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DREDGE DISPOSAL STUDY, SAN FRANCISCO BAY AND ESTUARY. APPENDIX --ETC(U)
SEP 78

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1 OF 4
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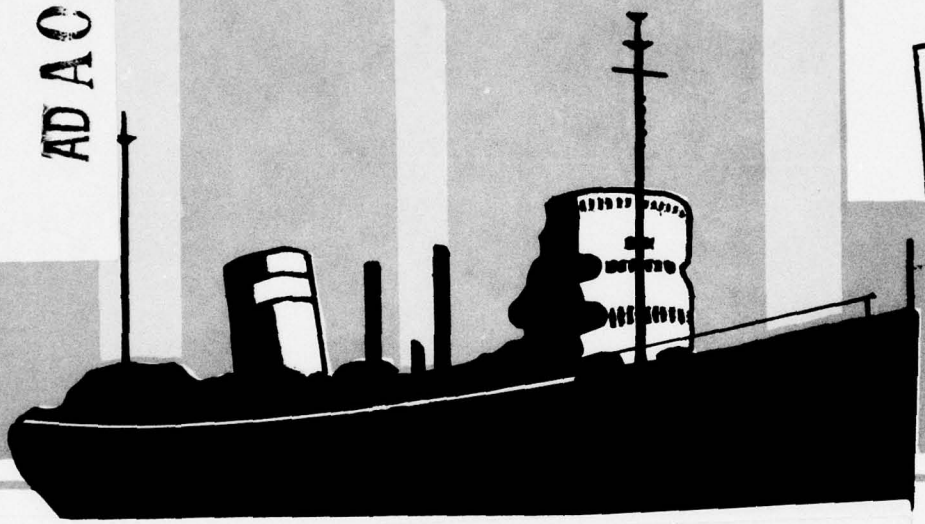


LEVEL II

DREDGE DISPOSAL STUDY

SAN FRANCISCO BAY AND ESTUARY

AD A061142



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APPENDIX N

ADDENDUM

SEPTEMBER 1978

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DREDGE DISPOSAL STUDY, SAN FRANCISCO BAY AND ESTUARY

APPENDIX N

ADDENDUM

AD-A038 315

(12) 348 P.

(11) SEPTEMBER 1978

U.S. Army Engineer District, San Francisco
Corps of Engineers
211 Main Street
San Francisco, California 94105

78 11 09 025
391 022

ABSTRACTS

FOREWORD

In April 1972, the San Francisco District of the United States Army Corps of Engineers initiated a study to quantify the impact of dredging and dredged sediment disposal operations on the environment of San Francisco Bay and Estuary. The study has generated factual data, based on field and laboratory studies, needed for the Federal, State and local regulatory agencies to evaluate present dredging policies and alternative disposal methods.

The study was set up to isolate the questions regarding the environmental impact of dredging operations and to provide answers at the earliest date. The study was organized to investigate (a) the factors associated with dredging and the present system of aquatic disposal in the Bay, (b) the condition of the pollutants (biogeochemical), (c) alternative disposal methods, and (d) dredging technology. The study elements were intended first, to identify the problems associated with dredging and disposal operations and, second, to address the identified problems in terms of mitigation and/or enhancement. The division into separate but inter-related study elements provided a greater degree of expertise and flexibility in the Study.

Since the publication of the Main Report in February 1977, several miscellaneous studies dealing with dredging were conducted in the Bay. Although the studies were not part of the Dredge Disposal Study, they have been gathered together to form this appendix in order to make the basic data available.

ABSTRACT

ACCESSION for
NTIS White Section
DDC Buff Section
UNANNOUNCED
JUSTIFICATION
BY
DISTRIBUTION/AVAILABILITY CODES
Dist. SPECIAL
A 23

The following is an index of appendices in the Dredge Disposal Study:

APPENDIX	REPORT	DATE PUBLISHED	NTIS NUMBER/ PRICE CODE *
-	MAIN REPORT	FEB 1977	AD-A037 727/SWP or AD-A038 308/3WP PC A06/MF A01
A	MAIN SHIP CHANNEL (SAN FRANCISCO BAR)	JUNE 1974	AD-A038 309/1WP PC A10/MF A01
B	POLLUTANT DISTRIBUTION	(Not yet published)	
C	WATER COLUMN (WATER COLUMN - OXYGEN SAG)	APR 1976	AD-A038 310/9WP PC A09/MF A01
D	BIOLOGICAL COMMUNITY	AUG 1975	AD-A037 728/3WP PC A20/MF A01
E	MATERIAL RELEASE	AUG 1977	AD-A043 790/5 GI
F	CRYSTALLINE MATRIX	JULY 1975	AD-A037 542/8WO PC A12/MF A01
G	PHYSICAL IMPACT	JULY 1975	AD-A038 311/7WP PC A10/MF A01
H	POLLUTANT UPTAKE	SEPT 1975	AD-A037 543/6WO PC A08/MF A01
I	POLLUTANT AVAILABILITY	OCT 1975	AD-A038 312/5WP PC A15/MF A01
J	LAND DISPOSAL	OCT 1974	AD-A038 313/3WP PC A18/MF A01
K	MARSH DEVELOPMENT	APR 1976	AD-A037 544/4GI PC A19/MF A01
L	OCEAN DISPOSAL	SEPT 1975	AD-A038 314/1WP PC A06/MF A01
M	DREDGING TECHNOLOGY	SEPT 1975	AD-A038 315/8WP PC A17/MF A01
N	ADDENDUM	SEPT 1978	-

* National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161

CONVERSION FACTORS

If conversion between Metric and British systems is necessary, the following factors apply:

LENGTH

1 kilometer (km)=10^3 meters=0.621 statute miles=0.540 nautical miles
1 meter (m)=10^2 centimeters=39.4 inches=3.28 feet=1.09 yards=0.547 fathoms
1 centimeter (cm)=10 millimeters (mm)=0.394 inches=10^4 microns (μ)
1 micron (μ)=10^{-3} millimeters=0.000394 inches

AREA

1 square centimeter (cm^2)=0.155 square inches
1 square meter (m^2)=10.7 square feet
1 square kilometer (km^2)=0.386 square statute miles=0.292 square nautical miles

VOLUME

1 cubic kilometer (km^3)=10^9 cubic meters=10^{15} cubic centimeters=0.24 cubic statute miles
1 cubic meter (m^3)=10^6 cubic centimeters=10^3 liters=35.3 cubic feet=264 U.S. gallons=1.308 cubic yards
1 liter=10^3 cubic centimeters=1.06 quarts=0.264 U.S. gallons
1 cubic centimeter (cm^3)=0.061 cubic inches

MASS

1 metric ton=10^6 grams=2,205 pounds
1 kilogram (kg)=10^3 grams=2.205 pounds
1 gram (g)=0.035 ounce

SPEED

1 knot (nautical mile per hour)=1.15 statute miles per hour=0.51 meter per second
1 meter per second (m/sec)=2.24 statute miles per hour=1.94 knots

TEMPERATURE

Conversion Formulas

$$°C = \frac{°F-32}{1.8} \qquad °F = 1.8(°C) + 32$$

DREDGE DISPOSAL STUDY
SAN FRANCISCO BAY AND ESTUARY

APPENDIX N - ADDENDUM

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Inclosure	Title
1	Results of Benthic Survey Near new U.S. Army Corps of Engineers Base Yard, Richardson Bay, Sausalito, California by the Marine Ecological Institute under San Francisco District Contract P.O. DACW07-75-E-1388, October 1974.
2	Analysis of Benthic Infaunal Samples, Oakland Outer Harbor, September 1975 - March 1976 by Leighton and Associates under San Francisco District Contract DACW07-76-C-0016, October 1976.
3	Laboratory Analysis of Phosphatic by U.S. Geologic Survey (USGS), 1 December 1977.
4	Sediment Dispension from a Submerged Pipeline, Symposium on Technical, Environmental, Socio-Economic and Regulatory Aspects of Coastal Zone Planning and Management, March 1978.
5	Survey of Benthic Macrofauna at the San Pablo Bay Dredge Disposal Site, July 1977 - April 1978 by Underwater Biological Research under Corps of Engineers Contract DACW07-77-C-0022, July 1977, Including:

Appendix A - Evaluation of Biological Sampling Procedure

Appendix B - Diver Observations During Inspection of Diffusen Pipe and Disposal Site

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Inclosure	Title
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	Appendix F - Benthic Infaunal Data Benthic Species and Abundance by Station and Period Benthic Species and Abundance by Repticate for Each Station
	Appendix G - Ten Most Abundant Species and Abundance by Stations and Periods in Numbers per Liter
6	Sediments and Sediment Disturbance During Dredging, Proceedings of the Fourth U.S. - Japan Experts' Meeting October 1978.

RESULTS OF BENTHIC SURVEY

NEAR NEW U. S. ARMY CORPS OF ENGINEERS BASE YARD,

RICHARDSON BAY, SAUSALITO, CALIFORNIA

Prepared by the

MARINE ECOLOGICAL INSTITUTE

811 Harbor Boulevard
Redwood City, California 94063

October 1974

The Marine Ecological Institute was contracted on October 1, 1974 (P. O. #DACW07-75-E-1388) to conduct a benthic fauna survey of macro-invertebrates within the project area of the new Corps of Engineers Base Yard, Richardson Bay, Sausalito, California (Chart 1.).

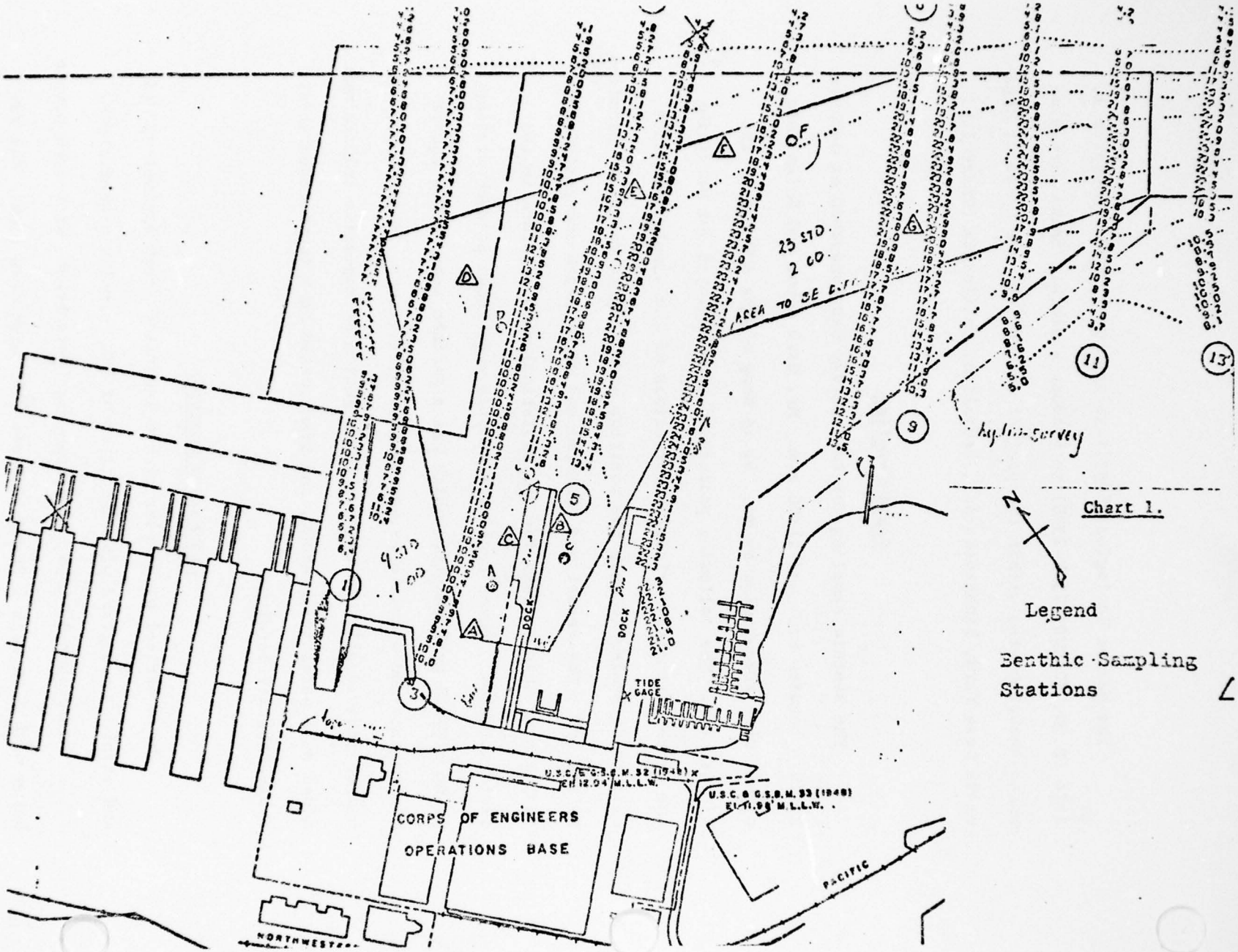
Field Sampling

The benthic sampling for this survey was conducted on October 2, 1974 between 8:00 and 11:00 a.m. Mr. Mark Kehoe and Brian Cole of MEI were accompanied by Mr. Calvin Wong of the ACE aboard the R/V Carolyn. The following procedures were employed for obtaining the benthic samples: visual observations of the sample site were made to determine roughly the position according to the chart provided by the ACE. The vessel was anchored and water depth and position (using hand-held compass for triangulation) were recorded in the field notebook. Three replicate samples were taken at each station, using a PONAR grab sampler, which has a surface area of 529 square centimeters and a sample volume of 5500 milliliters. Each sample was bagged individually, to which a 10% solution of magnesium sulfate was added as a narcotizing agent, and transported back to the laboratory aboard the R/V Carolyn.

Laboratory Analysis

Upon arrival of samples at the laboratory each bag was opened and samples were fixed with one liter of 10% formalin preservative.

On October 3, 1974, laboratory analysis began, with each sample being washed through a Standard Sieve #18, mesh size 1 mm. The raw


Chart 1.
Legend
Benthic Sampling Stations
CORPS OF ENGINEERS
OPERATIONS BASE
DOCK
TIDE GAGE
PACIFIC
NORTHWEST
AREA TO BE
25 STD
2 CO
survey

benthic material was sent to the sorting tables, where sorting into various phyla took place. Specimen identification followed the sorting, with various members of the MEI staff and California Academy of Science associates handling the identification task. Upon identifying the organisms reference collections were compiled. The most common species were retained in reference collections at MEI and the ACE. Those specimens which were rare or new to the region, along with the remainder of the collection, were given to Cal Academy. The academy will maintain this collection, which is available for verification upon request.

The following is a list of personnel who either identified or verified the various specimens collected during the survey:

Betty Bogle - Marine Ecological Institute -- barnacles.
Roger Leverette - " " " -- Amphipods.
W. J. Light - California Academy of Science -- Polychaete worms.
Jim Sutton - " " " -- bivalves, Ophiuroideas, opisthobranchs.
Pete Slatterly - Moss Landing Marine Lab -- Cumaceans.
Merritt Tuel - Marine Ecological Institute -- Bryozoans, Algae, fish, Coelenterates, crustaceans.

Results

Some general observations can be made concerning the area surveyed under this contract.

The sediment characteristics were pretty uniform throughout the sampling area (Table I). Sediment type ranged from silty clay to clay, and its color from greenish gray to black. The samples from Stations D through G were relatively free from detritus, with only small quantities of worm tubes and shell hash. However, these stations had less species diversity (Table I) than the stations closer to the pier. At the Stations A, B, and C, the sediments were dark gray to

black, most having a greasy feeling and an oily odor. The samples from this area contained large amounts of trash (cans, wire, glass, etc.), along with substantial quantities of organic detritus and muck. Yet, at these stations the species diversity was greater than the channel stations. At Station C the greatest diversity of species existed (27) in what appeared to be the worst anaerobic sediments in the area.

The polychaete worms were the most abundant and diversified group of organisms collected. There were 37 species of polychaetes found. The arthropods were second most abundant and third most diversified. The molluscan group was second most diversified and third most abundant.

As a result of this survey, a number of new species (to the San Francisco Bay Area) have been identified and will be on record at the Cal Academy of Science.

Table I contains the species and numbers found at the various stations. The following is a list of phyla in order of relative abundance found in the sampling area (starting with the most abundant, diminishing to the least abundant):

Phyla: Annelida
Arthropoda
Mollusca
Coelenterata
Nemertea
Bryozoa
Nematoda
Echinodermata
Chordata
Tardigrada
Phoronidea
Chlorophyta
Rhodophyta
Chrysophyta

Recommendations

The Institute would recommend that on future benthic surveys of macrofauna, sieving of samples be completed using a U. S. Standard Sieve of 0.5 mm. mesh. We also recommend that the samples be fixed with 10% formalin solution immediately upon obtaining the sample, and final preservation of the organisms be done with 70% ethanol.

References

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Light, S. F. et al Intertidal Invertebrates of the Central California Coast. 1954 University of California Press

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Richardson, H. Monogram: The Isopoda of North America. 1905 Bull. U. S. Nat. Mus. 54:liii - 727.

Shoemaker, C. R. The amphipod genus Corophium on the West Coast of America. 1949 Jour. Wash. Acad. Sci. 39:49-51, Figs. 2,3.

Slatterly Pete Cumacean identification. (Oral communication).

Smith, G. M. Marine Algae of the Monterey Peninsula. 1966 Stanford University Press.

Sutton, J. Bivalve identification. (Oral communication).

TABLE I

Sample	A-1	A-2	A-3	B-1	B-2	B-3	C-1	C-2	C-3	D-1	D-2	D-3	E-1	E-2	E-3	F-1	F-2	F-3	G-1	G-2	G-3	Piling
Physical Characteristics:																						
Sediment type (s = silt, c = cla)	s. cl.	s. cl.	s. cl	clay	s. cl.	s. cl.	s. cl.	s. cl.	s. cl.	s. cl.	s. cl.	s. cl.	s. cl.	s. cl.	s. cl.	s. cl.	s. cl.	s. cl.	s. cl.	s. cl.	s. cl.	
Color (dk = dark, gr = gray, blk = black, gn = green)	gray	dk. gr	dk. gr	dk. gr	blk.	dk. gr.	blk.	blk.	blk.	gn.gr.	gray	gray	dk. gr	dk. gr	dk. gr	dk. gr	dk. gr	dk. gr	gray	gray	gray	
Volume of Sample (in liters)	5.0	5.0	5.5	5.0	4.5	4.5	.5	2.5	1.5	5.5	5.0	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	
Fauna and Flora List:																						
· Phylum: COELENTERATA																						
Class: ANTHOZOA																						
Diadumene leucolena				1			3	1														
Stylatula elongata										3	5	2						1		1		
· Phylum: NEMERTEA																						
unidentified	8		1	1				1		1			1									6
· Phylum: BRYOZOA																						
Bowerbankia gracilis																						1 co
Bugula californica	1 col.			1 col		1 col.	1 col	1 col	1 col								1 col	1 col.				
Bugula neritina								1 col														
· Phylum: PHORONIDEA																						
unidentified								1														
· Phylum: NEMATODA																						
unidentified							7			2										1		
· Phylum: ANNELIDA																						
Class: OLIGOCHAETA																						
unidentified				2	8				1	11							3					
Class: POLYCHAETA																						
Armandia brevis	2	1	1	1	7	8	7	25	20				1						1			
Asychis elongata				4	1	8				1		6						1		4		
Capitella capitata			1		2		5	7	9					1								
Cossura nr. candida	105		88	8	35	34		2	1	6	1		17	20	12		93	612	111	26	89	

TABLE I (Cont.)

Sample	A-1	A-2	A-3	B-1	B-2	B-3	C-1	C-2	C-3	D-1	D-2	D-3	E-1	E-2	E-3	F-1	F-2	F-3	G-1	G-2	G-3	Pil ing
Dorvillea annulata								5														
Dorvillea sp.								2														
Eteone dilatae																			4			
Eteone longa			1														1					
Exogone lourei					1	4		4	2													
Glycera americana				1		5		1	2		10				1				1			
Glycera sp. (juv.)					1					1							5					
Glycinde sp.	10	2	5	2	1	11	2	6	2	3		3	3	15	2	3	5	9	6	13	9	
Gyptis cf. brevipalper			1									1										
Haploscoloplos elongatus		13																				
Haploscoloplos pugettensis			5	6	9	1	1	19	13	4	1	3	10	6	5	3		3	5	3	5	
Harmothoe cf. imbricata						2				1												
Harmothoe sp.								2	1		1							1				
Heteromastus filobranchus	5			3		1				4	1		2	4	2	1	4	5	5	7	11	
Lumbrineris zonata										1												
Lumbrineris sp.											1											
Malmgrenia lunulata	1										1		1	1	2							
Mediomastus californiensis													1									
Nephtys caecoides											1											
Nephtys cornuta franciscana					2					1	1		1		3	3	2	16	3		6	
Nephtys ferruginea	1																					
Nereis procera				3	3																	
Nereis sp.							1		1			1										
Pectinaria californiensis		1											1		1						2	
Pholoe minuta	1										1						2					
Platynereis bicanaliculata							2															
Polydora ligni	2		1					2														
Polydora sp.									1													
Polynoids (juv.)																	1					
Pseudopolydora kempi		1	1																			

TABLE I (Cont.)

