0.00	--	--	--	0.00	0.00	--	--	--	--	--	
<i>Acanthogobius flavimanus</i>	0.00	0.00	--	--	--	0.00	0.00	--	--	--	--	--	
<i>Tridentiger trigonocephalus</i>	0.00	0.00	--	--	--	0.00	0.00	--	--	--	--	--	

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Control Area

Project Area

taxa	n=4				n=4					
	freq	x NO.	x SL <sup>1</sup>	MIN	MAX	freq	x NO.	x SL <sup>1</sup>	MIN	MAX
<b>BOTHIDAE</b> (Lefteye Flatfishes)	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<u>Citharichthys stigmaeus</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<u>Paralichthys californicus</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<b>PLEURONECTIDAE</b> (Righteye Flatfishes)	0.50	0.50	222.50	175	270	0.00	0.00	--	--	--
<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	--	--	--
<b>CYNOGLOSSIDAE</b> (Tonguefishes)	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<u>Sympodus atricauda</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--

<sup>1</sup> Standard Length

Table 3. FISHES SAMPLED WITH GILLNET DURING THE NIGHT

taxa	Control Area				Project Area			
	freq	x NO.	x SL <sup>1</sup>	MIN MAX	freq	x NO.	x SL <sup>1</sup>	MIN MAX
<b>TRIAKIDAE</b> (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	--	-- --
<b>MYLIOBATIDAE</b> (Eagle Rays)								
<u>Myliobatis californica</u>	0.00	0.00	00	--	0.00	0.00	--	-- --
<b>CLUPEIDAE</b> (Herrings)								
<u>Clupea harengus pallasi</u>	0.00	0.00	--	--	0.00	0.00	--	-- --
<b>ENGRAULIDAE</b> (Anchoovies)								
<u>Engraulis mordax</u>	0.25	0.25	120.00	120 120	0.00	0.00	--	-- --
<b>OSMERIDAE</b> (Smelts)								
<u>Spirinchus starksii</u>	0.25	0.25	106.00	106 106	0.25	0.25	90.00	90 90
<b>BATRACHOIDIDAE</b> (Toadfishes)								
<u>Porichthys notatus</u>	0.25	0.25	150.00	150 150	0.00	0.00	--	-- --
<b>SCORPAENIDAE</b> (Rockfishes)								
<u>Sebastes auriculatus</u>	0.00	0.00	--	--	0.00	0.00	--	-- --
<b>COTTIDAE</b> (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	--	-- --
<b>SCIAENIDAE</b> (Croakers)								
<u>Genyonemus lineatus</u>	0.25	0.25	180.00	180 180	0.00	0.00	--	-- --
<b>EMBIOTOCIDAE</b> (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	--	-- --

(CONT 2 of 2)

taxa	Control Area				Project Area					
	freq	x NO.	x SL <sup>1</sup>	MIN	MAX	freq	x NO.	x SL <sup>1</sup>	MIN	MAX
<b>GOBIIDAE</b> (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 triquonocephalus</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<b>BOTHIDAE</b> (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	--	--	--
<b>PLEURONECTIDAE</b> (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	--	--	--
<b>CYNOGLOSSIDAE</b> (Tonguefishes)										
<u>Symphurus atricauda</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--