Sample	A-1	A-2	A-3	B-1	B-2	B-3	C-1	C-2	C-3	D-1	D-2	D-3	E-1	E-2	E-3	F-1	F-2	F-3	G-1	G-2	G-3	Piling
Pseudopolydora paucibranchiata																		1				
Streblospio benedicti	21	1	14	8	50	9	1	2	2			2	1									
Tharyx parvus			1	8	2	1												6				
Trochochaeta multisetosum	2				2					4	3	6		2		1		7		7	1	
Phylum: ARTHROPODA																						
Class: CRUSTACEA																						
Ostracoda (unidentified)	1		1																			
Order: Thoracica																						
Balanus glandula																						105
Class: MALACOSTRACA																						
Order: Cumacea																						
Eudorella pacifica	10	15	44		2			2	14	5	5	4		4	6		2	18		3	3	
Order: Amphipoda																						
Ampelisca milleri	2	2	3	11	12	6		7	7				4	1		1			11			
Caprella equilibra																						1
Corophium acherusicum	5		1	2	4	16		5	24	1							1	1	4			3
Grandidierella japonica	11	3	4		14	23	22	32	32									1			1	
Synchelidium fimbriatus							1	3														
Order: Tanaidacean																						
Leptochelia savignyi		1	1	2	7	2		14														
Order: Isopoda																						
Gnorimosphaeroma oregonensis																						1
Order: Decapoda																						
Pinnixa franciscana															1							
Class: INSECTA																						
Order: Diptera																						
Diptera larva																						1
Phylum: TARDIGRADA																						1
Phylum: MOLLUSCA																						
Class: GASTROPODA																						
Order: Cephalaspidea																						
Aglaja diomedea											1											

TABLE I (Cont.)

Sample	A-1	A-2	A-3	B-1	B-2	B-3	C-1	C-2	C-3	D-1	D-2	D-3	E-1	E-2	E-3	F-1	F-2	F-3	G-1	G-2	G-3	Pil-ing
Class: PELECYPODA																						
Order: Filibranchia																						
Mytilus edulis																						11
Order: Eulamellibranchia																						
Clinocardium nuttallii	1		1																			
Gemma gemma			1														1					
Macoma inquinata	2	1		2		1		2		1												
Macoma nasuta	9	6	3	2	2	1		1		6	5	7		6	2	3	4	6	7	5	4	
Macoma sp.													1		1			2	6		2	
Macoma yoldiformis									1													
Mya arenaria		1		1																		
Mysella sp.															1	1		1				
Protothaca staminea		1									1											
Solen sicarius				1	1	1																
Transenella tantilla		9	1								1		4	2	1	1	2	1	12		4	
Phylum: ECHINODERMATA																						
Class: OPHIUROIDEA																						
Amphiodia urtica											2							1				
Class: HOLOTHUROIDEA																						
unidentified	1		4																			
Phylum: CHORDATA																						
Class: OSTEICHTHYS																						
Porichthys notatus (plain fin midshipmen)									1													
Fish larva									1													
Phylum: CHLOROPHYTA																						
Enteromorpha chlorophyta					1 cl.			1 cl.														1 cl.
Rhizoclonium implexum	1 str.																					
Ulva sp.							1 cl.	1 cl.							1 cl.							1 cl.

TABLE I (Cont.)

Sample	A-1	A-2	A-3	B-1	B-2	B-3	C-1	C-2	C-3	D-1	D-2	D-3	E-1	E-2	E-3	F-1	F-2	F-3	G-1	G-2	G-3	Pil ing
· Phylum: RHODOPHYTA																						
Gracilaria verrucosa						1 cl.	1 cl.	1 cl.				1 cl.		1 cl.			1 cl.	1 cl.			1 cl.	
· Phylum: CHRYSOPHYTA																						
Achnanthes sp. (diatom)																						1 cl
Total number of species per sample	22	15	23	21	23	20	13	27	20	18	18	11	14	12	15	9	16	21	13	10	13	12
Total number of species per station		23			23			27			18			15			21			13		

col. = colony
cl. = clump
str. = strand

PROJECT 2894
ALL SURVEYS
COMPUTER CODES

SPECIES LIST

COMPUTER CODE	FULL NAME	GROUP
1. Arachnida US	Arachnida-Unidentified spp.	Arthropoda
2. A milleri	Ampelisca milleri	Arthropoda
3. Anaitides	Anaitides sp.	Polychaeta
4. A brevis	Armandia brevis	Polychaeta
5. A williamsi	Anaitides williamsi	Polychaeta
6. A williamsi J	Anaitides williamsi - juvenile	Polychaeta
7. A diegensis	Adula diegensis	Mollusca
8. $Asychis	? Asychis sp.	Polychaeta
9. Asychis	Asychis sp.	Polychaeta
10. Ampharetidae US	Ampharetidae-Unidentified spp.	Polychaeta
11. Autolytus	Autolytus sp.	Polychaeta
12. A compacta	Alvinia compacta	Mollusca
13. A parasiticum	Alcyonidium parasiticum	Ectoprocta
14. Acarina US	Acarina-Unidentified spp.	Arthropoda
15. near A williamsi	Anaitides sp., near williamsi	Polychaeta
16. Ascidiacea US	Ascidiacea-Unidentified spp.	Chordata
17. Amphipoda US	Amphipoda-Unidentified spp.	Arthropoda
18. Anthuridae US	Anthuridae-Unidentified spp.	Arthropoda
19. A polyoum	Alcyonidium polyoum	Ectoprocta
20. A anquina	Aetea anquina	Ectoprocta
21. B cf amphitrite	Balanus sp., cf amphitrite	Arthropoda
22. Brachyura US	Brachyura-Unidentified spp.	Arthropoda
23. Bugula	Bugula sp.	Ectoprocta
24. B neritina	Bugula neritina	Ectoprocta
25. B gracilis	Bugula gracilis	Ectoprocta
26. B canaliculatum	Busycon canaliculatum	Mollusca
27. B truncata	Boccardia truncata	Polychaeta
28. B californica	Bugula californica	Ectoprocta
29. B improvisus	Balanus improvisus	Arthropoda
30. C acherusicum	Corophium acherusicum	Arthropoda
31. C insidiosum	Corophium insidiosum	Arthropoda
32. Corophium	Corophium sp.	Arthropoda
33. C cf insidiosum	Corophium sp., cf insidiosum	Arthropoda
34. Copepoda US	Copepoda-Unidentified spp.	Arthropoda
35. C vulgaris	Cumella vulgaris	Arthropoda
36. C capitata	Capitella capitata	Polychaeta
37. C mutabilis	Carinoma mutabilis	Nemertea
38. $C mutabilis	? Carinoma mutabilis	Nemertea
39. C convexa	Crepidula convexa	Mollusca
40. C plana	Crepidula plana	Mollusca
41. cf C mutabilis	cf Carinoma mutabilis	Nemertea
42. C pygodactylata	Cossura pygodactylata	Polychaeta
43. C cirratus	Cirratulus cirratus	Polychaeta
44. Cumacea US	Cumacea-Unidentified spp.	Arthropoda
45. Cnidaria US	Cnidaria-Unidentified spp.	Cnidaria
46. C hamata	Caulleriella hamata	Polychaeta
47. Calypto USA	Calyptoblastea-Unidentified sp. A	Hydrozoa
48. Calypto USB	Calyptoblastea-Unidentified sp. B	Hydrozoa

		GROUP?
49. Calypto US	Calyptoblastea-Unidentified spp.	Hydrozoa
50. Callopora	Callopora sp.	Ectoprocta
51. C paluta	Chapperia paluta	Ectoprocta
52. C praelonga	Cheilopora praelonga	Ectoprocta
53. Cellaria	Cellaria sp.	Ectoprocta
54. C maxima	Crisia maxima	Ectoprocta
55. C occidentalis	Crisia occidentalis	Ectoprocta
56. $Chaetozone	? Chaetozone sp.	Polychaeta
57. Chaetozone	Chaetozone sp.	Polychaeta
58. C minuta	Chone minuta	Polychaeta
59. C cf antennarius	Cancer sp., cf antennarius	Arthropoda
60. C cf ecaudata	Chone sp., cf ecaudata	Polychaeta
61. Cirratulidae US	Cirratulidae-Unidentified spp.	Polychaeta
62. C pallasiana	Cryptosula palliasana	Ectoprocta
63. $Chone	? Chone sp.	Polychaeta
64. C ambiseta	Capitita ambiseta	Polychaeta
65. C reticulum	Conopeum reticulum	Ectoprocta
66. Cirripedia US	Cirripedia-Unidentified spp.	Arthropoda
67. C spirabrancha	Cirriformia spirabrancha	Polychaeta
68. Capitella	Capitella sp.	Polychaeta
69. Capitellidae US	Capitellidae-Unidentified spp.	Polychaeta
70. $Capitella	? Capitella sp.	Polychaeta
71. C armata	Callopora armata	Ectoprocta
72. C commensale	Conopeum commensale	Ectoprocta
73. $Capitella J	? Capitella sp. - juvenile	Polychaeta
74. Capitellidae UJ	Capitellidae-Unidentified juvenile	Polychaeta
75. Decamastus	Decamastus sp.	Polychaeta
76. Dorvillea J	Dorvillea sp. - juvenile	Polychaeta
77. D annulata	Dorvillea annulata	Polychaeta
78. Dorvillea	Dorvillea sp.	Polychaeta
79. Decapoda US	Decapoda-Unidentified spp.	Arthropoda
80. Decapoda UL	Decapoda-Unidentified larvae	Arthropoda
81. cf Diadumene	cf Diadumene sp.	Hydrozoa
82. E lourei	Exogene lourei	Polychaeta
83. E long calif	Eteone longa californica	Polychaeta
84. Eggs US	Eggs-Unidentified spp.	----------
85. E dilatae	Eteone dilatae	Polychaeta
86. E lighti	Eteone lighti	Polychaeta
87. E limnicola	Euchone limnicola	Polychaeta
88. E arctica	Electra arctica	Ectoprocta
89. $Euchone	? Euchone sp.	Polychaeta
90. Enigmatica	Enigmatica	----------
91. Exogene	Exogene sp.	Polychaeta
92. Eumida	Eumida sp.	Polychaeta
93. E cf long calif	Eteone sp., cf longa californica	Polychaeta
94. Eubranchidae US	Eubranchidae-Unidentified spp.	Mollusca
95. near E sanguinea	near Eumida sanguinea	Polychaeta
96. E crustulenta	Electra crustulenta	Ectoprocta
97. Eunicidae US	Eunicidae-Unidentified spp.	Polychaeta
98. E cf lighti	Eteone sp., cf lighti	Polychaeta
99. E cf dilatae	Eteone sp., cf dilatae	Polychaeta
100. E tinctum	Epitonium tinctum	Mollusca
101. Ectoprocta US	Ectoprocta-Unidentified spp.	Ectoprocta

			GROUP
102.	Foraminifera US	Foraminifera-Unidentified spp.	Protozoa
103.	Fartulum	Fartulum sp.	Mollusca
104.	Filicrisia	Filicrisia sp.	Ectoprocta
105.	Glycinde	Glycinde sp.	Polychaeta
106.	G japonica	Grandidierella japonica	Arthropoda
107.	G gemma	Gemma gemma	Mollusca
108.	cf Gonothyraea	cf Gonothyraea sp.	Hydrozoa
109.	near Gonothyraea	near Gonothyraea sp.	Hydrozoa
110.	G americana	Glycera americana	Polychaeta
111.	G tenuis	Glycera tenuis	Polychaeta
112.	Gammaridae US	Gammaridae-Unidentified spp.	Arthropoda
113.	G arenicola glabra (Bill check-off name)	Gyptis brevipalpa	Polychaeta
114.	Glycinde J	Glycinde sp. - juvenile	Polychaeta
115.	Gonothyraea	Gonothyraea sp.	Hydrozoa
116.	Glycera J	Glycera sp. - juvenile	Polychaeta
117.	Glycera	Glycera sp.	Polychaeta
118.	H imbricata	Harmothoe imbricata	Polychaeta
119.	H filiformis	Heteromastus filiformis	Polychaeta
120.	cf Haliplanella	cf Haliplanella sp.	Hydrozoa
121.	H pugettensis	Haploscoloplos pugettensis	Polychaeta
122.	cf Harmothoe	cf Harmothoe sp.	Polychaeta
123.	Holothuroidea US	Holothuroidea-Unidentified spp.	Echinodermata
124.	Harmothoe	Harmothoe sp.	Polychaeta
125.	Hyperiidae US	Hyperiidae-Unidentified spp.	Arthropoda
126.	Hesionura	Hesionura sp.	Polychaeta
127.	Hydrozoa US	Hydrozoa-Unidentified spp.	Hydrozoa
128.	H hyalina	Hippothoa hyalina	Ectoprocta
129.	H cornuta	Hippothoa cornuta	Ectoprocta
130.	H arctica	Hiatella arctica	Mollusca
131.	Hesionidae US	Hesionidae-Unidentified spp.	Polychaeta
132.	$Harmothoe	? Harmothoe sp.	Polychaeta
133.	Insecta US	Insecta-Unidentified spp.	Arthropoda
134.	I anguipes	Ischyrocerus anguipes	Arthropoda
135.	I fenestrata	Iselica fenestrata	Mollusca
136.	Keratosa US	Keratosa-Unidentified spp.	Porifera
137.	L dubia	Leptochelia dubia	Arthropoda
138.	L californica	Lyonsia californica	Mollusca
139.	L cf californica	Lyonsia sp., cf californica	Mollusca
140.	cf Leptosynapta	cf Leptosynapta sp.	Echinodermata
141.	L punctulata	Lagenipora punctulata	Ectoprocta
142.	Lumbrineris	Lumbrineris sp.	Polychaeta
143.	L quadripunctata	Limnoria quadripunctata	Arthropoda
144.	Lumbrineridae US	Lumbrineridae-Unidentified spp.	Polychaeta
145.	M perfragilis	Membranipora perfragilis	Ectoprocta
146.	M sanguinea	Marphysa sanguinea	Polychaeta
147.	M senhousia	Musculus senhousia	Mollusca
148.	M membranacea	Membranipora membranacea	Ectoprocta
149.	M arenaria	Mya arenaria	Mollusca
150.	M nasuta	Macoma nasuta	Mollusca

			GROUP
151.	M balthica	Macoma balthica	Mollusca
152.	H californiensis	Mediomastus californiensis	Polychaeta
153.	M inquinata	Macoma inquinata	Mollusca
154.	M acolasta	Macoma acolasta	Mollusca
155.	M ferruginosa	Mysella ferruginosa	Mollusca
156.	M californica	Microporella californica	Ectoprocta
157.	M edulis	Mytilus edulis	Mollusca
158.	Microphthalmus	Microphthalmus sp.	Polychaeta
159.	Melita	Melita sp.	Arthropoda
160.	M dentata	Melita dentata	Arthropoda
161.	Membraniporella	Membraniporella sp.	Ectoprocta
162.	Macoma J	Macoma sp. - juvenile	Mollusca
163.	Membranipora	Membranipora sp.	Ectoprocta
164.	M villosa	Membranipora villosa	Ectoprocta
165.	Modiolus	Modiolus sp.	Mollusca
166.	Nema US	Nematoda-Unidentified spp.	Nematoda
167.	Nemer US	Nemertea-Unidentified spp.	Nemertea
168.	N caecoides	Nephtys caecoides	Polychaeta
169.	N parva	Nephtys parva	Polychaeta
170.	N corn fran	Nephtys cornuta franciscana	Polychaeta
171.	N cirratulus	Nerine cirratulus	Polychaeta
172.	N cf cirratulus	Nerine sp., cf cirratulus	Polychaeta
173.	N succinea	Neanthes succinea	Polychaeta
174.	N obsoletus	Nassarius obsoletus	Mollusca
175.	Neanthes	Neanthes sp.	Polychaeta
176.	Nereidae US	Nereidae-Unidentified spp.	Polychaeta
177.	N mendicus	Nassarius mendicus	Mollusca
178.	N caecoides J	Nephtys caecoides - juvenile	Polychaeta
179.	N latescens	Nereis latescens	Polychaeta
180.	$N cirratulus J	? Nerine cirratulus - juvenile	Polychaeta
181.	N cirratulus J	Nerine cirratulus - juvenile	Polychaeta
182.	Oligo US	Oligochaeta-Unidentified spp.	Oligochaeta
183.	Ostracoda US	Ostracoda-Unidentified spp.	Arthropoda
184.	O Men fetella	Odostomia (Menestho) fetella	Mollusca
185.	O Eval a	Odostomia (Evalea) sp. A	Mollusca
186.	O Eval franciscana	Odostomia (Evalea) franciscana	Mollusca
187.	O Eval tenuisculpta	Odostomia (Evalea) tenuisculpta	Mollusca
188.	O Eval cf deliciosa	Odostomia (Evalea) sp., cf deliciosa	Mollusca
189.	O Eval valdezi	Odostomia (Evalea) valdezi	Mollusca
190.	O Eval	Odostomia (Evalea) sp.	Mollusca
191.	O lurida	Ostrea lurida	Mollusca
192.	O lurida J	Ostrea lurida - juvenile	Mollusca
193.	$Oenone	? Oenone sp.	Polychaeta
194.	P brachycephala	Polydora brachycephala	Polychaeta
195.	P ligni	Polydora ligni	Polychaeta
196.	Polydora	Polydora sp.	Polychaeta
197.	P socialis	Polydora socialis	Polychaeta
198.	Polydoridae UJ	Polydoridae-Unidentified juvenile	Polychaeta
199.	P brachycephala J	Polydora brachycephala - juvenile	Polychaeta
200.	P cf caeca	Polydora sp., cf caeca	Polychaeta

			GROUP
201.	P cf magna	Polydora sp., cf magna	Polychaeta
202.	P $ socialis J	Polydora ? socialis - juvenile	Polychaeta
203.	P ligni J	Polydora ligni - juvenile	Polychaeta
204.	PP paucibranchiata	Pseudopolydora paucibranchiata	Polychaeta
205.	PP kempi	Pseudopolydora kempi	Polychaeta
206.	Pseudopolydora	Pseudopolydora sp.	Polychaeta
207.	P bellis	Paleanotus bellis	Polychaeta
208.	$Polycirrus	? Polycirrus sp.	Polychaeta
209.	Phoronida US	Phoronida-Unidentified spp.	Phoronida
210.	Polycirrus J	Polycirrus sp. - juvenile	Polychaeta
211.	Polynoidae US	Polynoidae-Unidentified spp.	Polychaeta
212.	Polychaeta US	Polychaeta-Unidentified spp.	Polychaeta
213.	P cf cirrifera	Prionospio sp., cf cirrifera	Polychaeta
214.	Polycirrus	Polycirrus sp.	Polychaeta
215.	cf Phoronopsis	cf Phoronopsis sp.	Phoronida
216.	Pycnogonida US	Pycnogonida-Unidentified sp.	Arthropoda
217.	P pugettensis	Parapleustes pugettensis	Polychaeta
218.	P minuta	Pholoe minuta	Polychaeta
219.	Phoronis	Phoronis sp.	Polychaeta
220.	P tuberculata	Pyromaia tuberculata	Arthropoda
221.	P californiensis	Pectinaria californiensis	Polychaeta
222.	P franciscana	Pinnixia franciscana	Arthopoda
223.	P brevipes	Photis brevipes	Arthopoda
224.	P cf carditoides	Petricola sp., cf carditoides	Mollusca
225.	Promystides	Promystides sp.	Polychaeta
226.	Pennatulacea US	Pennatulacea-Unidentified spp.	Cnideria
227.	Polynoidae UJ	Polynoidae-Unidentified juvenile	Polychaeta
228.	Prionospio	Prionospio sp.	Polychaeta
229.	$Prionospio	? Prionospio sp.	Polychaeta
230.	P milleri	Paraphoxus milleri	Arthropoda
231.	Platyhelminthes US	Platyhelminthes-Unidentified spp.	Platyhelminthes
232.	P trispinosa	Parasmittina trispinosa	Ectoprocta
233.	Paleonemertea US	Paleonemertea-Unidentified spp.	Nemertea
234.	Phyllodocidae USA	Phyllodocidae-Unidentified sp. A	Polychaeta
235.	Phyllodocidae USB	Phyllodocidae-Unidentified sp. B	Polychaeta
236.	$Paleanotus	? Paleanotus sp.	Polychaeta
237.	P staminea	Protothaca staminea	Mollusca
238.	Phyllodocidae US	Phyllodocidae-Unidentified spp.	Polychaeta
239.	P cirrifera	Prionospio cirrifera	Polychaeta
240.	Phyllodocidae UJ	Phyllodocidae-Unidentified juvenile	Polychaeta
241.	P cancellatus	Platyodon cancellatus	Mollusca
242.	Pododesmus J	Pododesmus sp. - juvenile	Mollusca
243.	P $ cirrifera	Prionospio ? cirrifera	Polychaeta
244.	Pygospio	Pygospio sp.	Polychaeta
245.	S benedicti	Streblospio benedicti	Polychaeta
246.	S californica	Scrupocellaria californica	Ectoprocta
247.	Sphaerosyllis	Sphaerosyllis sp.	Polychaeta
248.	S laticauda	Synidotea laticauda	Arthropoda
249.	S fimbriata	Spiophanes fimbriata	Polychaeta
250.	S bombyx	Spiophanes bombyx	Polychaeta

		GROUP
251. Sarsiella	Sarsiella sp.	Arthropoda
252. S cf laticauda	Synidotea sp., cf laticauda	Arthropoda
253. Syllides	Syllides sp.	Polychaeta
254. Scrupocellaria	Scrupocellaria sp.	Ectoprocta
255. S prolifica	Smittoidea prolifica	Ectoprocta
256. Sipuncula US	Sipuncula-Unidentified spp.	Sipuncula
257. Sabellidae US	Sabellidae-Unidentified spp.	Polychaeta
258. SN prolifica	Smittina prolifica	Ectoprocta
259. $Styela	? Styela sp.	Chordata
260. Syllidae US	Syllidae-Unidentified spp.	Polychaeta
261. Spiophanes	Spiophanes sp.	Polychaeta
262. $Syllides	? Syllides sp.	Polychaeta
263. S patula	Siliqua patula	Mollusca
264. Spionidae UJ	Spionidae-Unidentified juvenile	Polychaeta
265. $Sthenelanella	? Sthenelanella sp.	Polychaeta
266. T japonica	Tapes japonica	Mollusca
267. Tunicata US	Tunicata-Unidentified spp.	Chordata
268. T parvus	Tharyx parvus	Polychaeta
269. T tantilla	Transennella tantilla	Mollusca
270. T ternata	Tricellaria ternata	Ectoprocta
271. T multisetosum	Trochochaeta multisetosum	Polychaeta
272. T cf monilaris	Tharyx sp., cf monilaris	Polychaeta
273. T occidentalis	Tricellaria occidentalis	Ectoprocta
274. T armifera	Tegella armifera	Ectoprocta
275. T modesta	Tellina modesta	Mollusca
276. T multisetosum J	Trochochaeta multisetosum - juvenile	Polychaeta
277. Terebellidae US	Terebellidae-Unidentified spp.	Polychaeta
278. Tharyx	Tharyx sp.	Polychaeta
279. Tricellaria	Tricellaria sp.	Ectoprocta
280. U cinerea	Urosalpinx cinerea	Mollusca
281. Z pilsbryi	Zirfaea pilsbryi	Mollusca

ANALYSIS OF BENTHIC INFAUNAL SAMPLES OAKLAND OUTER HARBOR

SEPTEMBER 1975 - MARCH 1976

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INTRODUCTION

This report presents the results of an investigation into the presence and abundance of benthic macrofauna in the Oakland Outer Harbor Channel and adjacent undredged areas. The primary purpose of this study was to define and quantify the bottom organisms of the study area to allow an assessment of the potential environmental impacts of dredging the Oakland Outer Harbor Channel. Secondarily the study was to determine where possible, the general relationships between the benthic macrofauna and the environmental conditions encountered to provide a general ecologic baseline summary of the area.

The specifications for the study were initially prepared by the United States Army Corps of Engineers (USACE) in early June of 1975 and later refined in discussions between United States Army Corps of Engineers (USACE) and Leighton and Associates in August and September of that year. The final Scope of Services was included in contract DACW07-76-C-0016 dated 21 October 1975. The schedule for submission of the initial draft of the final report and subsequent 30-day period for review and incorporation of comments was revised in March of 1976 due to a delay in the winter sampling period of approximately 30 days.

SCOPE OF THE INVESTIGATION

1. The benthic macrofauna of the study area were surveyed over a period of one year. The survey consisted of two (2) seasonal sampling periods (one in the summer (September) and one in the winter (March)). Quantitative samples of benthic infauna were taken by District personnel (scuba divers) from six (6) stations located in the study area. A minimum of three (3) replicate samples (a total of approximately ten to fifteen liters of bottom material) were taken at each station. All samples collected were washed through a .5mm screen and the entrapped organisms were preserved for identification by the contractor.

2. The Government performed basic water quality tests (temperature and salinity) and sediment analysis (percent sand, silt, clay) for each station. Pollution tests of the sediment were also made in the general area. This information was available to the contractor as needed for data analysis. The Government also furnished the contractor with a bathymetric map of the area detailing station locations after the initial sampling period.

3. The contractor provided two of his personnel to supervise the organism washing and preservation. Narcotization was performed under their direction with appropriate materials and methods specified by the contractor. Materials were provided by the Government based upon the contractors recommendations.

4. The contractor identified all organisms collected according to species or lowest taxonomic category. Based on the specific identifications and organism counts, the existing community at the individual stations was established. Population densities, diversities and differences were determined where applicable and species interaction patterns defined where possible. The resultant data were interpreted as to the ecological environmental importance of the benthic infauna encountered.

DESCRIPTION OF THE STUDY AREA

The study area is located to the south of the San Francisco-Oakland Bay Bridge along the margin of the bay east of Yerba Buena Island (Figure 1). The Oakland Outer Harbor Channel trends generally SW-NE lying immediately north of the Oakland Mole and adjacent to a portion of the Port of Oakland oil and cargo facilities. The bay is approximately 3 1/2 miles wide at this point, and Yerba Buena Island lies at the approximate midpoint between either shore. Water depths in the Outer Harbor Entrance Channel are 50 feet or less whereas water depths within the Oakland Outer Harbor proper are 40 feet or less.

Current activity within this portion of the bay is controlled primarily by tidal activity, although there is some influence from the Sacramento, San Joaquin river outflow, particularly during years when winter precipitation levels are high and/or when spring snow melt is large. During flood tide, ocean water flows into central San Francisco Bay through the Golden Gate, diverges around both sides of Treasure Island to the north and flows under the Bay Bridge into lower San Francisco Bay. On ebb tide, the flow of water reverses direction flowing outward along the same route. The San Francisco Bay area is subject to a mixed tide cycle incorporating two unequal high waters and two unequal low waters within each tidal day. The tide range from higher high to lower low water is rarely greater than eight feet at the Golden Gate. The mean range at that locality is over three feet. Although somewhat variable, the occurrence of high or low water is approximately one-half hour later in the study area than the same high or low water at the Golden Gate. Tidal current speeds in the study area vary from slightly less than one knot to greater than three knots within the minimum to maximum tide range.

SAMPLING AND ANALYSES METHODS

The collection of water sediment and marine biological samples recovered during the initial sampling period was accomplished concurrently on 17 and 18 September 1975 using the government operated 50 foot R/V Grizzly. Samples were taken by USACE District Office scuba divers and initially processed aboard the vessel by Army Corps and Contractor personnel. Similar procedures were followed during the second sampling period on 22 and 23 March 1976.

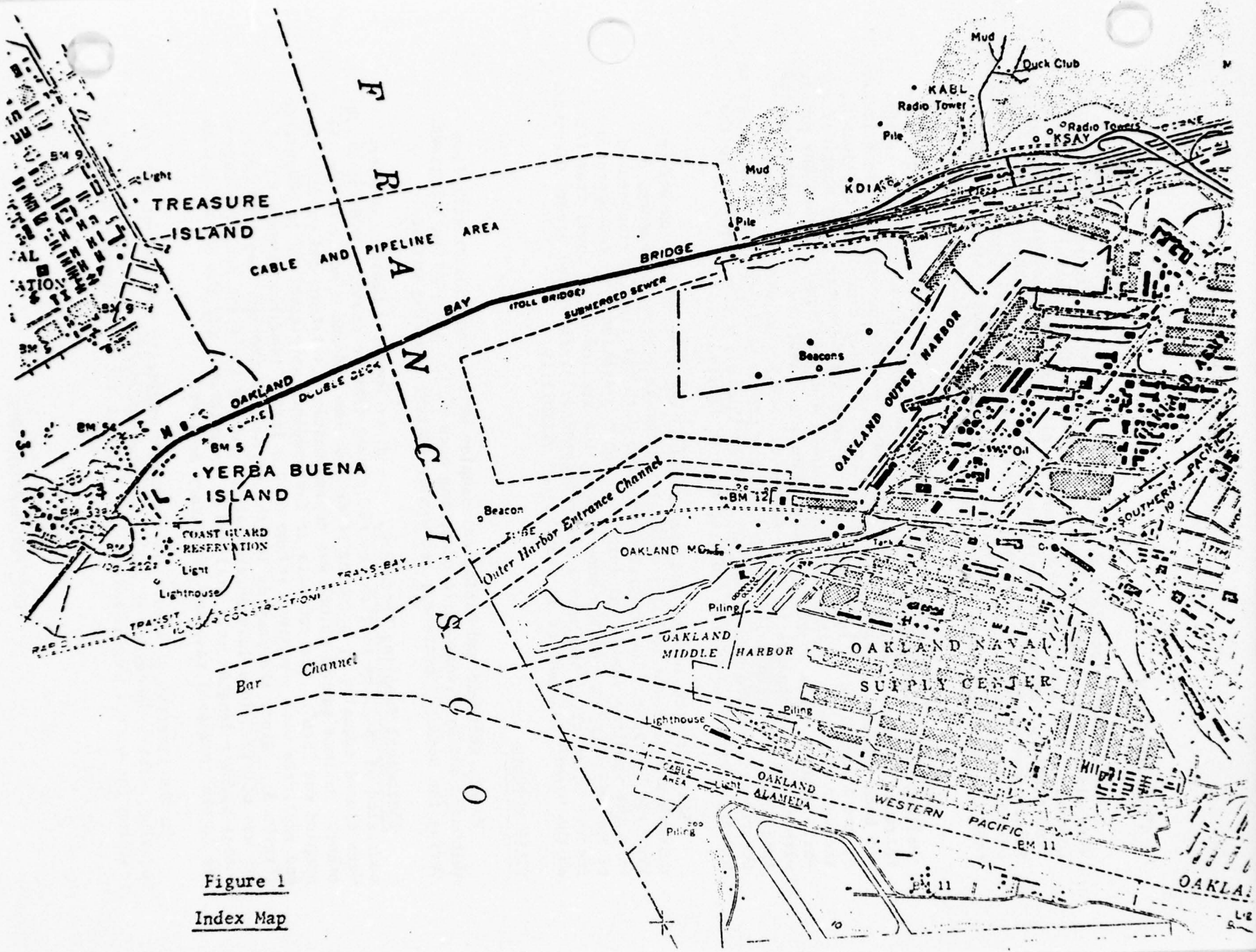


Figure 1

Index Map

STATION LOCATIONS

Six sampling locations were occupied as shown in Figure 2. The stations were distributed around the axis of the Oakland Outer Harbor and Entrance Channel. The locations were chosen to allow for the excavation of material from stations subject to varying degrees of exposure to the impact of annual maintenance dredging. The most recent dredging of this type was to a depth of approximately 35 feet in December of 1975 and January of 1976. Note that the reference level for depths in this report is Lower Low Water.

As shown in Figure 2, station 1 (reference station) was located in the shallows with a water depth of 2.7 meters on the northern periphery of the Entrance Channel. Station 1 was selected as a reference station since it has not been subject to significant disturbance by prior dredging. Stations 2, 4, and 5 were located in deeper water (7 meters to 9 meters) but marginal to the main channel. It is noted that station 4 was in San Francisco Bay proper, while station 5 was adjacent to the shoreline. Stations 3 and 6 were located within the main channel in water depths of 15.6 meters and 9.2 meters respectively. Station 3 lies toward the bay proper while station 6 was close to the terminus of the harbor. Depths greater than 9.1 meters occur where the Bay Area Rapid Transit bay crossing tube is located.

Stations were located and documented by visual trangulation and by azimuth and distance to major natural and man-made terrain features as measured by radar. The precision of these data was clearly illustrated when the sampling vessel was forced to leave a station with the approach of inbound shipping and the buoy marking the station broke loose from its anchor. Soon after the vessel was relocated on station, the divers discovered the "lost" buoy anchor in near "zero" visibility.

FIELD METHODS

Water, sediment and biological samples were taken concurrently from shipboard and by divers while occupying each of the six station locations during the summer (September) and winter (March) sampling periods.

Biological Sampling Procedure. The diver operated benthic samplers consisted of 28-33 cm sections of PVC piping (inside diameter 9.8 cm) which were closed manually by a rubber stopper on one end and a metal lid on the other. Maximum sample volume was approximately 2.4 liters and surface area sampled was 75cm^2. The contents of two samplers were combined to constitute one replicate with a maximum volume of 4.9 liters (sampling area 0.015 m^2 (Figure 3). Since the sampler lengths varied, an average length of 29.2 cms was utilized in volume determinations during the first sampling period. Actual sampler lengths were utilized in calculations for the second period due to the increased sampling efficiency achieved.

In the interest of safety and to ensure replicate sampling at the same location, divers descended in pairs along an anchored safety line. Upon reaching the bottom they moved a short distance from the descent line to an

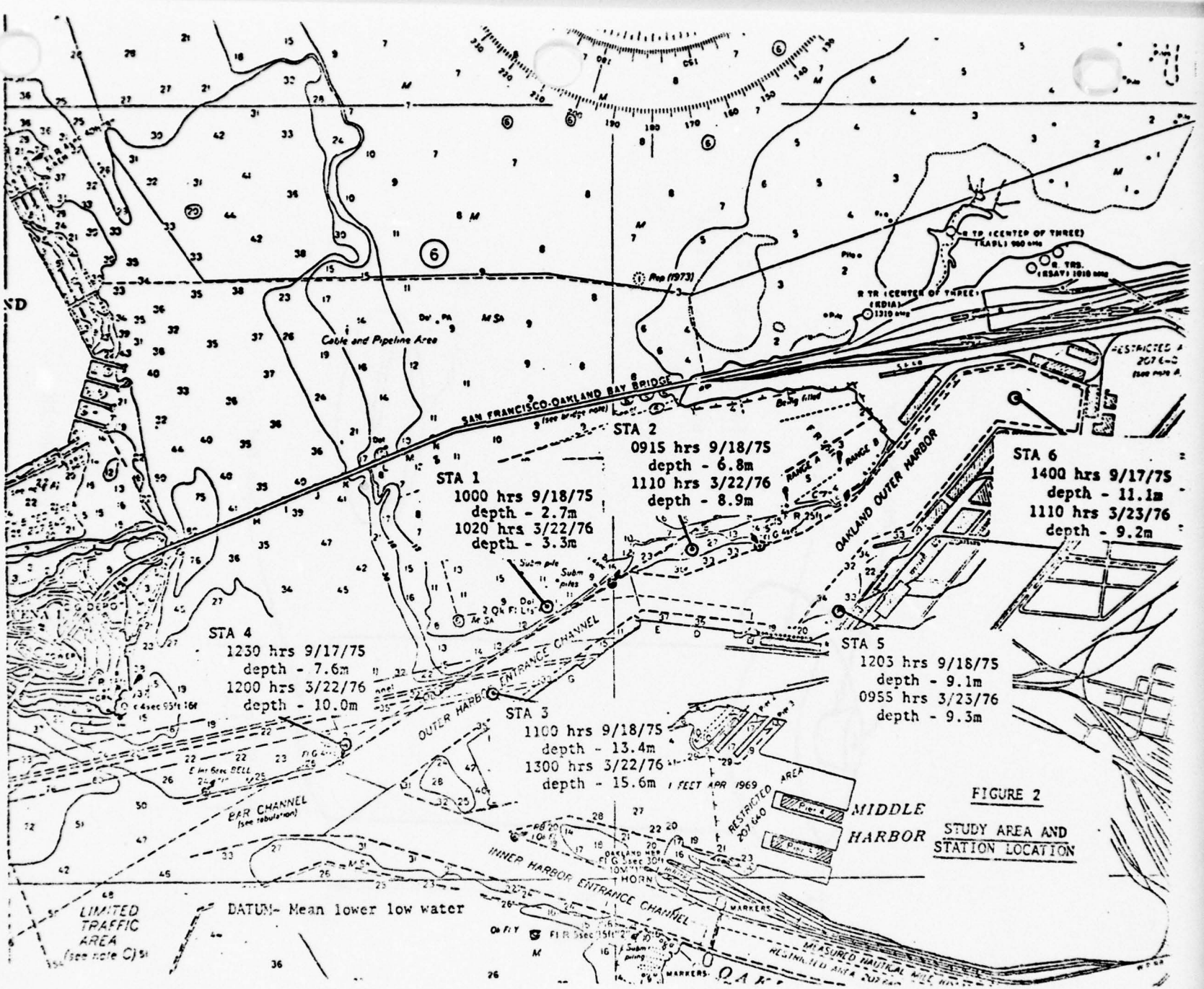


FIGURE 2

STUDY AREA AND STATION LOCATION

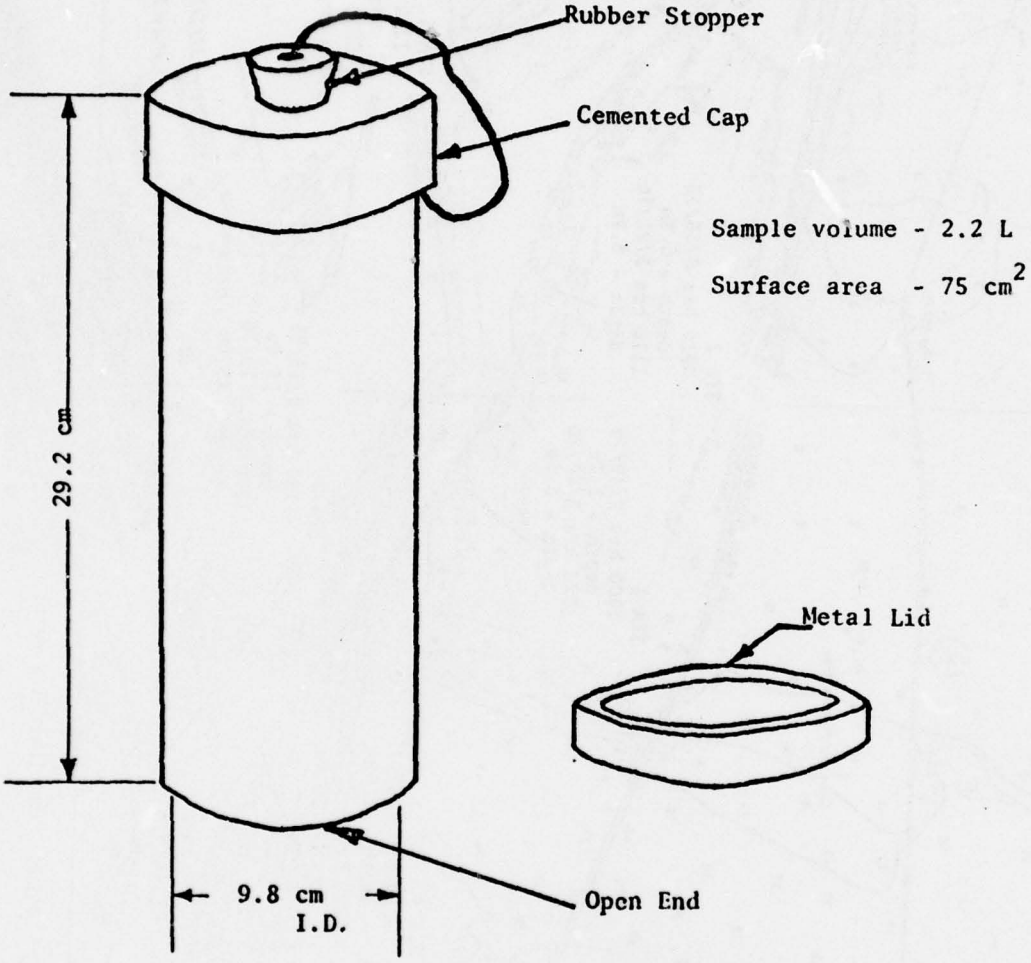


FIGURE 3 - PVC SAMPLER

undisturbed area and proceeded to collect two samples (one replicate). The diver pushed the entire length of the PVC sampler into the sediment and stoppered the top. The sediment was partially removed from around the sampler and the bottom lid applied. Each pair of samples was transported to the surface immediately upon collection, examined for signs of leakage and adequacy of sample volume and combined for further processing. Inadequate replicates were discarded wherever possible unless repeated sampling did not produce adequate samples. Such samples were retained in a number of instances where the sediments repeatedly prohibited routine sampling. Volumes of incomplete samples were determined by measuring the length of the empty portion of the sampler, subtracting the total sampler length and calculating remaining volume.

As indicated in Table 1, the replicate volumes achieved during the second sampling period were far more adequate than those recovered during the first period. In general the replicate volumes for all stations during the second period were reasonably uniform and consistent. Hence the effect of variations in replicate volume for the second period is considered minimal.

During the first sampling period however, replicate volumes varied significantly, particularly at stations 2, 3, 5, and 6 and must therefore be considered to have had some potential effect on the resulting organism populations established for these stations during that period. Additionally, the resulting total volume of sediment analyzed for each period for each station is also significantly different for each of the periods. Both of these considerations are of importance in consideration of the final results of this study.

A discussion of the effectiveness of the sampling procedures utilized in this study is included as Appendix A of this report.

Biological Sieving Procedure. The sieves were constructed of 0.5 mm mesh Nytex screening laminated between two sections of PVC pipe (inside diameter 15.0 cm). On the first day in September portions of each replicate were transferred to the sieve and filtered (0.25 mm mesh) bay water was applied directly to the sediment. On the second day in September each replicate was mixed thoroughly with filtered bay water and poured through the sieve. Wash water was applied directly to the screen only occasionally and this modification appeared to reduce fragmentation of more delicate forms and loss of sample due to splash as well as to decrease processing time. The latter procedure was followed during the March period also.

All materials retained on the screen were washed into a pan by reversing water flow through the sieve and then transferred to jars. Occasionally the volume of the water in the jar became excessive and it was in turn resieved until wash water volume was minimized. Organisms were stained by adding rose-bengal and narcotized by addition of a sufficient volume of concentrated $MgCL_2$ solution (300 gm/liter) to achieve a final concentration of 75 gm/liter. After approximately one hour the samples were "fixed" by adding buffered formaldehyde (hexamethylenetetramine added at 120 gms/liter)to achieve a final concentration of 10 percent formalin.