<sup>1</sup> Standard Length

Table 4. FISHES SAMPLED WITH TRAWL DURING THE DAY

taxa	Control Area				Project Area					
	n=4 freq	x NO.	x SL <sup>1</sup>	MIN	MAX	n=4 freq	x NO.	x SL <sup>1</sup>	MIN	MAX
<u><i>Mustelus henlei</i></u>	0.25	0.25	265.00	265	265	0.50	1.50	258.83	235	270
<u><i>Triakis semifasciata</i></u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<b>MYLIOBATIDAE (Eagle Rays)</b>	0.25	0.25	500.00	500	500	0.00	0.00	--	--	--
<u><i>Myliobatis californica</i></u>										
<b>CLUPEIDAE (Herrings)</b>	0.25	0.75	51.33	48	56	0.00	0.00	--	--	--
<u><i>Clupea harengus pallasi</i></u>										
<b>ENGRAULIDAE (Anchoovies)</b>	1.00	33.00	65.18	49	92	1.00	5.00	75.28	55	100
<u><i>Engraulis mordax</i></u>										
<b>OSMERIDAE (Smelts)</b>	0.50	0.50	36.00	35	37	0.00	0.00	--	--	--
<u><i>Spirinchus starksii</i></u>										
<b>BATRACHOIDIDAE (Toadfishes)</b>	1.00	3.25	69.08	22	173	0.50	20.25	30.34	20	190
<u><i>Porichthys notatus</i></u>										
<b>SCORPAENIDAE (Rockfishes)</b>	0.50	0.50	64.00	48	80	0.50	3.00	74.58	40	100
<u><i>Sebastodes auriculatus</i></u>										
<b>COTTIDAE (sculpins)</b>	0.25	0.50	49.50	44	55	0.00	0.00	--	--	--
<u><i>Arctedius notospilotus</i></u>	0.75	9.00	84.75	61	112	1.00	10.75	88.76	67	115
<u><i>Leptocottus armatus</i></u>										
<b>SCIACENIDAE (croakers)</b>	0.50	1.00	56.75	47	67	0.75	5.75	133.50	67	186
<u><i>Genyonemus lineatus</i></u>										
<b>EMBIOTOCIDAE (Surfperches)</b>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<u><i>Amphistichus argenteus</i></u>	0.75	7.25	65.52	43	100	1.00	1.00	66.50	46	95
<u><i>Cymatogaster aggregata</i></u>										
<u><i>Damalichthys vacca</i></u>	1.00	2.75	97.18	52	180	0.00	0.00	--	--	--
<u><i>Embiotoca jacksoni</i></u>	0.50	0.50	75.00	65	85	0.00	0.00	--	--	--
<u><i>Hyperprosopon argenteum</i></u>	0.00	0.00	--	--	--	0.50	0.50	62.50	62	63
<u><i>Micrometrus minimus</i></u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<b>GOBIIDAE (Gobies)</b>	0.75	24.50	55.64	41	72	1.00	27.00	58.75	40	74
<u><i>Lepidogobius lepidus</i></u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<u><i>Acanthogobius flavimanus</i></u>	0.75	4.00	48.94	39	65	0.50	0.50	49.00	48	50
<u><i>Tridentiger triquonocephalus</i></u>										

(CON'T 2 of 2)

taxa	Control Area				Project Area					
	freq	n=4 x NO.	x SL <sup>1</sup>	MIN	MAX	freq	n=4 x NO.	x SL <sup>1</sup>	MIN	MAX
<b>BOTHIDAE</b> (Lefteye Flatfishes)										
<u>Citharichthys stigmatus</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
<b>PLEURONECTIDAE</b> (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	--	--	--
<b>CYNOGLOSSIDAE</b> (Tonguefishes)										
<u>Symphurus atricauda</u>	0.75	0.25	85.50	73	95	0.50	3.75	78.50	77	80
<sup>1</sup> Standard Length										

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

taxa	n=4				n=4					
	freq	x NO.	x SL <sup>1</sup>	MIN	MAX	freq	x NO.	x SL <sup>1</sup>	MIN	MAX
<b>TRIAKIDIDAE</b> (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	--	--	--
<b>MYLIOBATIDIDAE</b> (Eagle Rays)										
<u>Myliobatis californica</u>	0.25	0.25	550.00	550	550	0.00	0.00	--	--	--
<b>CLUPEIDAE</b> (Herrings)										
<u>Clupea harengus pallasi</u>	0.00	0.00	--	--	--	0.00	0.00	--	--	--
<b>ENGRAULIDIDAE</b> (Anchoovies)										
<u>Engraulis mordax</u>	1.00	21.50	82.95	55	125	1.00	8.25	94.67	55	139
<b>OSMERIDAE</b> (Smelts)										
<u>Spirinchus starksii</u>	0.50	1.25	35.00	31	39	0.00	0.00	--	--	--
<b>BATRACHOIDIDAE</b> (Toadfishes)										
<u>Porichthys notatus</u>	1.00	17.50	32.90	20	218	1.00	5.75	32.35	19	142
<b>SCORPAENIDAE</b> (Rockfishes)										
<u>Sebastes auriculatus</u>	0.25	.25	100.00	100	100	1.00	6.00	61.50	37	105
<b>COTTIDAE</b> (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
<b>SCIACENIDAE</b> (Croakers)										
<u>Gennonemus lineatus</u>	1.00	10.25	134.54	36	230	0.75	4.00	126.50	48	193
<b>EMBIOTOCIDAE</b> (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
<b>GOBIIDAE</b> (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)