TABLE 1

REPLICATE VOLUMES BY STATION FOR SEPTEMBER AND MARCH SAMPLING PERIODS

Station Number	REPLICATE VOLUMES (LITERS) SEPTEMBER 1975				REPLICATE VOLUMES (LITERS) MARCH 1976			
	I	II	III	Total	I	II	III	Total
1	4.4	4.4	4.4	13.2	4.8	4.7	4.7	14.2
2	4.4	2.9	1.7	9.0	4.7	4.8	4.8	14.3
3	3.6	2.5	2.3	8.4	4.8	4.6	4.4	13.8
4	4.2	4.4	4.4	13.0	4.9	4.8	4.7	14.4
5	4.0	2.9	4.4	11.3	4.7	4.7	4.7	14.1
6	4.4	2.3	4.4	11.1	4.8	4.8	4.6	14.2

LABORATORY METHODS

After recovery and initial processing aboard ship, the sediment and water samples were returned to the Corps laboratories for analysis, while the contractor was responsible for the analysis of the biological samples. The data provided by the Corps concerning the results of the water and sediment analysis is summarized in the following section of this report and also included as Appendix B.

Biological Sample Processing. Following three to four days in formalin, the samples were transferred to 70 percent isopropyl alcohol. This was achieved by pouring the fixative off through a 0.5 mm sieve, washing the sample with fresh water and "pouring off" through the sieve. The washing was repeated until all formalin and any excess sediment was removed. This process also required resieving to reduce wash water volume in the sample. The material retained on the screen was washed into a shallow pan and then transferred to the bottle. Loss of additional specimens by retention in the sieve was negligible as confirmed by careful examination of the mesh with a magnifier.

Sorting of Biological Specimens. Each replicate was sorted initially to major taxonomic and/or other convenient groupings. Larger items such as worm tubes were removed and examined individually for stained organisms with a 10X stereo microscope. Then small portions of the remaining material were transferred to a petri dish and observed as above. Organisms were generally readily detectable due to the rose-bengal stain, and were removed to fresh 70 percent alcohol. Great care had to be taken to dissect all Ampelisca tubes as this amphipod was frequently found within its flacid tube of cemented silt. This initial sort separated the fauna into four categories: annelids, arthropods, molluscs, and miscellaneous phyla. Upon removal of the organisms, all sorted sediment materials and debris were stored for future re-examination. Large worm tubes were separated and dissected separately.

Upon completion of the initial sorting, organisms were further sorted to the lowest possible taxon. While the molluscs were often successfully separated visually, all other groups required initial preliminary identifications or at least determination of those diagnostic characters which facilitated tentative separation. When there was no doubt as to the identity or homogeneity of a group of organisms, they were counted prior to submission to taxonomists for verification.

Taxonomic Processing. After determination of organisms to the lowest possible taxon or at least consolidation into homogeneous groups, vouchers were prepared for examination by taxonomic consultants. In the case of some particularly difficult groups, namely the Capitellids, Oligochaetes and Corophium spp. mixed samples were submitted for sorting as well as identification. The completed vouchers were used by our personnel to identify and enumerate the remaining organisms.

Acknowledgements. We wish to acknowledge the assistance of the following taxonomic authorities in identifications and/or identity confirmations of organisms during this study. This does not imply that they have checked

all species or individual of a species listed herein.

Dr. James A. Blake Pacific Marine Station UOP	Polychaeta (also sorted and identified Capitellidae)
Mr. Dustin Chivers California Academy of Sciences	Decapoda
Mr. William J. Light California Academy of Sciences	Oligochaeta
Dr. Barry Roth California Academy of Sciences	Bivalva and Gastropoda
Mr. Pete Slattery Moss Landing Marine Laboratories	Tanaidacae, Cumacea, Gammaridea, Copepoda, Decapoda
Mr. DeBoyd Smith West Valley College	General Taxonomy
Mr. James Sutton California Academy of Sciences	Ophiuroidea, Misc. Taxa
Dr. Louis S. Kornicker U.S. National Museum	Ostracoda

ANALYTICAL METHODS

The analysis of organism distribution has been approached in two ways. Initially a general analysis of the most abundant organisms at each location and those that are common to each location for each sampling period is included. Variations in distribution between sampling periods at specific stations and a comparison of the distribution changes throughout the total environment are also discussed.

The limited number of stations included in the study has some negative impact on the value of diversity, evenness and similarity calculations for the less prevalent groups in the area. Such calculations are still of value however in enhancing the interpretation involving the more prevalent organisms, and in more accurately defining the significant populations in the area. Additionally this data will allow some comparison to be made with the previous work performed in this location (U.S. Army Corps of Engineers, 1975) and adjacent thereto (Environmental Quality Analysts, et. al., 1975).

Species Diversity. Species diversity was determined for significant stations utilizing the Shannon-Wiener diversity index (H^1) (Pielou, 1975), defined by the equation:

$$H^i = \sum_i^S \frac{N_i}{N} \ln \frac{N_i}{N}$$

Where: N = The total number of individuals

N_i = The number of individuals of species i

S = The total number of species.

A diversity index measures the variability of the organisms' species identity.

Species Evenness. Species Evenness (Pielou, 1975) (J^i) may be defined by the equation:

$$J^i = \frac{H^i}{\ln S}$$

This parameter is a measure of the relative equality of distribution of individuals among the species present.

Faunal Similarity Between Stations. The similarity of faunal composition between stations was determined when of value by determining the Sorensen (1948) quotient of similarity (QS) defined by the equation:

$$QS = \frac{2C}{A+B}$$

Where: C = Number of species common to both stations.

A = Number of species at Station A.

B = Number of species at Station B.

This coefficient may serve as an indicator of the homogeneity of infaunal species composition in the study area.

PHYSICAL-CHEMICAL ENVIRONMENTAL CHARACTERISTICS

As previously indicated the Corps of Engineers was responsible for the analysis of the physical-chemical analysis of water samples and for the size determination of the sediment collected. The results of these analysis are included as Appendix B of this report and are summarized in Table 2 for each of the sampling periods. It is noted that total Kjeldahl Nitrogen and Total Phosphate values were determined only for the first sampling period. They are included here, therefore, primarily for information purposes. It is noted that the analysis of the water samples in September was accomplished in the laboratory using chemical analysis methods. In March the analysis was

accomplished on-site using an Interocean Model 500 probe. During both periods, the measurements were made on bottom water samples.

HYDROGEN-ION CONCENTRATION (pH)

The hydrogen ion concentration, a measure of the acidity/alkalinity of a solution or substance, ranged from 7.5 to 7.8 during the initial sampling period and from 8.6 to 8.7 during the final period. Thus the environment may have been only slightly alkaline in September increasing in alkalinity in March. This apparent increase was demonstrated at all stations occupied and was relatively uniform throughout the area, as were the respective pH values during each sampling period. These values are within the normal range for the San Francisco Bay environment (Gram, 1966). The pH of the September water samples was not determined until two days after collection. Escape of CO_2 from the samples however could be expected to increase the pH values of the samples.

Many factors may affect the aciditic/basic condition of a bay environment such as organism activity, chemical input, evaporation rate, freshwater input and/or sediment-water ion exchange. The late winter season is normally a time of increased freshwater input to the bay, which could be expected to reduce the alkalinity rather than increase it. The 1976-1976 year however was extremely dry and therefore freshwater input into the bay was significantly below normal levels. Other factors may also have been operating in this instance, such as reduction of CO_2 content due to increased photosynthetic activity of plants, but this issue was not addressed in this study.

SALINITY (‰)

Salinity is a measure of the total dissolved solids present in a water sample and is of particular significance in its potential effect on organism activity. The salinity ranged from 31.30‰ to 32.90‰ during the first sampling period and from 29.00‰ to 30.25‰ during the second period. Salinity decreased at each individual station in the second sampling period which would be expected, considering the time of year, with the associated increase in freshwater input. The decrease in salinity encountered was relatively uniform throughout the area. As mentioned above, however, the salinity determinations were delayed for two days during the first sampling period, and the time interval between the September and March sampling periods was extremely dry. It is possible therefore that the higher salinities obtained during the first sampling period are partially the result of evaporation prior to analysis.

Salinities were highest at station 4 near the entrance of the Harbor entrance channel during the first sampling period, and were lowest at station 1 in the shallows near the mouth of the Outer Harbor proper and at station 6 at the head of the Harbor during this same period. During the second sampling period the high salinity was found at station 5 in the intermediate area of the Harbor proper. During both periods, however, and particularly during March, the range in salinities is sufficiently low to be the result of the irregular mixing effects of tidal current activity and associated wave motion. No correlation between water depth and salinity was evident.

TABLE 2

WATER AND SEDIMENT CHARACTERISTICS

Station Number	Depth ** (m)		pH		Salinity (o/oo)		Total Kjeldahl Nitrogen (n) (mg/L)		Total Phosphate (P) (mg/L)		Sediment Description	
	Sept	Mar	Sept	Mar	Sept	Mar	Sept	Mar	Sept	Mar	Sept	March
1 (Shallows)	2.7	3.3	7.6	8.7	31.30	29.20	0.36	*	0.19	*	Compact, gray silt with clay and coarse sand, Worm tubes, amphipod (Ampelisca milleri) abundant	Compact, gray silt with clay and coarse grained sand (Little change). Worm, amphipod tubes less abundant. Coloration the same.
2	6.8	8.9	7.5	8.65	32.20	29.00	0.62	*	0.11	*	Loose, semi-fluid, brown, gray-green clayey silt.	Compact sandy clayey silt. (Increase in both sand and clay content, but silt still predominant). Coloration the same.
3 (Channel)	13.4	15.6	7.5	8.58	32.10	29.74	0.66	*	0.10	*	Loose, semi-fluid, brown, gray-green silty sand.	Compact clayey silt. (Large decrease in sand content). Fibrous plant material abundant. Coloration the same.
4	7.6	10.0	7.7	8.68	32.90	29.20	0.20	*	0.15	*	Compact, dark gray silty sand. Coarse sand. Empty bivalve shells abundant, other biologic debris.	Compact silty sand. (Little change). Increased quantity of bivalve shells. Coloration the same.
5 (Channel)	9.1	9.3	7.6	8.56	31.90	30.25	0.80	*	0.21	*	Compact, gray silt. Empty bivalve shells common. Sediment pellets abundant.	Loose clayey silt. (Slight increase in sand content and distinct increase in clay content). Coloration the same.
6 (Channel)	11.1	9.2	7.8	8.55	31.50	29.95	0.28	*	0.10	*	Loose to compact blue-green fine sandy silt with scattered pebbles. In-situ textrure included flocculated aggregates of clay and sand size material.	Compact clayey silt. Distinct decrease in sand content with distinct increase in clay content. Coloration the same.

* Not determined this period

** Reference Level: lower low water

Thus neither the salinity nor the pH appear to be controlled by any localized condition within the Harbor or surrounding area, but rather to be responding to a general, probably seasonal change, operating throughout the environment.

SEDIMENTS

The texture of the sediment present in the study area range from silty sands to clayey silts with the finer size material predominating throughout the area. During September, significant amounts of fine sand were encountered at stations 3 and 4 in the Entrance Channel and adjacent thereto, and at station 6 at the head of the Outer Harbor. The remaining areas demonstrated predominantly silt size material during this period. In general sediment size is large in areas where current velocity is high or where wave action is at a maximum, since the waters in such areas are more capable of transporting greater amounts of finer size material. The effect of wave action diminishes with depth and tidal or other current activity is probably therefore the controlling sediment mover in the channel areas.

Some change in sediment type was encountered during the second sampling period at stations 2, 3, 5 and 6, while the sediment type at stations 1 and 4 remained essentially the same. Thus in March the amount of sand present at station 2 increased, and decreased at stations 3 and 6. Correspondingly the amount of silt decreased at station 5 with an associated increase in clay content.

In general therefore a decrease in the amount of coarser size material present in the area occurred between the two sampling periods. Although the change is slight, and station 2 shows a slight increase in the amount of sand that is present during this period, it is believed that the overall change in sediment distribution may be related to both a decrease in tidal current activity and wind action during the late winter, early spring season, and to the effects of dredging in the area.

In general, the sediment types and distribution are similar to those established by Conomos (1963) for the south Bay and by Gram (1966) for the central Bay. Station 2 is somewhat anomalous but the results for this station may be due to the effect of the more shallow areas that lie to the north of this station. Thus the wave and current action effecting this location may be diminished in the late summer and increased somewhat in the late winter due to changes in prevailing wave and current direction as modified by the bottom configuration. Additionally, as noted in the discussion under Section Locations, the Outer Harbor Channel proper was dredged in January of 1976. This procedure may be expected to have had some direct effect on the sediment distribution patterns encountered at stations 2 and 6. Stations 3 and 5 may have been subject to potential secondary dredging effects, however, neither of these locations were specifically dredged. Dredging did occur on both sides of station 3.

As mentioned previously, station 1 was chosen as a reference station since it has been essentially uneffected by dredging. Station 4 probably suffered little impact from the recent dredging. Thus the lack of sediment change at these localities would indicate that the recent dredging certainly contributed to the sediment variations between the two sampling periods at stations 2, 3, 5 and 6.

BIOLOGICAL STUDIES

As previously mentioned, the stations evaluated during this study were selected for the purpose of establishing a general ecological baseline description of the benthic infauna for the Oakland Outer Harbor, the Entrance Channel and the immediately adjacent areas. The study is largely descriptive although limited quantification summaries of the raw data have been included to enhance the interpretation and to allow a comparison of the data included herein with other studies of Bay fauna.

NUMBERS OF SPECIES AND INDIVIDUALS, SPECIES DIVERSITY AND EVENNESS

The raw data from the infaunal analysis are presented in Appendix C (Tables C-1 through C-4) for the two sampling periods including a summary comparison of the two periods in Table C-5 of that Appendix.

As shown in Table 3, fifty-five (55) species representing 3225 individuals were identified and enumerated during the September sampling period. In the March sampling period, 53 species representing 7152 individuals were identified and enumerated. Thus a slight decrease in the number of species with an associated increase in the number of individuals present in the area developed between the late summer and the following late winter sampling period. A total of 68 specifically identified species were observed throughout this study.

The total number of species observed at each station during September ranged from 8 species at station 5 to 36 species at station 4. The mean total number of species observed overall during this period was 22 per station. During this same period, the total number of individuals collected at each station ranged from 48 at station 5 to 1525 at station 1. The mean total number of individuals overall was 538 per station during September.

The total number of species observed at each station during March ranged from 12 at station 2 to 46 at station 4. The mean total number of species observed overall during March was 25 per station. During this same period the total number of individuals collected at each station ranged from 19 at station 2 to 5940 at station 4. The mean total number of individuals overall was 1193 per station during March.

Species Diversity and Evenness. The Shannon-Wiener species diversity (H') (Pielou, 1975) and the Pielou species evenness (1975) were calculated for the total fauna at each station using the abundances of those organisms identified to the species level (Appendix C).

STATION	TOTAL ABUNDANCE OF FAUNA (N)		NUMBER OF SPECIES (S)		SPECIES DIVERSITY (H^i)		SPECIES EVENNESS (J^i)	
	SEPT 1975	MARCH 1976	SEPT 1975	MARCH 1976	SEPT 1975	MARCH 1976	SEPT 1975	MARCH 1976
1	1305	774	25	31	1.71	2.45	.53	.71
2	240	19	23	12	2.27	2.38	.72	.96
3	656	223	25	25	1.93	2.35	.60	.73
4	888	5940	36	46	2.21	1.22	.62	.31
5	48	60	8	17	1.07	2.44	0.51	.86
6	88	141	17	20	2.32	1.73	.82	0.57
TOTAL	3225	7157	55	53				
MEAN	538	1193	22	25	1.92	2.09	.63	.69

TABLE 3 - SUMMARY OF INFAUNAL ORGANISM SAMPLE ANALYSIS

Species diversity values for the September sampling period ranged from 1.07 at station 5 to 2.32 at station 6 averaging 1.92 for the six stations. In general, the diversity values increased during the March sampling period ranging from 1.22 at station 4 to 2.45 at station 1 with an average of 2.09. It is noted that stations 4 and 6 demonstrated decreased diversity values in March.

Species evenness values for the September period ranged from 0.51 at station 5 to 0.82 at station 6 with an average of 0.63 for the period overall. Species evenness values generally increased during the second sampling period ranging from 0.31 at station 4 to 0.96 at station 2 with an average for this period of 0.69. Stations 4 and 6 demonstrate a decrease in species evenness in March.

Similarity of Faunal Composition Between Stations. The faunal similarity between stations was evaluated using the Sorensen (1948) Quotient of Similarity (QS). Although species similarity patterns between stations may be an indicator of adverse condition, detailed information concerning the many variables present in a given location are required for accurate interpretation of this statistic in this report. The Sorensen Quotient of Similarity for the six stations during the September and March sampling periods are given in Table 4. The quotients range from 0.18 to 0.79 with a mean of 0.54 indicating only an intermediate level of homogeneity of species composition in the study area. The highest levels of homogeneity occurred between stations 2 and 3, and 2 and 6 in September and between stations 1 and 3 and 3 and 5 in March. The lowest similarities as demonstrated by this index occurred at stations 1 and 5 and 4 and 5 in September and between 2 and 4 in March.

As a further means of identifying changes in the benthic faunal distribution in the area between sampling periods, the Sorensen Quotient of Similarity was computed for each of the stations comparing the September and March sampling periods.

Table 5 shows the relationships of the Sorensen Similarity Coefficient between stations between the two sampling periods. The range of coefficients between stations for the different periods is 0.35 for station 6 (September) versus station 4 (March) to 0.75 for station 3 (September) versus station 2 (March). The mean of the coefficients is 0.56.

The table is of value in that it allows an evaluation to be made of the similarity in faunal composition at individual stations during the two sampling periods, and it also gives a measure of the variability in faunal composition throughout the area at the individual stations during the separate sampling periods at different locations.

Comparing the individual stations from September to March indicates that all of the stations have an intermediate to high degree of homogeneity from one period to the next except station 2 which has a lower value for the comparison of the two periods. In general it is noted that stations 2, 5, and 6 have lower coefficient values than do station 1, 3, and 4 indicating a greater variability in species composition for the inner harbor locations between the

STATION	1		2		3		4		5	
	SEPT 1975	MARCH 1976	SEPT 1975	MARCH 1976	SEPT 1975	MARCH 1976	SEPT 1975	MARCH 1976	SEPT 1975	MARCH 1976
1										
2	0.63	0.56								
3	0.56	0.79	0.71	0.59						
4	0.52	0.68	0.51	0.43	0.39	0.65				
5	0.30	0.63	0.45	0.48	0.42	0.67	0.18	0.48		
6	0 52	0.59	0.70	0.50	0.57	0.53	0.37	0.52	0.56	0.65

TABLE 4 - SPECIES SIMILARITY (QS) FOR SAMPLING PERIODS
SEPTEMBER 1975 AND MARCH 1976

STATION		MARCH 1976					
		1	2	3	4	5	6
SEPTEMBER 1975	1	0.68					
	2	0.49	0.46				
	3	0.68	0.75	0.72			
	4	0.65	0.60	0.56	0.62		
	5	0.52	0.55	0.57	0.37	0.56	
	6	0.44	0.56	0.62	0.35	0.42	0.59

TABLE 5 - SPECIES SIMILARITY BETWEEN STATIONS BETWEEN SAMPLING PERIODS SEPTEMBER 1975 AND MARCH 1976

two periods than for those stations in and adjacent to the entrance channel. Stations 1 and 3 demonstrate the highest coefficient values; this may support the concept that these stations have suffered the least impact from the annual maintenance dredgings.

The difference between the inner and outer stations in terms of composition similarity is also demonstrated by comparing the similarity coefficients between the sampling periods for different stations. In general, the coefficients are low when the inner stations are compared to the outer stations for September versus March while the coefficients are intermediate to high when the inner stations are compared to inner stations for the two periods or when outer stations are compared to outer stations. In other words, the changes within a general area are somewhat less, in terms of species composition, for the two periods than between the two areas.

INFAUNAL COMPOSITION

The predominant benthic fauna identified and enumerated during this study in both the September and March sampling periods are members of the Phyla Annelida, Mollusca and Arthropoda. In general the Annelids are the most prevalent averaging 53 percent (range 17 to 86 percent) of the samples in September and 63 percent (range 15 to 92 percent) of the samples in March. The dominance of the Annelids is not uncommon in relatively shallow locations having silt/clay rich sediments as are present in the subject study area (Lie, 1970). The Molluscs and the Arthropods alternated in being of secondary and teritary importance although the Molluscs, with an average of 26 percent (range 8 to 49 percent) in September and an average of 27 percent (range 1 to 70 percent) were the second most important in terms of average values. Arthropods averaged 19 percent (range 3 to 58 percent) in the September period and averaged 10 percent (range 3 to 15 percent) in the March period. These relationships are depicted graphically in Figures 4 and 5.

These predominant Phyla made up more than 95 percent of the total organisms in the samples evaluated for all stations and were present at levels of 97 percent or greater in all instances except at station 6 during the March sampling period. The percent composition of the remaining Phyla were considered insignificant for the purposes of this investigation.

To more clearly define the organism distribution present throughout the area of study, the ten most abundant species defined during the study were selected and are listed in Table 6. These species made up 84 percent of the total organism abundance during the September period and 91 percent of the total organism abundance present in the area in March. The ten most abundant species were chosen on the basis of three criteria:

a. The Environmental Quality Analysts study (1975) employed a similar approach;

b. that the organisms be present at the majority of the stations during both sampling periods, or alternately that relatively large numbers of the species be present at a few stations and;

c. that the total abundance of the species present in the study area be greater than 120 individuals in September and/or greater than 320 individuals in March.