**Control Area**

taxa	n=4						n=4					
	freq	x NO.	x SL <sup>1</sup>	MIN	MAX	freq	x NO.	x SL <sup>1</sup>	MIN	MAX		
<b>BOTHIDAE</b> (Lefteye Flatfishes)												
<u>Citharichthys stigmatus</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	--	--	--	
<b>PLEURONECTIDAE</b> (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	--	--	--	
<b>CYNOGLOSSIDAE</b> (Tonguefishes)												
<u>Symphurus atricauda</u>	0.50	1.75	76.00	65	80		0.25	0.25	82.00	82	82	

<sup>1</sup> Standard Length

TABLE 6. FISHES AND FISH EGGS SAMPLED WITH NEUSTON NET

	CONTROL AREA				PROJECT AREA			
	7/18 Day	7/20	7/18 Night	7/20	7/18 Day	7/20	7/18 Night	7/20
<i>Atherinopsis californicus</i> larvae	48	44	26	5	9	2	9	2
Unidentified fish larvae	0	0	4	2	0	0	0	2
<i>Engraulis mordax</i> 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			Size (mm) max
	x-	Volume	Size (mm) min max	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> )	315.0	0.0	-	10.0	0.1	-	11.0
Polynoidae unid.	5.0	1.0	2.0 14.0	510.0	0.1	2.0	12.0
Sabellidae unid.							

(CON'T 2 of 4)

	Control Area n=2			Project Area n=1		
taxa	$\bar{x}$	Volume	Size (mm) min max	$\bar{x}$	Volume	Size (mm) min max
<b>Spionidae</b>						
<u>Polydora</u> sp.	1.0	0.1	—	6.0	0.0	—
<b>Syllidae</b>						
<u>Syllidae</u> unid.	15.0	0.1	2.0	7.0	10.0	0.1
<u>Exogone laurei</u>	750.0	1.0	2.0	4.5	480.0	0.1
<b>Bivalvia</b>						
<u>Bivalvia</u> 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
<u>Musculus senhouseia</u>	50.0	0.1	1.2	5.0	80.0	0.1
<u>Mytilus edulis</u>	50.0	0.1	1.5	5.0	60.0	0.1
<u>Tapes iaponica</u>	0.5	0.1	—	12.0	0.0	—
<b>Gastropoda</b>						
<u>Alia carinata</u>	0.0	—	—	—	10.0	0.1
<u>Alvinia compacta</u>	45.0	0.1	1.5	2.5	60.0	0.1
<u>Lacuna marmorata</u>	1.0	0.1	—	2.0	0.0	—
<b>Ostracoda</b>						
<u>Podocopids</u> unid.	90.0	0.1	0.6	1.0	60.0	0.1
<u>Sarsiella zostericola</u>	10.0	0.1	1.0	1.3	10.0	0.1
<b>Copepoda</b>						
<u>Harpacticoida</u> unid.	7.5	0.1	0.8	1.0	0.0	—
<b>Cirripedia</b>						
<u>Balanus hesperius</u>	0.0	—	—	—	20.0	0.1
<u>Balanus 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
Tanaidacea						
<i>Leptocheilia dubia</i>	245.0	5.5	1.5    6.0	280.0	0.1	2.0    6.0
Isopoda						
<i>Anthuridae</i> unid.	5.0	0.1	4.0    8.0	0.0	-	-
Amphipoda						
Gammaridea						
<i>Gammaridea</i> unid.	0.0	-	-	20.0	0.1	2.0
<i>Amphilisca</i> sp.	1.0	0.1	2.0    4.0	0.0	-	-
<i>Corophium ascherusicum</i>	22.0	0.1	2.0    4.0	0.0	-	-
<i>Corophium baconi</i>	0.0	-	-	20.0	0.1	3.0
<i>Jassa falcata</i>	10.0	0.1	-	3.0	0.0	-
<i>Microdeutopus schmitti</i>	0.0	-	-	10.0	0.1	-
<i>Pleustidae</i> unid.	25.0	0.1	2.0    6.0	30.0	0.1	8.0
<i>Podocerus brasiliensis</i>	45.0	0.1	2.0    4.0	40.0	0.1	5.0
<i>Pontogenia rostrata</i>	22.5	0.1	3.0    5.0	20.0	0.1	4.0
<i>Stenothoidae</i> unid.	5.0	0.1	2.0    3.0	10.0	0.1	6.0
<i>Caprellidae</i>						
<i>Caprella californica</i>	255.0	1.0	3.0    14.0	270.0	0.1	5.0
<i>Caprella incisa</i>	1.0	0.1	-    7.0	0.0	-	12.0
<i>Caprella mutica</i>	52.5	0.1	-    7.0	0.0	-	-
<i>Caprella verrucosa</i>	6.0	0.1	2.5    5.0	0.0	-	-
<i>Caprella</i> sp.	0.0	-	-	130.0	0.1	5.0
Decapoda						
<i>Petrolisthes</i> sp.	0.5	0.1	-    4.0	0.0	-	-
Pycnogonida						
<i>unid.</i>	15.0	0.1	5.0    20.0	0.0	-	-