The small clam, Transennella tantilla was the dominant species considering both sampling periods as a unit with a total of 5077 organisms present. This organism was also dominant in the March sampling period with 4327 individuals present. During the September period, however, the Arthropoda Ampelisca milleri was dominant with a total of 770 individuals. During this same period Transennella tantilla was next in abundance with 750 individuals present. The Annelida Polycheata Exogone lourei was the second most numerous species considering both sampling periods together with a total of 1058 individuals present (202 in September and 856 in March).

Figures 6 through 15 depict the variability in distribution of these ten predominant organisms by station for the September and March sampling periods. Of importance here are the significant variations in abundance of these predominant species and where the variations occur, as well as the general patterns of distribution of these species. The pattern of abundance for the species: Exogone lourei, Pseudopolydora paucibranchiata, Peloscolex gabriellae, Mytilus edulis, Transennella tantilla, Ampelisca milleri and Leptochelia dubia is essentially the same for the two sampling periods, although the absolute numbers of individuals are considerably different for the individual periods. Thus the population densities for the Annelida are in general higher during March, while those of the Mollusca and the Arthropoda vary in this regard for the specific species involved.

There is at least a slight increase in population of all species at station 4 during the March sampling period. This increase is particularly marked for the species Exogone lourei, Pseudopolydora paucibranchiata, Transennella tantilla, Eudorella pacifica and Leptochelia dubia. An associated increase in population of the species: Monopylephorous irroratus and Peloscolex gabriellae occurs at station 3 during the same period.

The trend of relative population densities at individual stations for the two sampling periods is also of interest in terms of the location of the stations and the patterns involved. In general the abundance of individuals is low at station 2, 5, and 6 for both of the sampling periods, while stations 1, 3, and 4 demonstrate a much larger variability in population densities during both of the sampling periods and between the individual species abundance present at these stations within each of the sampling periods.

Both the Annelids Monopylephorous irroratus and Peloscolex gabriellae show a great increase in abundance during the March period at station 1. Oppositely the Annelid Pseudopolydora paucibranchiata and the Arthropoda Ampelisca milleri diminish greatly in abundance at this station in March.

Station 3 demonstrates a relatively large abundance of the Annelids Nephtys cornuta franciscana and Monopylephorous irroratus, the Mollusc Transennella tantilla and the Arthropod Eudorella pacifica in September. In March the population densities of these species decrease significantly at this location.

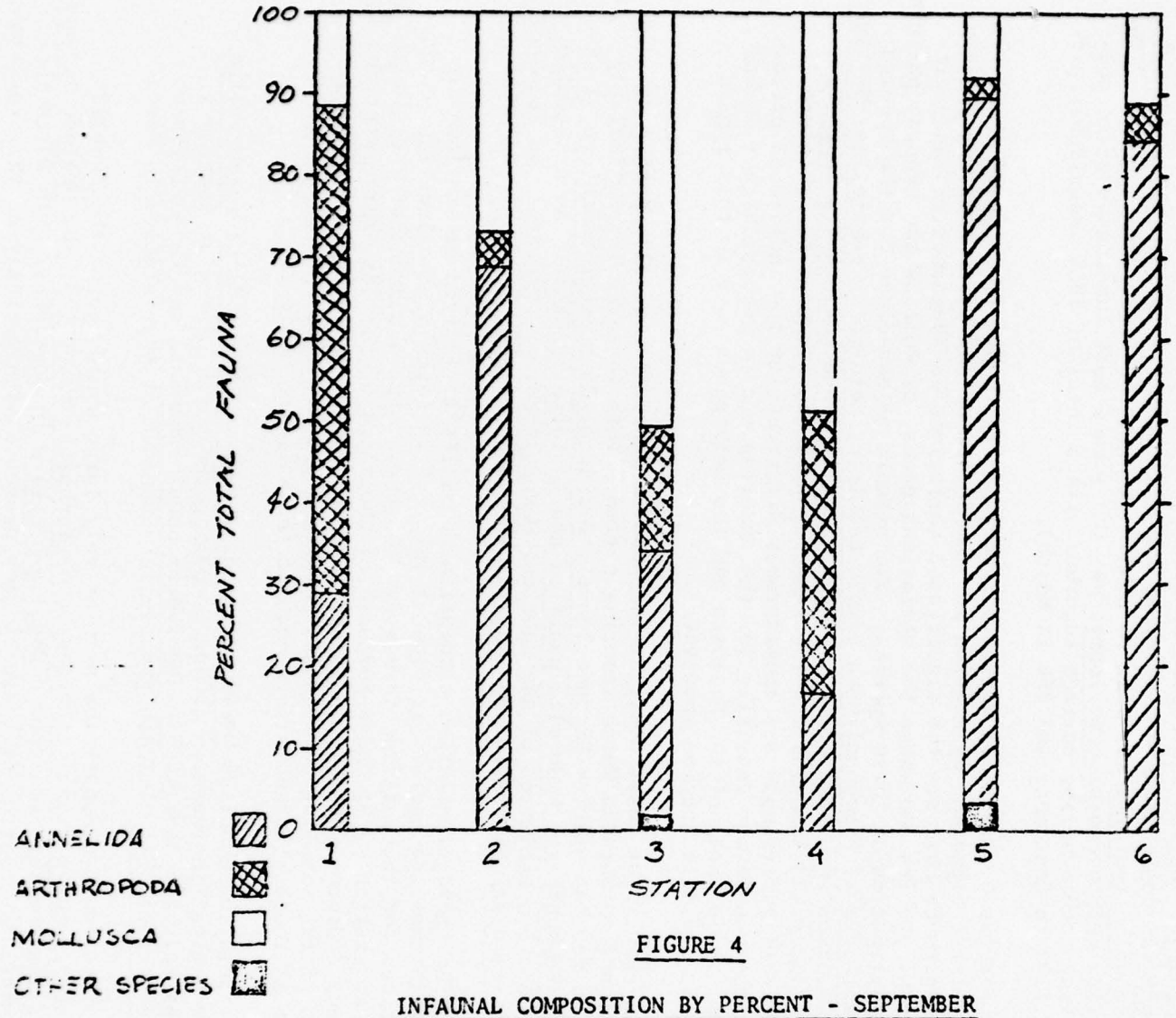


FIGURE 4

INFAUNAL COMPOSITION BY PERCENT - SEPTEMBER

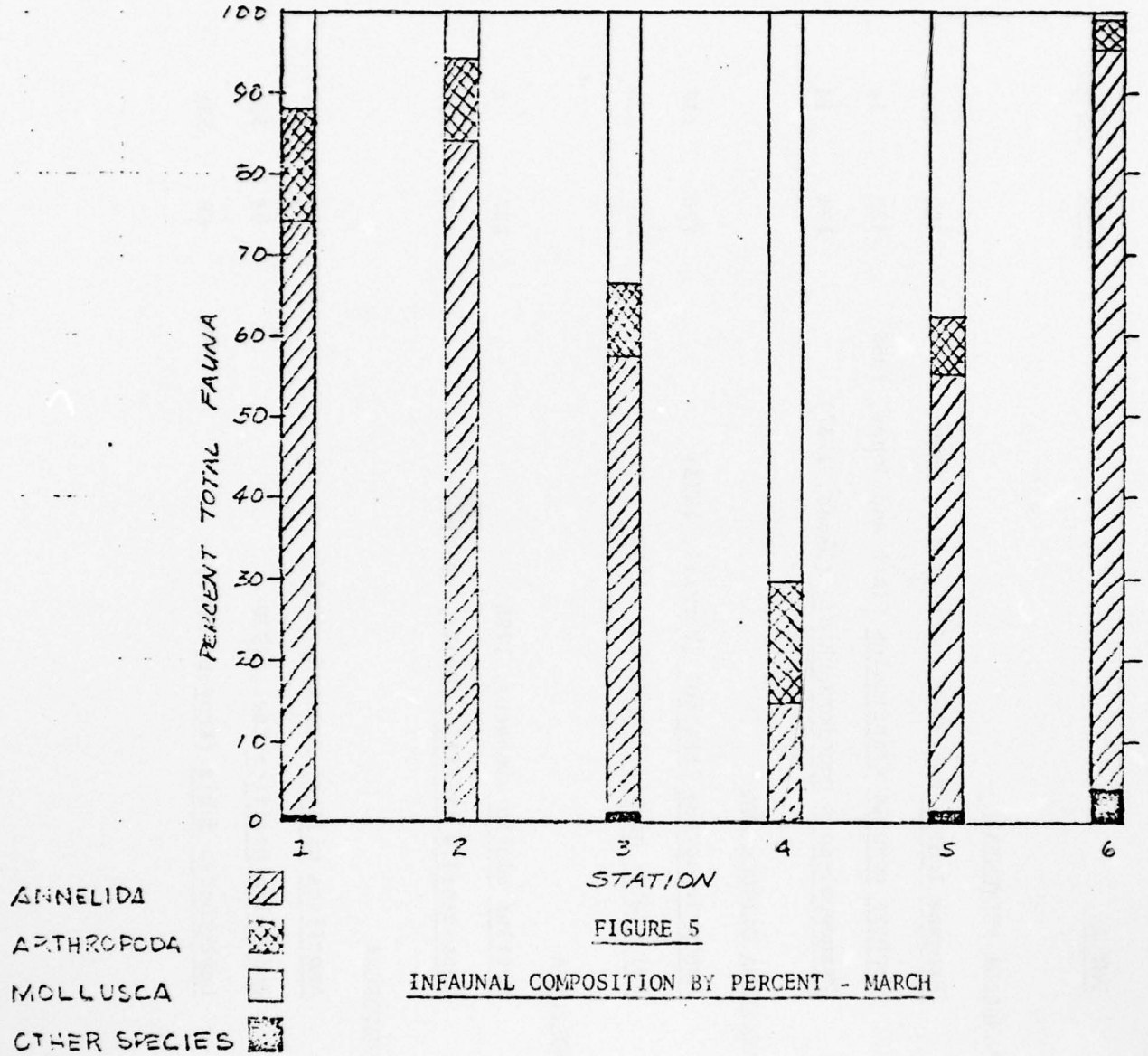


FIGURE 5

INFAUNAL COMPOSITION BY PERCENT - MARCH

TABLE 6

THE TEN MOST ABUNDANT SPECIES IN THE STUDY AREA

PHYLA	SEPT.	MARCH
ANNELIDA POLYCHEATA		
Exogone lourei Berkeley and Berkeley, 1938	202	856
Nephtys cornuta franciscana Clark and Jones, 1955	123	14
Pseudopolydora paucibranchiata (Okuda, 1937)	124	14
ANNELIDA OLIGOCHAETA		
Monopylephorous irroatus (Verrill, 1873)	170	137
Peloscolex gabriellae Marcus, 1950	150	326
MOLLUSCA		
Mytilus edulis Linnaeus, 1758	187	4
Transennella tantilla (Gould, 1853)	750	4327
ARTHOPODA		
Ampelisca milleri Barnard, 1954	770	17
Eudorella pacifica Carl, 1930	98	364
Leptochelia dubia (Kroyer, 1842)	66	331

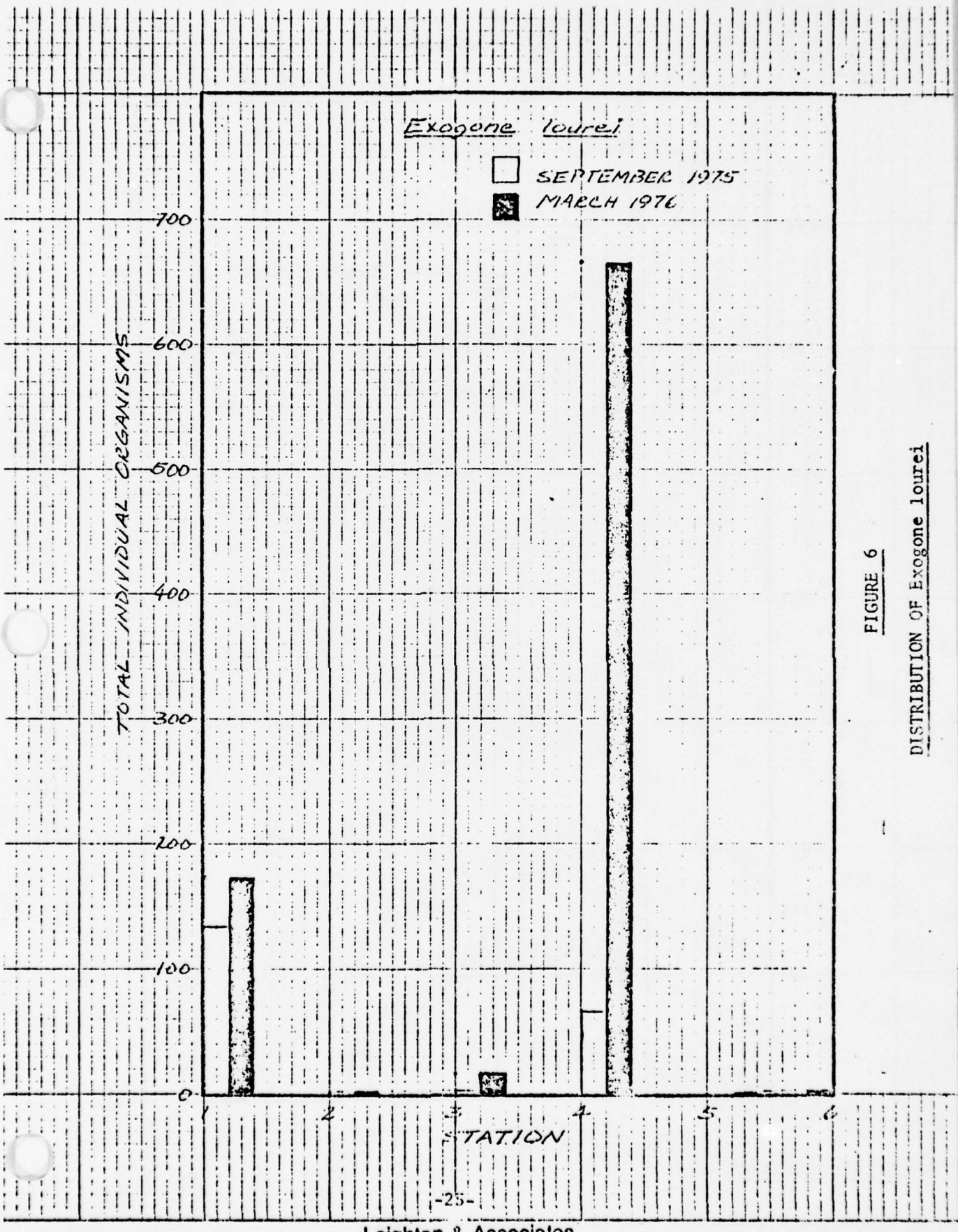


FIGURE 6

DISTRIBUTION OF Exogone lourei

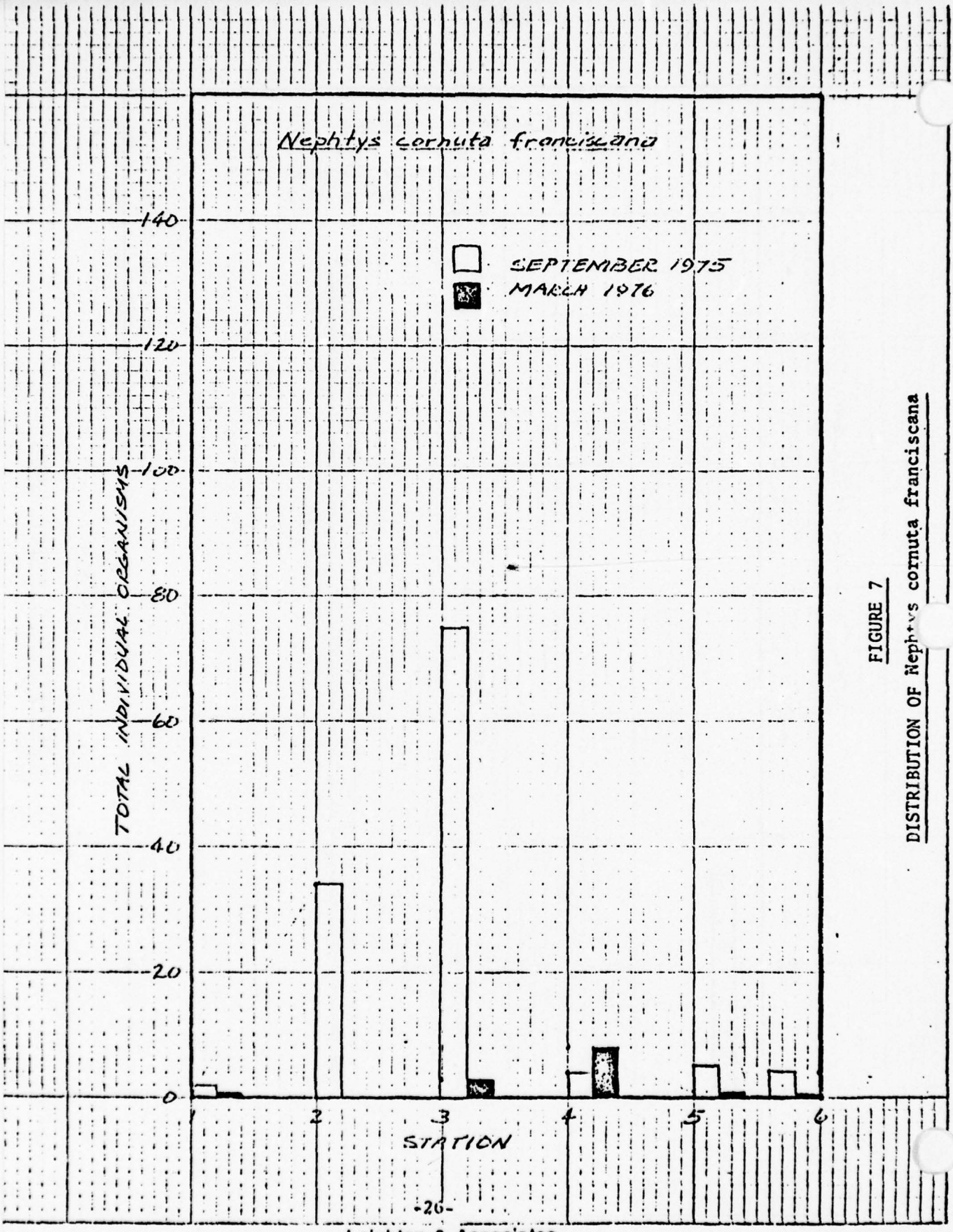


FIGURE 7

DISTRIBUTION OF Nephtys cornuta franciscana

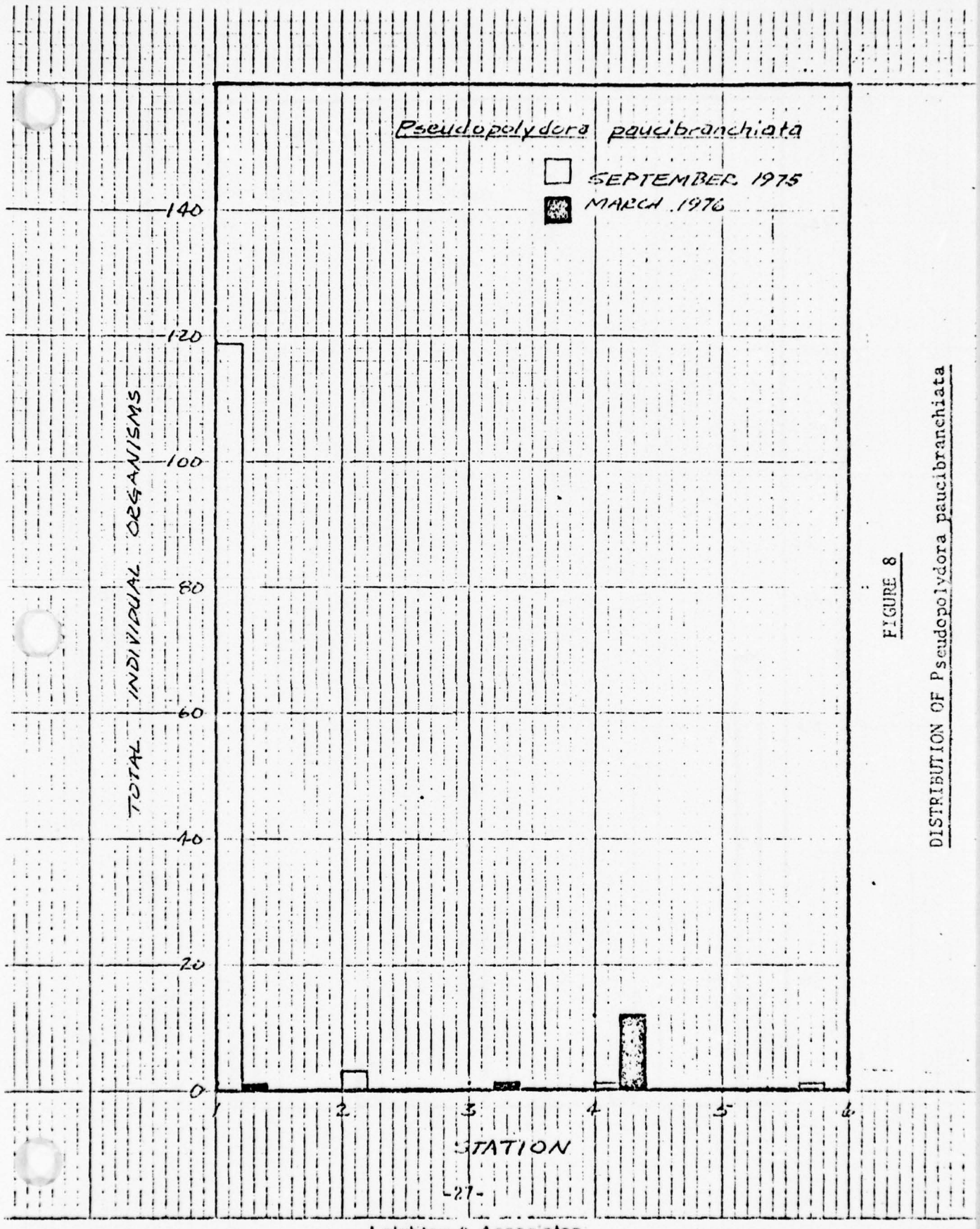


FIGURE 8

DISTRIBUTION OF Pseudopolydora paucibranchiata

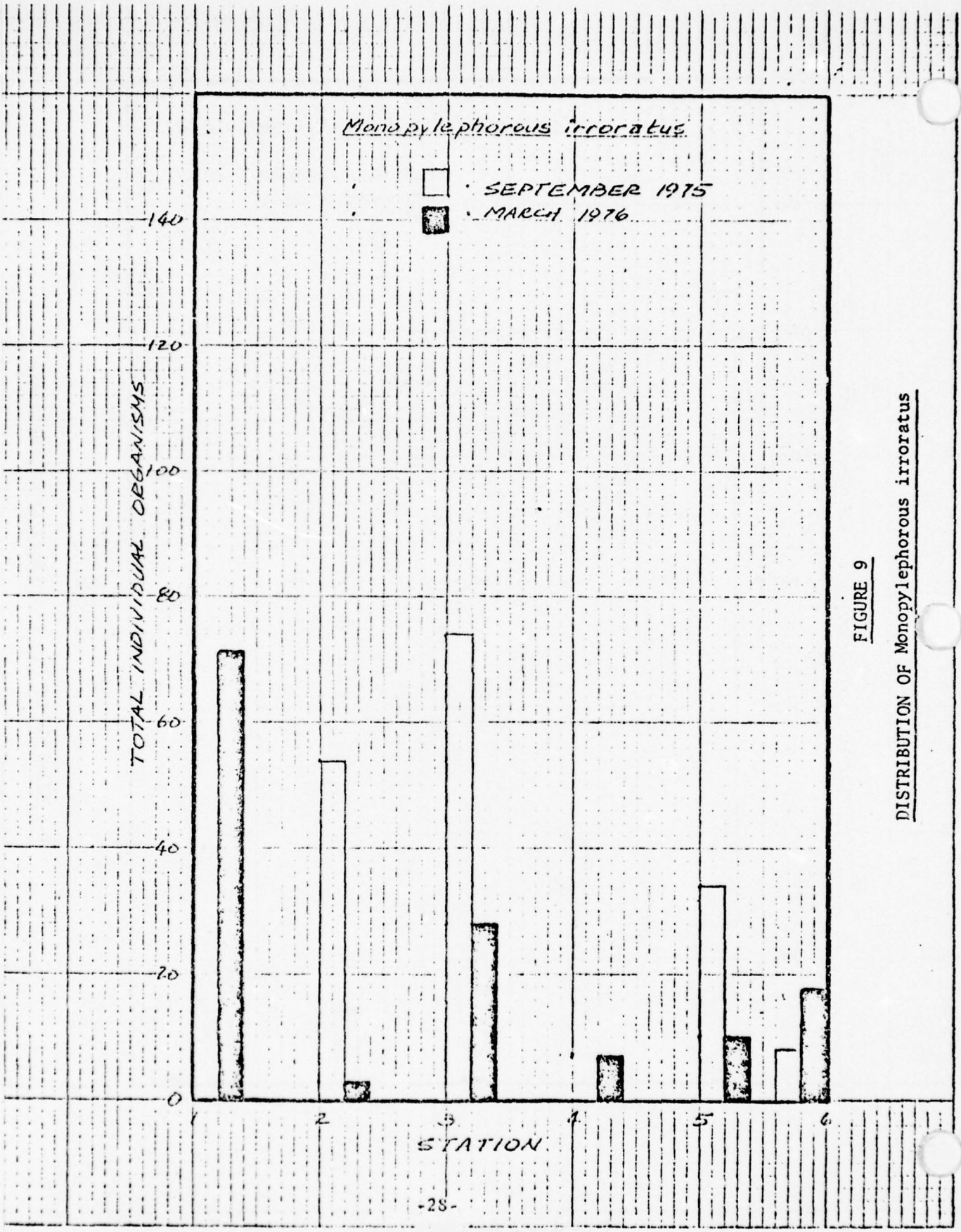


FIGURE 9

DISTRIBUTION OF Monopylephorous irroratus

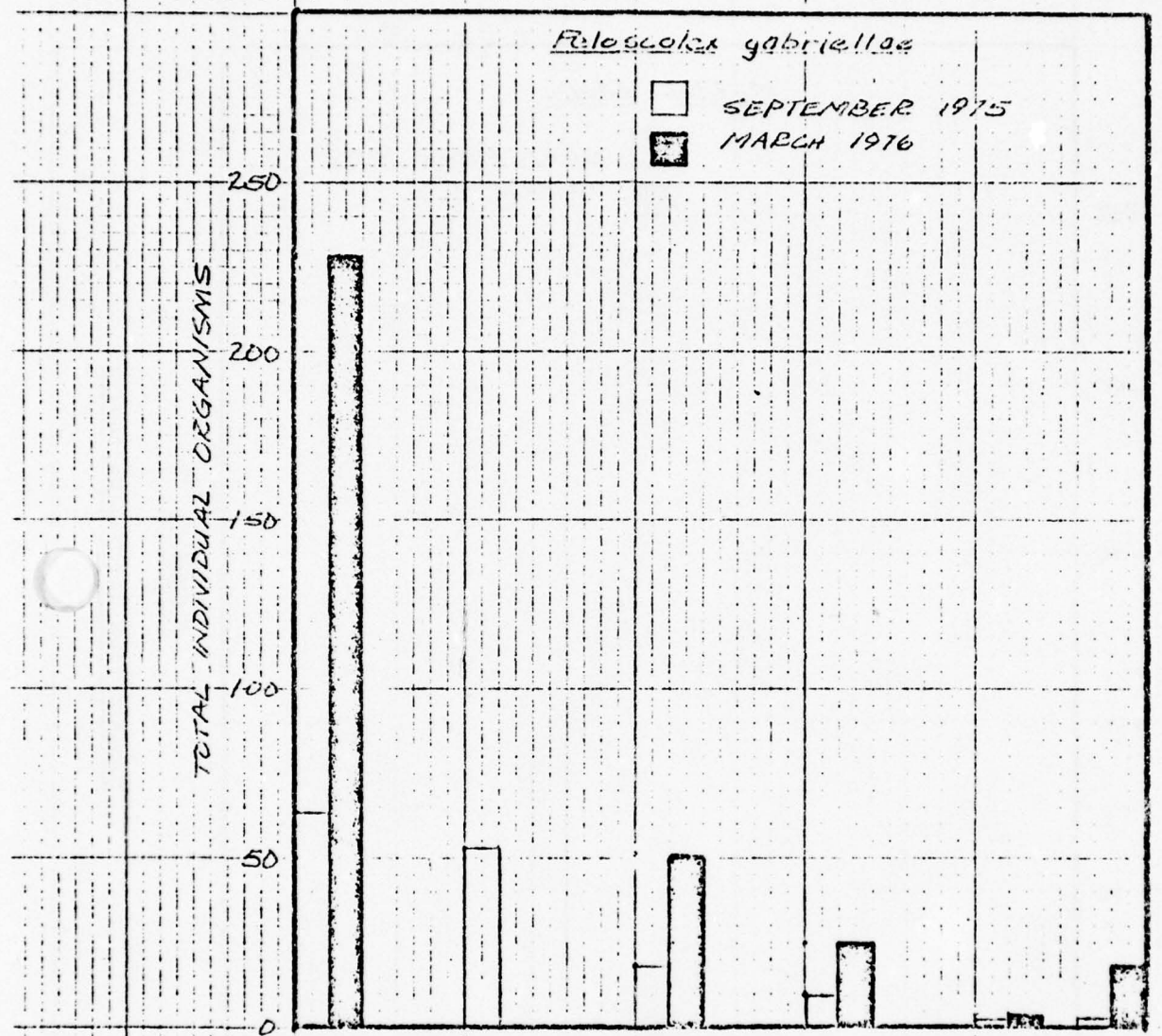


FIGURE 10

DISTRIBUTION OF Peloscolex gabriellae

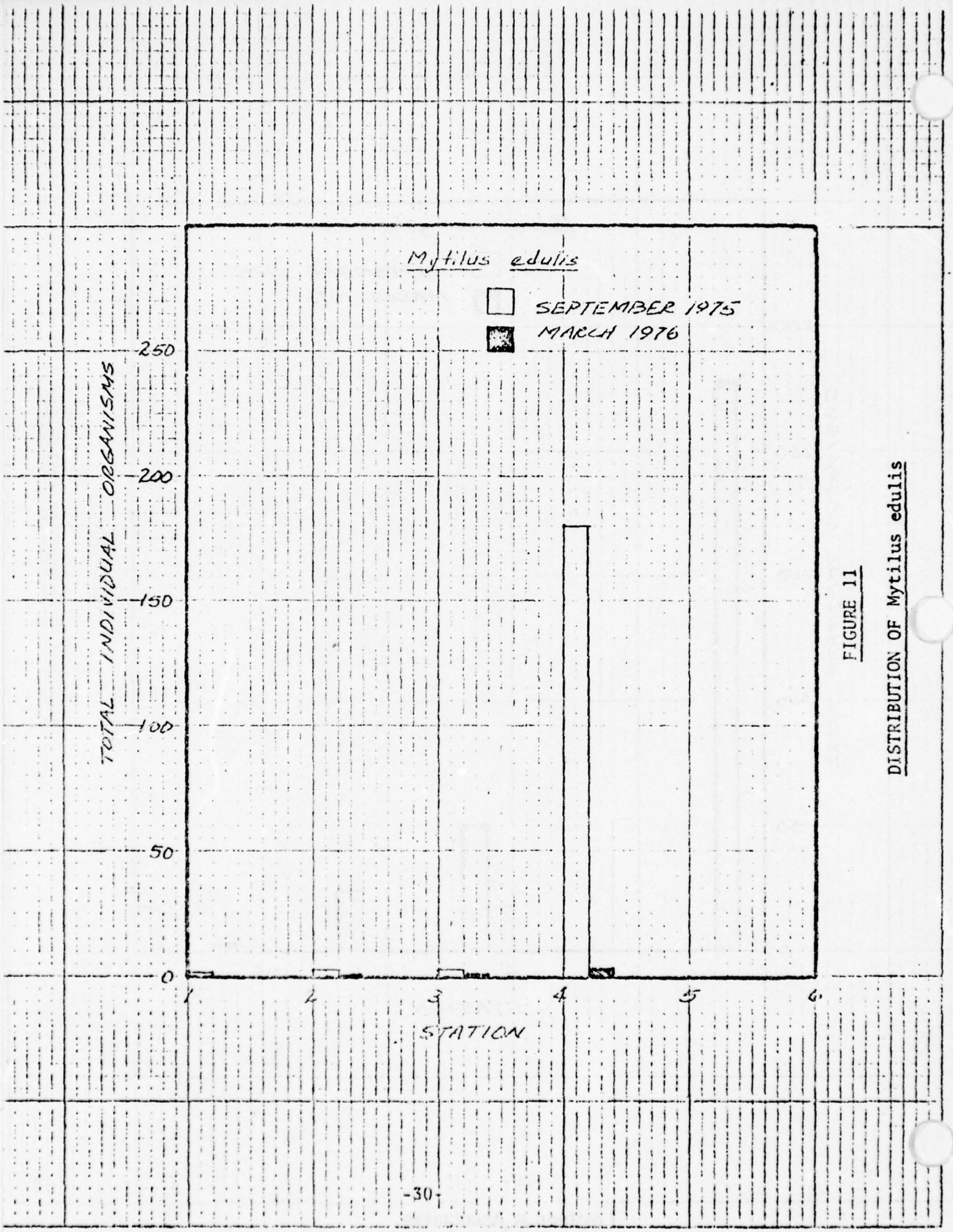


FIGURE 11

DISTRIBUTION OF Mytilus edulis

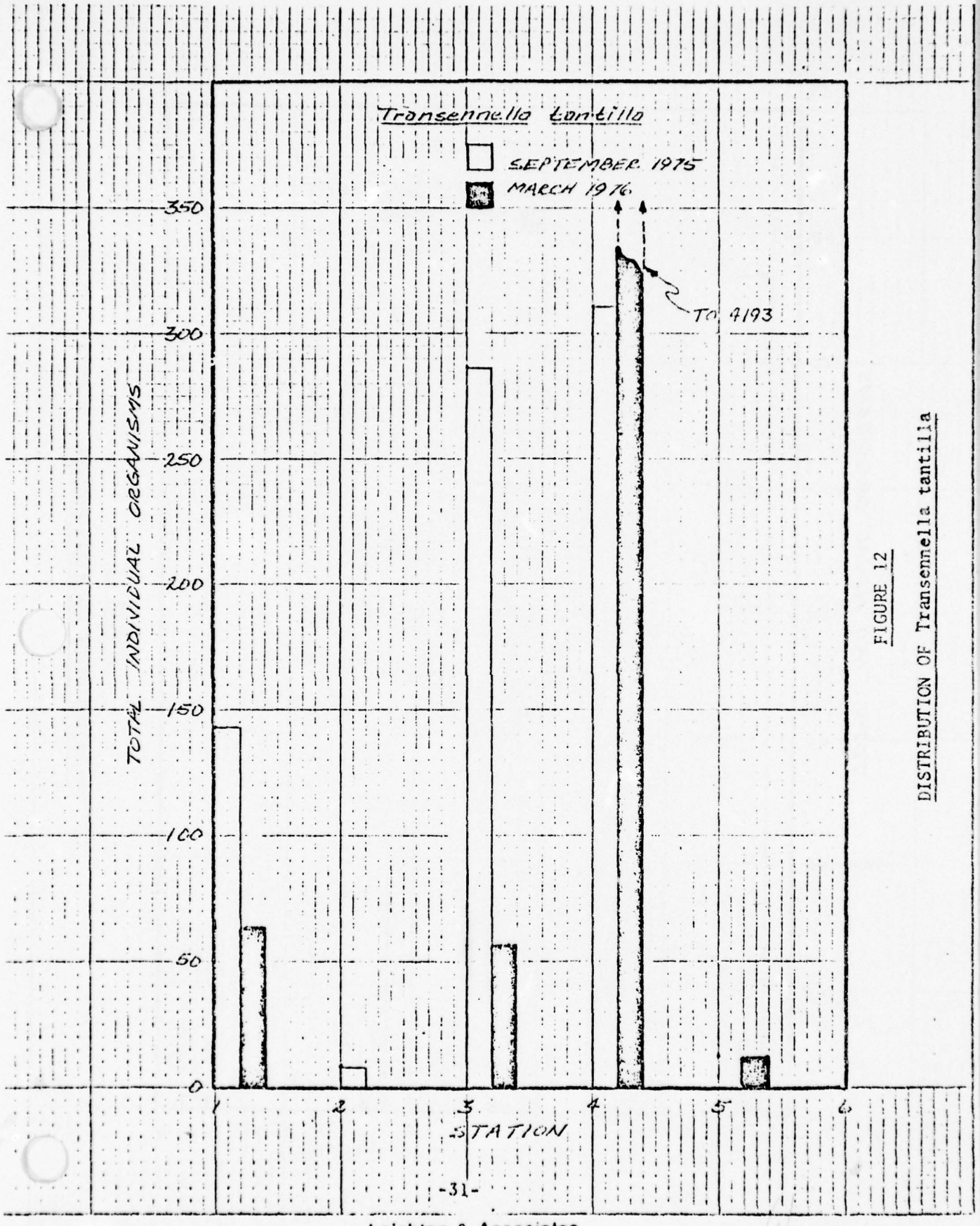


FIGURE 12

DISTRIBUTION OF Transennella tantilla

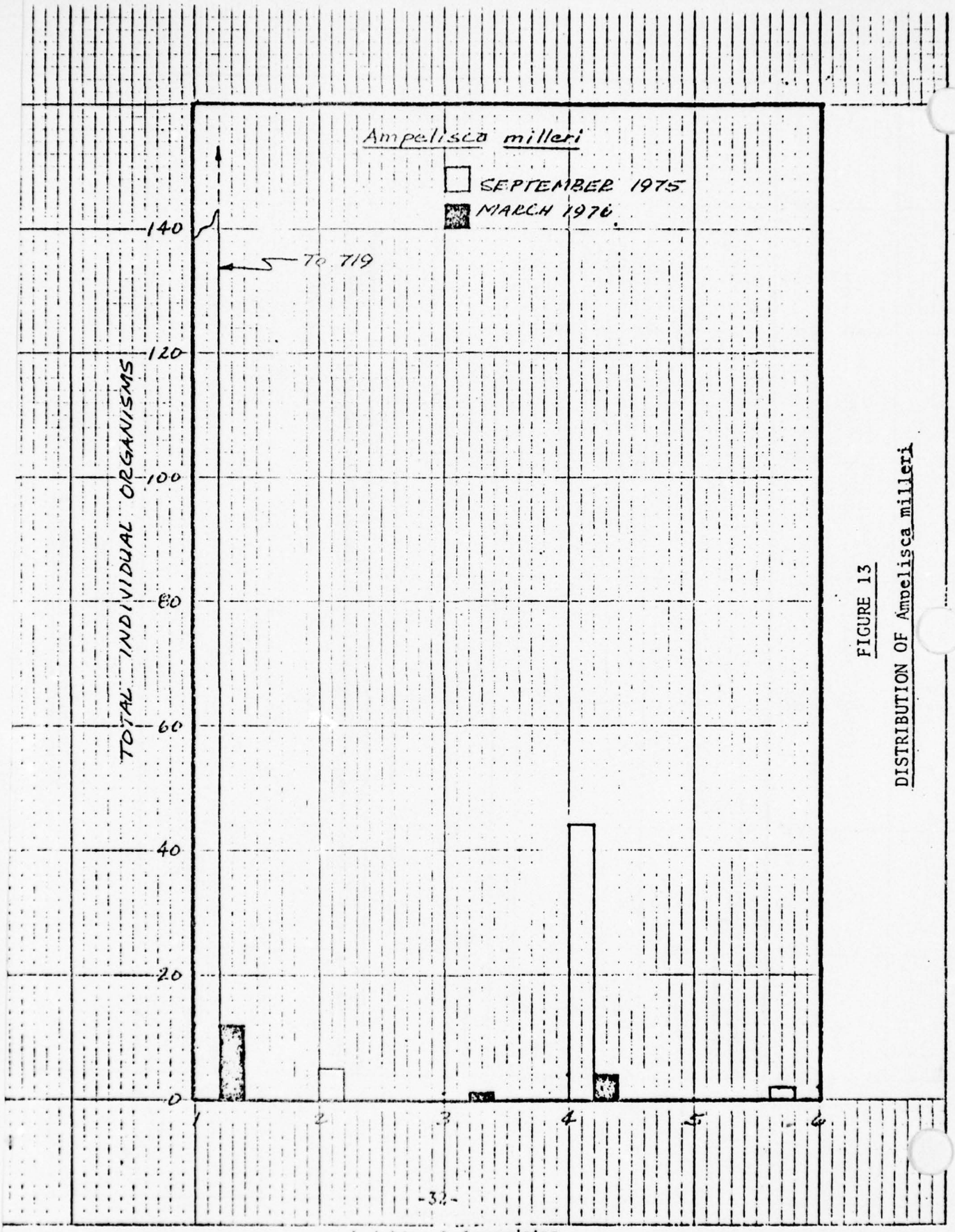


FIGURE 13

DISTRIBUTION OF Ampelisca milleri

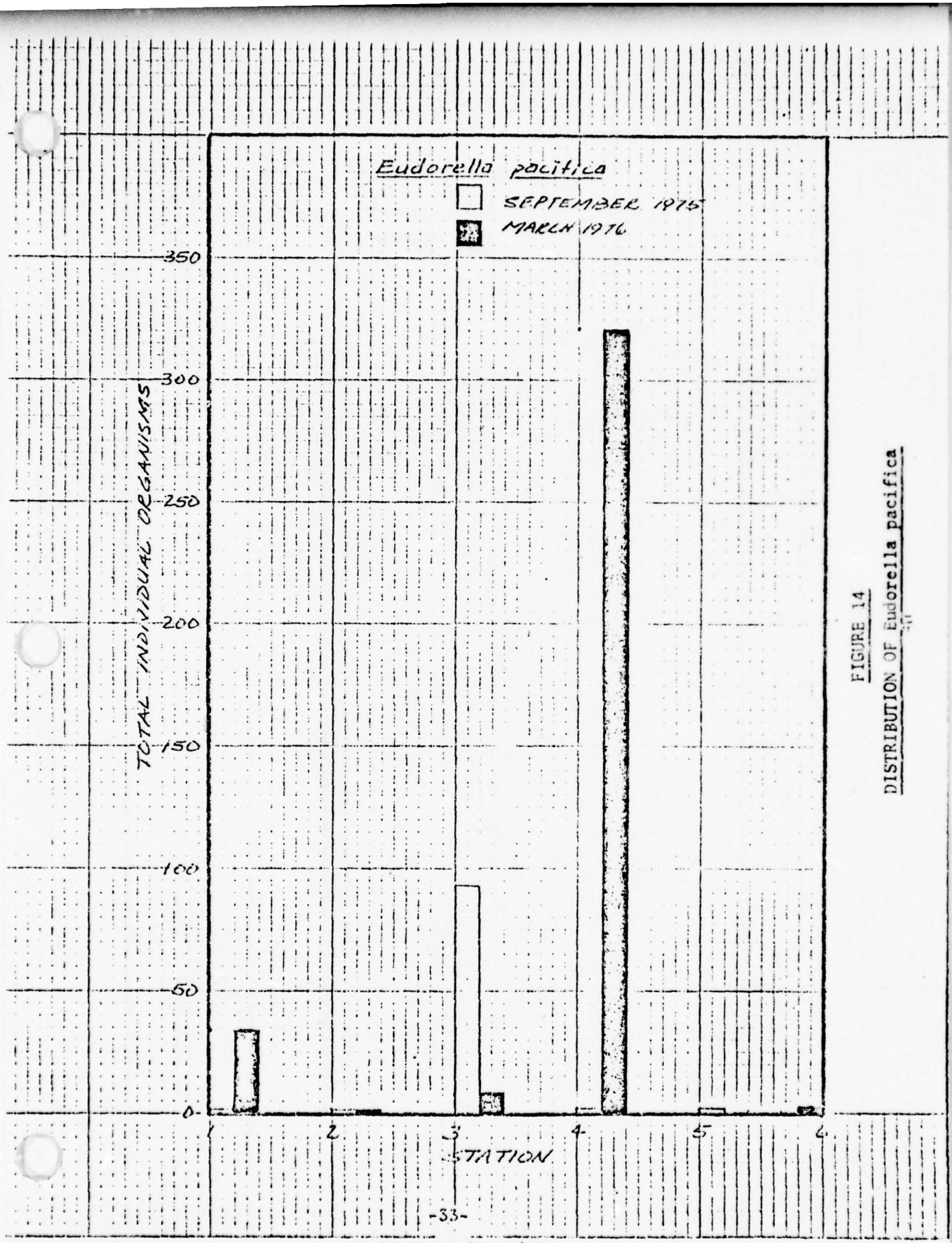


FIGURE 14

DISTRIBUTION OF Eudorella pacifica

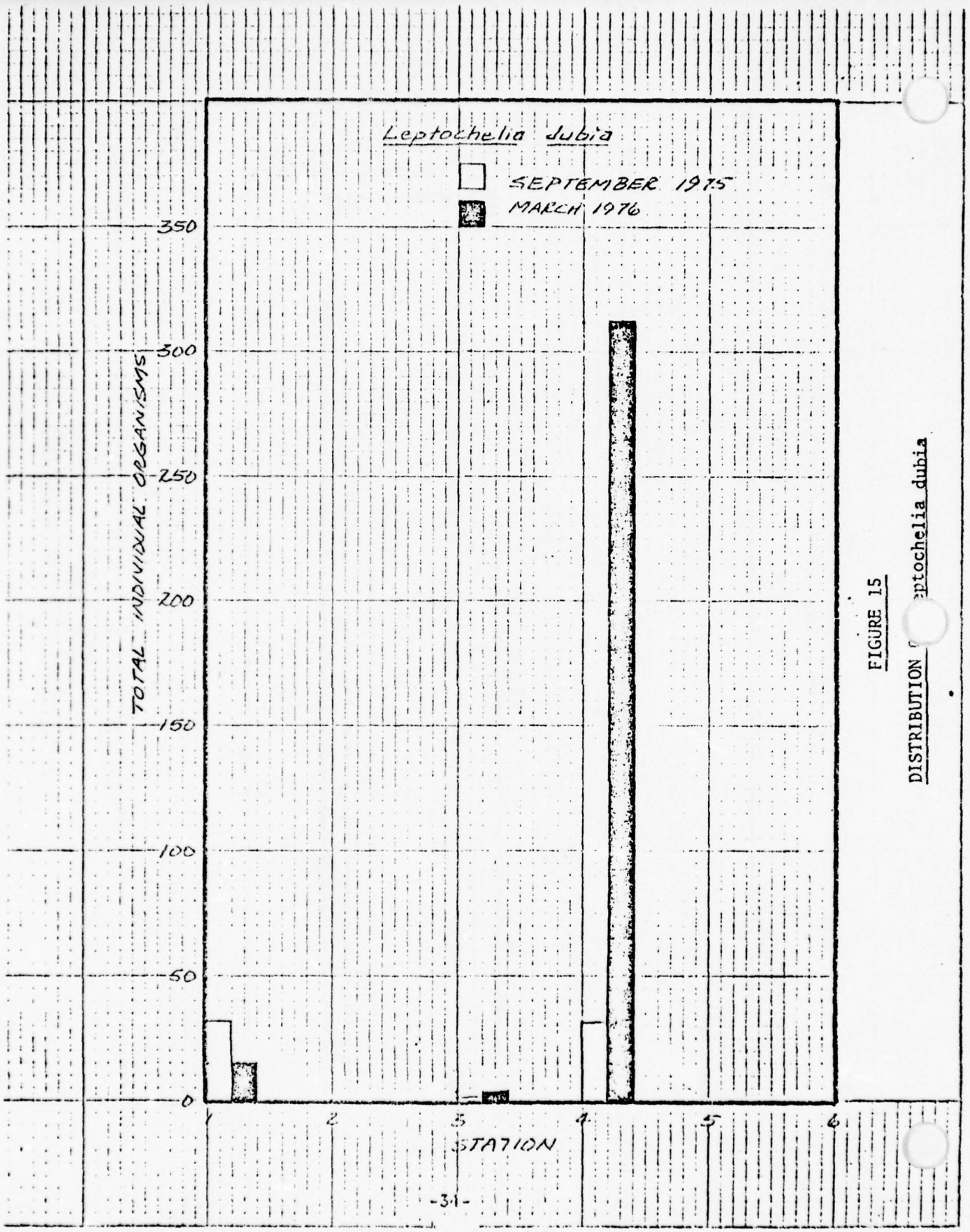


FIGURE 15

DISTRIBUTION [illegible]eptochelia dubia

The Annelid Peloscolex gabriellae is the only species to demonstrate a significant population increase at station 3 during the March sampling period.

Station 4 demonstrates the largest variability of all the sampled areas. The populations of the Annelid Exogone lourei, the Mollusc Transennella tantilla and the Arthropod Eudorella pacifica and Leptochelia dubia increase drastically at station 4 during the March period. However, the predominant species present at this location in September were the Mollusca Mytilus edulis and Transennella tantilla and the Arthropod Ampelisca milleri.

Finally all of these significant species show significant variations in abundance throughout the study area within each sampling period, and from period to period, particularly at stations 1, 3 and 4.

DISCUSSION OF BIOLOGICAL RESULTS

The station locations selected for this study, although limited in number, provide a general picture of the benthic infauna present in the Oakland Outer Harbor and the adjacent area. The study has addressed itself to establishing a general picture of the distribution and variations therein of the benthic fauna during the late summer-early fall, late winter-early spring periods of 1975-1976.

The physical parameters determined during the study indicate the environment was slightly alkaline with an average salinity of 32.0‰ in the late summer, and was of greater alkalinity with a lower salinity (average 29.56) during the late (dry) winter. These conditions parallel the expected situation in that evaporation is higher in the summer with little freshwater inflow, while the winter period is characterized by increased freshwater input. Interpretation of these values should be tempered with the fact that the salinity determinations on the initial water samples was subject to a two-day delay and that freshwater input tests of the study area was below normal between the September 1975 and March 1976 sampling periods. The higher pH in the March period is probably the result of increased photosynthetic activity during that time. It is noted that the sampling times employed in this study occurred at the end of the summer and at the end of the winter periods which are frequently the most detrimental times for organisms due to the changing physical conditions in the environment. Thus communities may be in a state of flux during such periods. Changing communities are therefore more likely to be evaluated at such times rather than climax communities. No specific relationship has been established in this study between the communities identified and the physical parameters established other than normal seasonal variations. It is noted, however, that much of the data necessary to this type of detailed analysis was not included in the sample design applied in this work. Considering the potential variability of such chemical/physical parameters during times of seasonal change, it is doubtful that the expended effort would have justified the results, had such data been included.

Other variables and limitations applicable to this study and worthy of consideration in review of the following discussion include:

a. the variation in replicate volumes recovered during the first sampling period compared to the more uniform samples obtained in March;

b. the possibility that the stations occupied during the second sampling period were not exactly the locations sampled during September (evidenced by the significant changes found in sediment type at locations potentially unaffected by the intermediate dredging in January of 1976) and the variations in depth;

c. the procedural change which occurred between the first and second sampling period relative to the establishment of the physical/chemical parameters determined for the area, and;

d. finally the length of the samplers which increased the volume of sediment collected at each station to a depth significantly greater than that considered to be optimum for benthic fauna collection.

As previously noted, the sediments encountered in this study consisted predominantly of silt and clayey silt with minor amounts of sand at stations 2, 3, 4, and 6. Nichols (1970) has concluded that the finer size materials are conducive to organism growth due to the presence of greater nutrient supplies. No overall correlation between sediment changes encountered at various stations during this study and corresponding increases or decreases in organism abundance was determined during this investigation. However, at stations 2 and 5 where the amount of sand increased from the September period to the March period, there is a corresponding decrease in organism abundance for the same period. It is possible therefore that the relative amounts of fine sized material in the average bay sediments are present in large enough amounts to provide a satisfactory sub-stratum for benthic fauna, and that this normal condition may be disturbed by a seasonal/abnormal influx of coarser material in specific instances.