(CONT 4 of 4)

taxa	Control Area n=2		Project Area n=1		Size (mm) min max
	x	vol.	x	volume	
Bryozoa					
<i>Bryozoa</i> unid.	P	0.1	-	-	P 0.1
<i>Aeverrillia</i> sp.	P	0.1	-	-	NP -
<i>Alcyonidium</i> sp.	P	3.0	-	-	NP -
<i>Bowerbankia</i> sp.	P	0.1	-	-	NP -
<i>Bugula pacifica</i>	P	3.0	-	-	P 1.0
<i>Bugula</i> sp.	P	0.1	-	-	NP -
<i>Crisia</i> sp.	P	0.1	-	-	P 0.1
<i>Filicriisia geniculata</i>	P	0.1	-	-	P 0.1
<i>Scrupocellaria diegensis</i>	P	89.0	-	-	P 95.0
Ascidians unid.	15.0	0.1	1.0	3.0	30.0 1.0
Fishes					
<i>Tridentiger trigonocephalus</i>	0.0	-	-	1.0	0.1 -

TABLE 8. MACRO ALGAE ON BREAKWATER<sup>1</sup>

taxa	<u>Estimated Rank<sup>2</sup> in Relative Abundance</u>			
	Intertidal		Subtidal	
	Control	Project	Control	Project
<b>CHLOROPHYTA</b>				
<u>Enteromorpha intestinalis</u>	6	5	-	-
<u>Ulva lobata</u>	1	2	-	-
<b>PHAEOPHYTA</b>				
<u>Fucus distichus</u>	-	1	-	-
<u>Sargassum muticum</u>	-	-	1	1
<b>RHODOPHYTA</b>				
<u>Porphyra lanceolata</u>	2	6	-	-
<u>Porphyra</u> sp.	-	-	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</u> sp.	-	-	-	8
<u>Cryptopleura violacea</u>	-	-	6	4
<u>Polysiphonia</u> sp.	-	-	8	7
<u>Polyneura latissima</u>	-	-	5	3
Crustose corallines	8	-	-	-

<sup>1</sup> Values in this table are estimated rank, based on visual assessments. Approximate wet weights of algae taken incidentally in air-lift collections were: Control Area 956.0 g/m<sup>2</sup>  
Project Area 916.4 g/m<sup>2</sup>

<sup>2</sup> 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 20m<sup>3</sup> 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.