A slight decrease 55 to 53 in the number of species in the area was established for the March sampling period versus the September period which is considered normal for the respective times of year involved. A volume of 66 liters of material was collected and analyzed during September whereas 85 liters of material was available for analysis in March. The inadequate sample volumes achieved in September for stations 2, 3, 5, and 6 may have had some impact on the accuracy of the number of species determined to be present during this period. A corresponding increase in the number of individuals occurred during the March period along with a slight increase in the average species diversity and species evenness values for the same time. A plot of Species Diversity for the two sampling periods by station is shown in Figure 16 and for Species Evenness for the two sampling periods by station is shown in Figure 17.

Station 2 is the only station to demonstrate a minimal change in Species Diversity between the two periods. The other stations all show a relatively large variation in this statistical parameter. Species Diversity increases

in March at stations 1, 2, 3, and 5 and decreases during this period at stations 4 and 6. All of the stations occupied demonstrate some significance change in Species Evenness between the two periods. Stations 1, 2, 3, and 5 again show an increase in this parameter while stations 4 and 6 demonstrate a decrease in Evenness in March.

The variations in Species Diversity between the two periods may well be due to two primary considerations:

a. normal seasonal changes in organism populations and community structures, and

b. the impact of the annual maintenance dredging that occurred in the area in January of 1976.

Those stations considered to be directly affected by the dredging operation include the channel station 6 and stations 2 and 3, which although not directly subject to dredging due to position (2) and depth (3), may have suffered secondary affects. Stations 1, 4, and 5 are side channel stations and other than for some short term effects resulting from potentially increased turbidity, were effectively free of the dredging impact. Thus station 6 experienced a Diversity decrease in March and was subject to dredging in January. However, station 4 also experienced a large drop in Diversity in March and was not subject to dredging nor exposed to secondary effects of dredging to any major degree.

Similar relationships exist for the Species Evenness determinations. Evenness decreases at both stations 4 and 6 for the March period again reflecting the possibility that the variation of both of these parameters may be dependent on seasonal considerations as well as dredging effects. It is noted that the inadequate sample volumes previously mentioned and the possible variation in station locations for the second sampling period may also be of importance here.

The benthic infauna of this area determined during the two sampling periods demonstrated only an immediate level of homogeneity in species composition, as shown by the computations of the Sorensen Quotient of Similarity. Comparison of the similarity quotients between stations and between periods between stations indicates the study area may be tentatively divided into two sub areas: the inner harbor area represented by stations 2, 5, and 6 and the outer entrance channel area represented by stations 1, 3, and 4. The homogeneity in species composition of the inner area is somewhat lower than for the outer stations. Titman (1976) has recently offered evidence that marine environments subject to fluctuating conditions may provide support for greater numbers of species than do more constant environments not subject to natural physical disturbances. Thus it is possible that the poorer homogeneity demonstrated by the inner harbor locations is a result of more polluted conditions and adverse impacts of ship traffic and dredging while the greater diversity and homogeneity of the outer stations (1, 3, and 4) are the result of a decreased but changing environmental resistance to community establishment.

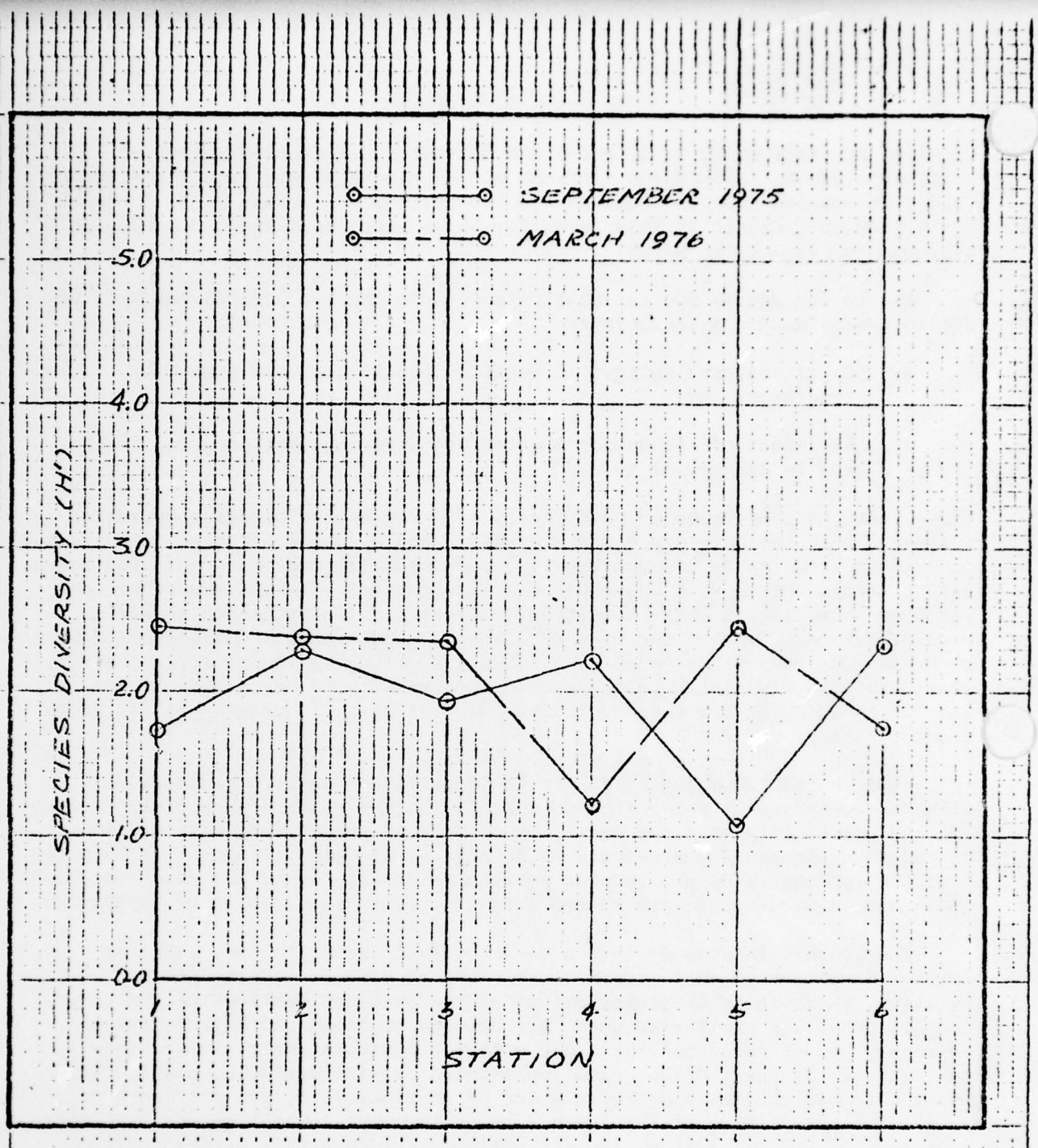


FIGURE 16

SPECIES DIVERSITY VS. STATION

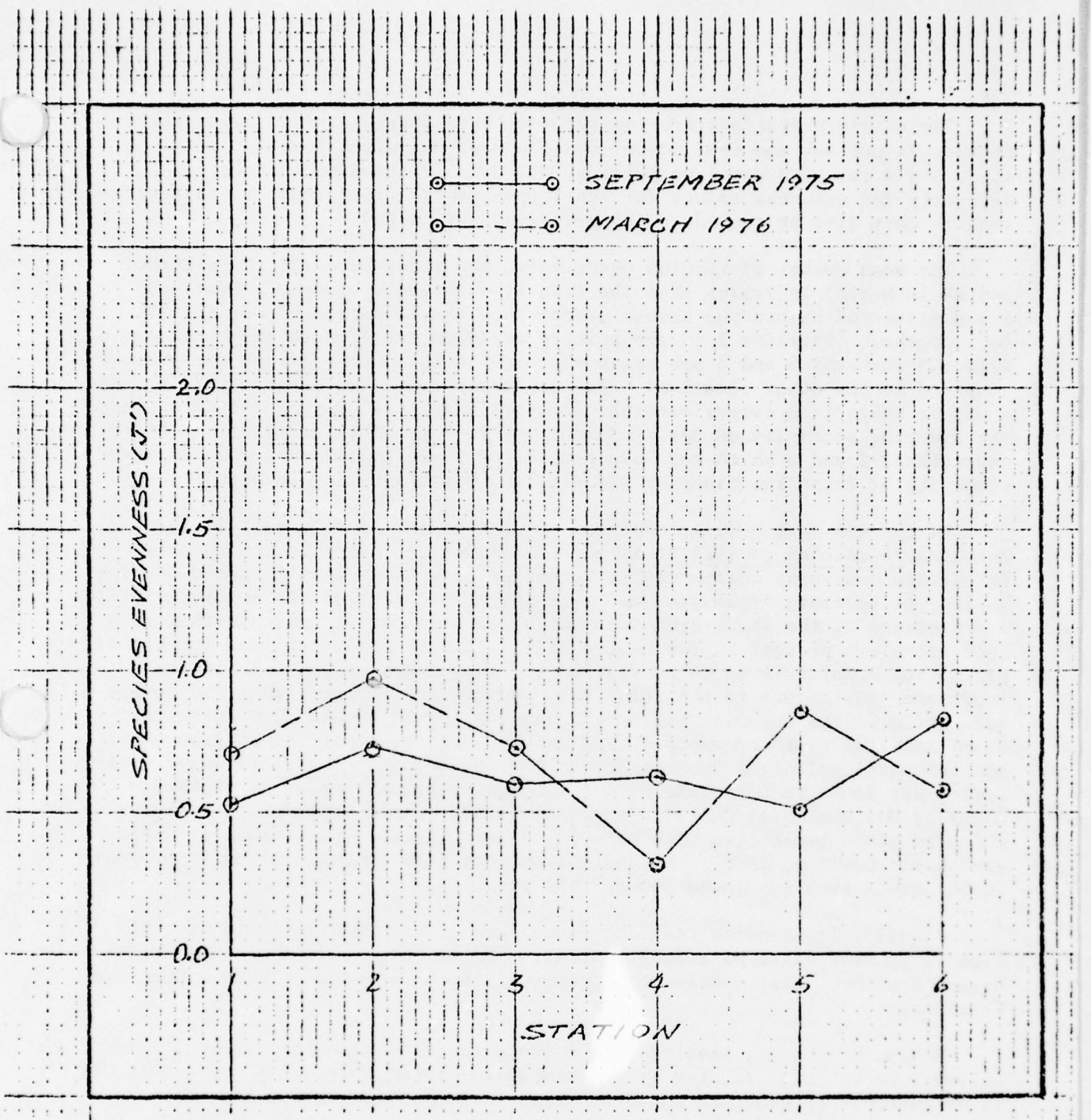


FIGURE 17

SPECIES EVENNESS VS. STATION

These interpretations are supported to some degree by the larger number of species present and the greater abundance of organisms found at stations 1, 3, and 4 for both sampling periods, but consideration of the species diversity and evenness values for the respective stations indicate that other factors must also be considered as previously discussed.

The mean number of species observed in the study area (22 in September and 24 in March) indicates that the area is relatively diverse. Stations 5 and 6 located within the harbor proper show the lowest number of species in September. Stations 2 is the primary depleted location in the March period, although stations 5 and 6 are again also low in the number of species present compared to the other locations. As previously mentioned, stations 2, 5, and 6 may be subject to larger external stresses and it is our understanding that the dredging accomplished during January of 1976 probably had a direct effect on stations 2 and 6 which may have prohibited the establishment of a diverse community at these locations by the time the March sampling occurred.

Of the ten most dominant species present in the study area only the Annelida Peloscolex gabriellae is particularly significant in its ability to withstand adverse environmental conditions. This species is noted for its ability to tolerate freshwater and gross organic pollution (Brinkhurst, 1971). Its presence in the study area does not however in itself indicate that such conditions are present in the environment. This organism achieved its highest population density in March at station 1. This location was selected as a reference station due to its relatively undisturbed nature. Thus the normal life cycle of the organism may be the controlling factor in this instance. Other Annelida that were encountered in the area, of significance from an environmental pollution standpoint, include Streblospio benedicti whose distribution was found to correlate with the organic carbon content of the sediments by Environmental Quality Analysts in 1973, and Monopylephorous irroratus, which is often associated with decaying plant material and freshwater seepages (Smith and Carlton, 1975). No indication that such an association is present in the study area was found during this investigation.

Finally, it is noted that the occurrence of Euchone limnicola in this area is considered to be a range extension by Dr. James Blake of the Pacific Marine Station. This species has previously been reported only from Southern California.

Since the channel stations 3 and 6 and the side channel station 2 were believed to be most affected by the annual maintenance dredging operations, it is of interest to evaluate these stations in comparison to the reference station 1 and the side channel stations 4 and 5 believed to be relatively unaffected by the dredging procedure.

As previously discussed, the predominant sediment present at stations 1 and 4 remained essentially the same for both of the sampling periods supporting the conclusion that these stations were effectively undisturbed by dredging impact. Station 5 demonstrated some change in sediment type between the two sampling periods which may be the result of the proximity of this station to the main inner channel coupled with the potential for decreased flushing activity in this area.

If station 1 is utilized as a reference station and noting that this station provided adequate sample volumes during the first sampling period, the variations at this station of the benthic community may tentatively be used as at least partially representative of the undisturbed changes in the area between the two periods. The total abundance of fauna at station 1 decreased in March while a slight increase occurred in the number of species present. Thus, the species diversity increased as did the species evenness for the second sampling period. None of the other stations follow the same pattern, i.e., abundance decreases for stations 2 and 3 while it increases at station 6. Similarily Diversity increases for stations 2 and 3 while it decreases at station 6. Evenness increases for stations 2 and 3 and decreases at station 6. Similar opposite relationships apply to stations 4 and 5. Thus no direct relationships appear to exist on the basis of the present study for these parameters.

Consideration of the similarity of faunal composition between stations does however provide the following relationships. The similarity of composition between stations 2 and 3 and 2 and 6 is high during the September period, whereas the similarity between these stations dropped to an intermediate level in March. The similarity of compositions between all stations and the reference station 1 is in the intermediate range except stations 3 in March when the value rises to a high level. Thus although no significant correlation appears to exist between the reference station and any of the other stations, there is some indication that some similarity in faunal composition had been established in the channel stations prior to the maintenance dredging. It is also noted that station 3, which was not dredged directly due to its pre-existing depth, shows a high level of similarity in faunal composition between the two sampling periods.

CONCLUSIONS

The foregoing analysis of the results of this study lead to the following conclusions:

1. The poorer homogeneity of the inner harbor locations (stations 2, 5, and 6) may be the result of pollution and the adverse impacts of ship traffic and annual maintenance dredging, while the greater diversity and homogeneity of the outer stations (1, 3, and 4) appear to be the result of a decreased but changing environmental resistance to community establishment.

2. The mean number of species determined for the study area (22 in September and 24 in March) indicates that the area is relatively diverse. Stations 5 and 6 located within the harbor proper show the lowest number of species in September. Station 2 is the primary depleted location in March although stations 5 and 6 were also low compared to the other locations. Stations 2, 5, and 6 may be subject to larger external stresses due to their location. Additionally it is our understanding that the dredging accomplished during January of 1976 potentially had a direct effect on stations 2 and 6. This action may therefore have prohibited the establishment of a diverse community at these locations prior to the time of the March sampling period.

3. The nature of the variations in Species Diversity and Species Evenness are indicative that they are the result of a combination of normal seasonal changes in organism and community development and the impact of the annual maintenance dredging that occurred in January of 1976.

4. Although the relationship between the reference station (1) and the other stations in the area, and the distinction between the channel stations and the side channel stations is somewhat diffuse in terms of the parameters evaluated, some significant similarity in faunal composition between the channel stations appears to have existed prior to the annual maintenance dredging.

5. There is some evidence to indicate that certain subenvironments in the study area are potentially subject to greater stress due to external disturbances. The effects of such stress do not however appear to be of major significance in determining the communities present throughout the area.

6. The influx of coarser sediment at certain stations during the winter season may have a minor adverse effect on organism population at these locations.

7. The relatively diverse infauna communities present throughout most of the area appear to be fairly viable and of a nature that considering depth changes, would allow for some re-establishment after dredging, particularly if the dredging was accomplished at proper time intervals.

8. Although the present study provides a general baseline picture of the benthic fauna in the study area and defines to a limited degree the interrelationships between these organisms and their environment, more detailed work would greatly enhance the value of the present work. It is recommended that additional effort include a more detailed analysis of the physical/chemical parameters of the area, including long term monitoring to establish normal patterns of variation, a more closely spaced sampling design with an increased number of stations, and utilization of an improved sampling procedure with a possible increased number of replicates.

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APPENDIX A

EVALUATION OF BIOLOGICAL SAMPLING PROCEDURE

EVALUATION OF SAMPLING PROCEDURE

Sampler dimensions cited in the section on Biological Sampling Procedure are those of the average sampling device since the lengths of individual samplers were found to range from 28.5 cm to 30.0 cm (sampler volume 2.17-2.28 liters). The introduced error in sample volume is considered negligible in relation to other variables.

One measure of the ability of a sampling device (which here must include the PVC sampler and diver) to take reliable replicate samples is the coefficient of variation of replicate sample volumes (CV=100 x standard deviation/mean). Low values indicate high sampling reliability. Hodgson and Nybakken (1973) applied this measure to the Smith-McIntyre grab in relation to their benthic infaunal survey of Northern Monterey Bay. Environmental Quality Analysts and Marine Biological Consultants (1975) utilized CV values to evaluate the performance of the Ponar grab in a benthic infaunal survey in the immediate vicinity of the Outer Harbor investigation. Coefficient values ranged from 0.00 to 15.75 percent, averaging 7.74 percent. However, the present survey encompasses a wider variety of sediment types and this is reflected by CV values ranging from 0.0 to 46.7 percent (Table A-1) and averaging 21.3 percent for the September 1975 sampling period. Improved sampling efficiency for the March 1976 sampling period led to lower CV values for the period, and consequently a much higher sampling reliability. The CV values for March 1976 ranged from 0.0 to 4.3 percent (Table A-1) and average 3.4 percent. It is interesting to note that station 10 of the EQA/MBC survey is in close proximity to station 4 of the current survey, and in both instances the respective samplers displayed equally high replication with CV values of 0.0.

During the course of their May 1974 survey EQA and MBC collected 36 Ponar grab samples from 12 stations. The low CV figures, the uniformly soft sediments and results of selected statistical analyses prompted the conclusion that three replicates per station (average volume 5.9 liters, sampling area 0.05m^2) were adequate to sample major components of the infauna. However, an opposing set of circumstances at four of the six stations precludes any such judgment in the current survey. That three replicates may be insufficient is further supported by the conclusion of Hodgson and Nybakken (1973) that six replicates were adequate to sample dominant species in coastal marine sediments of Monterey Bay using the Smith-McIntyre grab (sampling area 0.1 m). A comparison of the minimal sampling area of the PVC sampler (0.015 m) in relation to that of the remote samplers probably dictates collection of additional replicates to accurately characterize the faunal composition of the upper few centimerers of sediment. A more empiracle evaluation of the reduced number of samples should be undertaken by (1) subjecting data presented in this report to appropriate Statistical Analyses, and (2) if feasible, plotting cumulative number of species against increased sampling area as suggested by Hodgson and Nybakken (1973).

TABLE A-1

SEDIMENT VOLUMES OF PVC SAMPLER
AT EACH BENTHIC STATION

Stn. No.	No. of Replicates		Mean Vols. (liters)		Range of Variation		Standard Deviation		*CV(%)	
	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar
1	3	3	4.4	4.7	0.0	0.0	0.0	.05	0.0	1.1
2	(3)	3	3.0	4.8	1.7-4.4	4.7-4.8	1.4	.05	46.7	1.01
3	(3)	3	2.8	4.6	2.3-3.6	4.4-4.8	0.7	.20	25.0	4.31
4	3	3	4.3	4.8	4.0-4.4	4.7-4.9	0.1	.10	2.3	2.0
5	(3)	3	3.8	4.7	2.9-4.4	0.0	.08	0.0	21.1	0.0
6	(3)	3	3.7	4.7	2.3-4.4	4.6-4.8	1.2	.10	32.4	2.1

* CV = coefficient of variation = standard deviation/mean x 100

( ) = Inadequate sample volumes: Potential adverse impact on significance of data analysis.

The investigations cited thus far also tend to conclude that collecting sediments to a depth of 10 cm will adequately sample the bulk of the infauna. While maximum desirable depth of penetration undoubtedly varies with sediment type, the PVC sampler length of 29.5 cm is considered excessive. A sampling device of greater diameter and reduced length would probably achieve more representative sampling with fewer replicates by increasing sampling areas without drastically increasing sample volume and associated analysis expense.

While the use of divers to collect benthic samples is subject to the obvious limitations of depth, water conditions and expense, the trained and disciplined diver may offer the following advantages over remote sampling devices: (1) more consistent application of the sampler to the sediments, i.e., depth and angle of penetration and thus more uniform volumes and profiles, (2) minimal disturbance of the sediment surface (under ideal conditions) as opposed to the flushing action of the pressure wave which precedes the remote sampler as it approaches the bottom, (3) the ability to judge whether samples are representative and to qualify data accordingly, and (4) collection of additional visual information about the habitat being sampled. At station 1 divers were able to observe sea pens to be more common than sampling results indicated.

Successful application of divers to the task of benthic sampling in Oakland Outer Harbor during the first sampling period was impaired by three major factors: (1) diver performance, (2) adverse water conditions, and (3) sediment instability.

The most fundamental of these was diver performance and utilization. In some instances, diver performance was open to question due to the "black-water" diving conditions and use of the PVC sampler. This is not to say that divers did not function to the best of their ability and display considerable perserverence in a number of instances, but two of the divers had only minimal time in black water diving and had not previously utilized the PVC sampler. While it should be pointed out that this survey was also serving as a training exercise, this does not diminish the fact that experience and discipline remain fundamental to diver reliability. This source of error was compounded by varying sampling teams within and between stations, thus introducing an unnecessary source of variation which has an undetermined but real influence upon sampling consistency and validity. This consideration may be at least minimized by training divers to function as two man teams of consistent compostion and by eliminating variation of sampling personnel within any single station and at least reduce inconsistencies between stations. These procedures were incorporated into the sampling procedure during the second period and contributed immensley to the improved sampling reliability achieved in March 1976.

The disruptive influence of adverse water conditions was clearly demonstrated at station 3 and 4 where tidal currents of unanticipated force made it difficult to sample properly and consistently during the first sampling period. Only diver perserverence produced maximum sample volumes in two of the three replicates from station 4, and at station 3 even repeated sampling efforts failed to provide complete samples as indicated by replicate volumes of 2.3-3.6 liters.

At station 2 divers were unable to positively locate any consolidated sediments as the upper few feet of bottom material was in a colloidal state. Sample columes of 1.7-4-4 liters illustrate the problems of sampling such unstable sediments with divers, although it is questionable that remote samplers would have had greater success.

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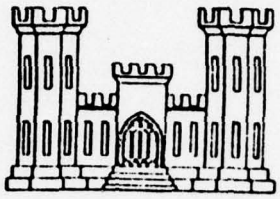
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APPENDIX B

ANALYSIS OF SEDIMENTS
AND
WATER SAMPLES

OAKLAND OUTER HARBOR

DEPARTMENT OF THE ARMY
SOUTH PACIFIC DIVISION, CORPS OF ENGINEERS
LABORATORY



ANALYSIS OF SEDIMENTS AND WATER SAMPLES

OAKLAND OUTER HARBOR

SAUSALITO, CALIFORNIA

October 1975

OAKLAND OUTER HARBOR

ANALYSIS OF SEDIMENTS AND WATER SAMPLES

October 1975

AUTHORIZATION

1. Results of tests reported herein were requested by DA Form 2544, No. E86-76-3008, 11 September 1975, and Change Order No. 1, 26 September 1975, from the San Francisco District.

PURPOSE

2. The purpose of this study was to determine the quantities of specified pollutants in water samples and to determine the mechanical analysis of the sediment samples.

SAMPLES

3. The following samples were delivered to the laboratory:

a. Six jar samples of sediments, received 18 September 1975.

b. Six bottles of water, received 18 September 1975.

TEST METHODS

4. Tests were performed as follows:

a. T.D.S., pH, Kjeldahl Nitrogen, and Total Phosphate tests were run according to the 13th edition of "Standard Methods for Examination of Water and Wastewater", published by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation.

b. Soil gradations were in accordance with Engineer Manual EM-1110-2-1906, "Laboratory Soil Testing", 30 May 1970.

TEST RESULTS

5. Test results are presented as follows:

a. Table 1 shows chemical tests made on the water samples.

b. ENG Forms 2087 show the gradation curves on selected samples.

COMMENTS

6. The results of tests on the water samples are reported as milligrams per liter (mg/l).

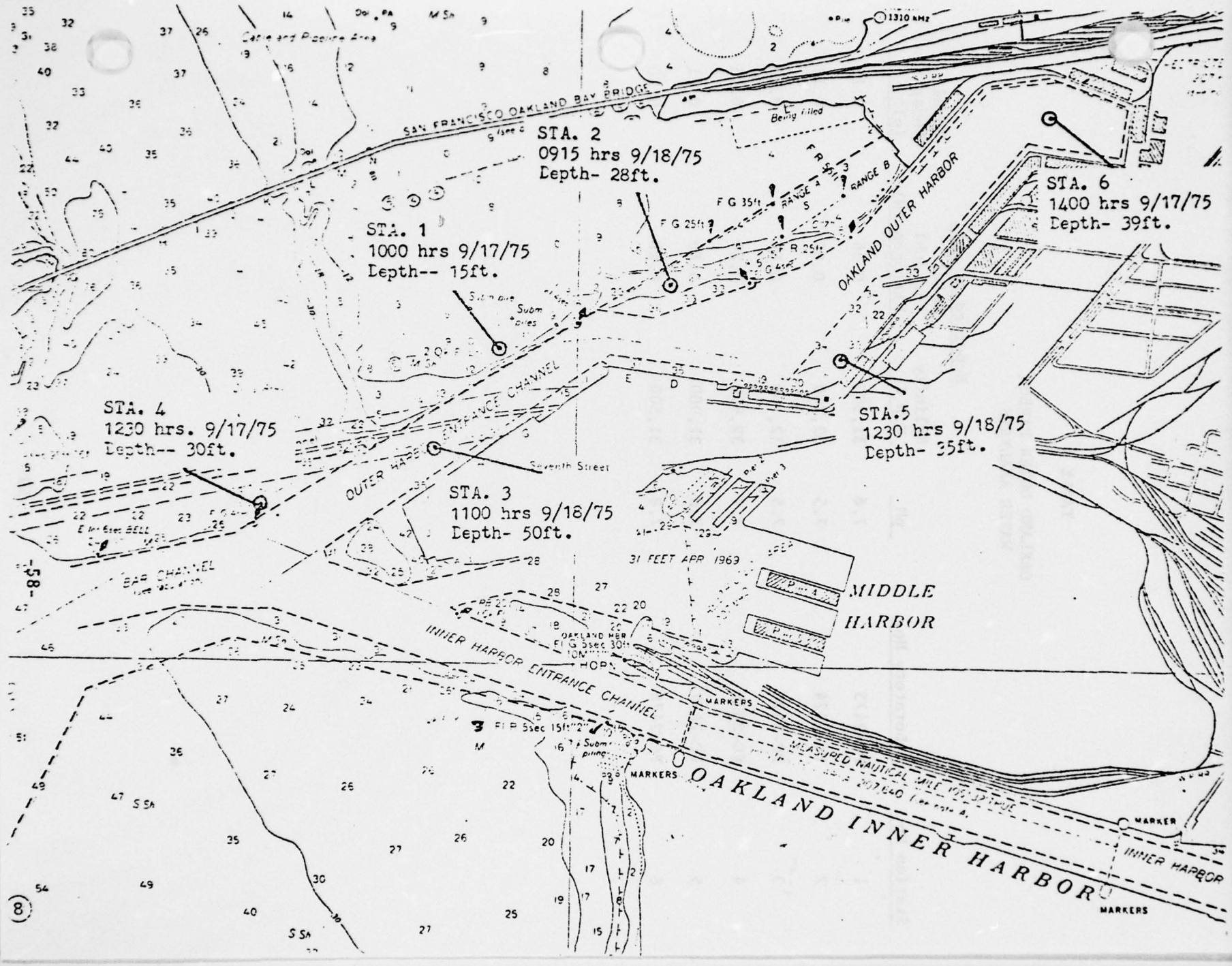
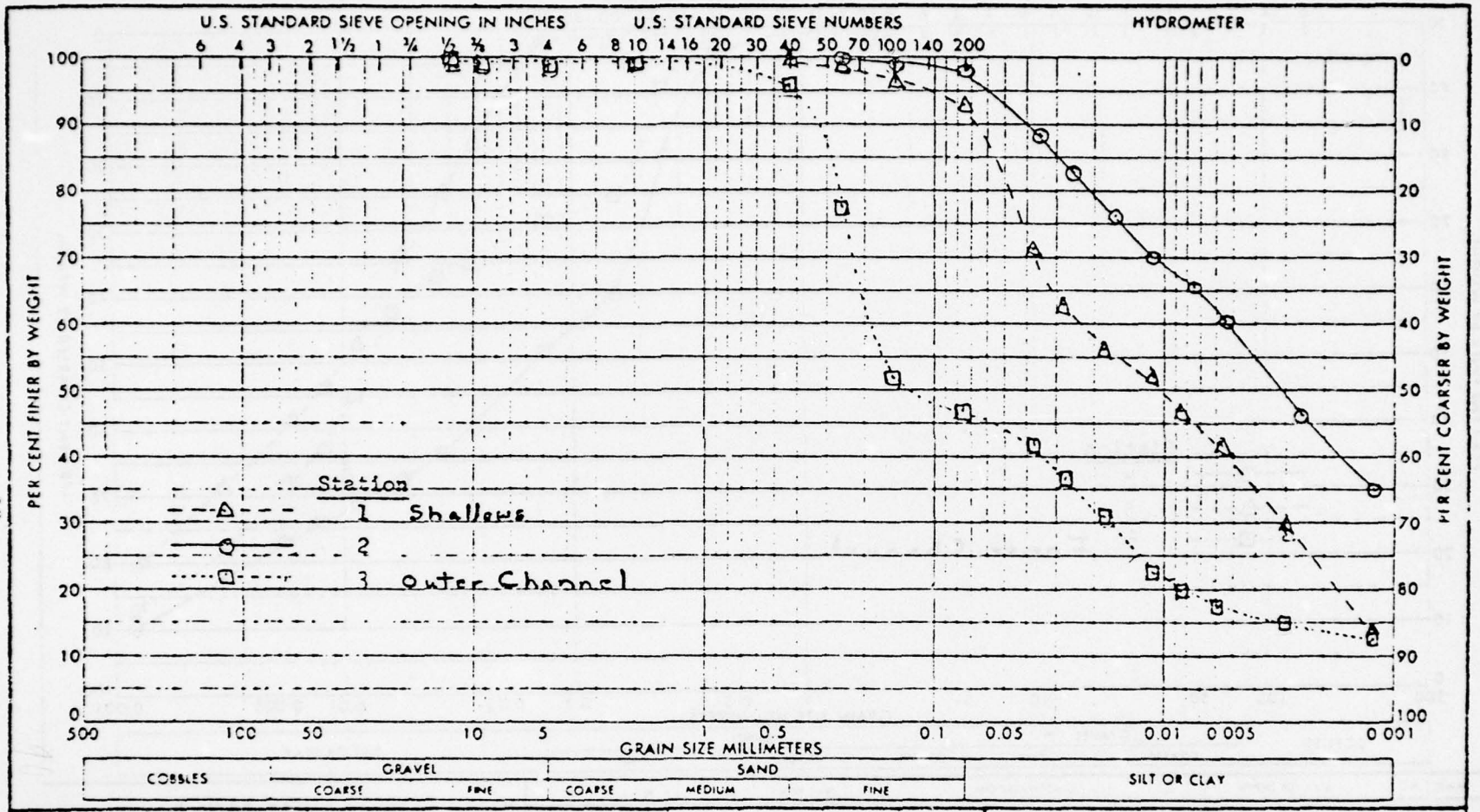

STA. 1
1000 hrs 9/17/75
Depth-- 15ft.
STA. 2
0915 hrs 9/18/75
Depth- 28ft.
STA. 3
1100 hrs 9/18/75
Depth- 50ft.
STA. 4
1230 hrs. 9/17/75
Depth-- 30ft.
STA.5
1230 hrs 9/18/75
Depth- 35ft.
STA. 6
1400 hrs 9/17/75
Depth- 39ft.
SAN FRANCISCO OAKLAND BAY BRIDGE
OAKLAND OUTER HARBOR
OUTER HARBOR ENTRANCE CHANNEL
INNER HARBOR ENTRANCE CHANNEL
BAR CHANNEL
MIDDLE HARBOR
OAKLAND INNER HARBOR
Seventh Street
31 FEET APP 1969
MARKERS
INNER HARBOR
MARKER

TABLE 1

OAKLAND OUTER HARBOR
WATER ANALYSIS

Station No.	Laboratory No.	pH	Reported as mg/l Salinity T.D.S.	Total Kjeldahl Nitrogen (N)	Total Phosphate (p)
1	PC-2473	7.6	31,300	0.36	0.19
2	Pc-2474	7.5	32,200	0.62	0.11
3	PC-2475	7.5	32,100	0.66	0.10
4	PC-2476	7.7	32,900	0.20	0.15
5	PC-2477	7.6	31,900	0.80	0.21
6	PC-2478	7.8	31,500	0.28	0.10



SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

GRADATION CURVES

PROJECT OAKLAND OUTER HARBOR

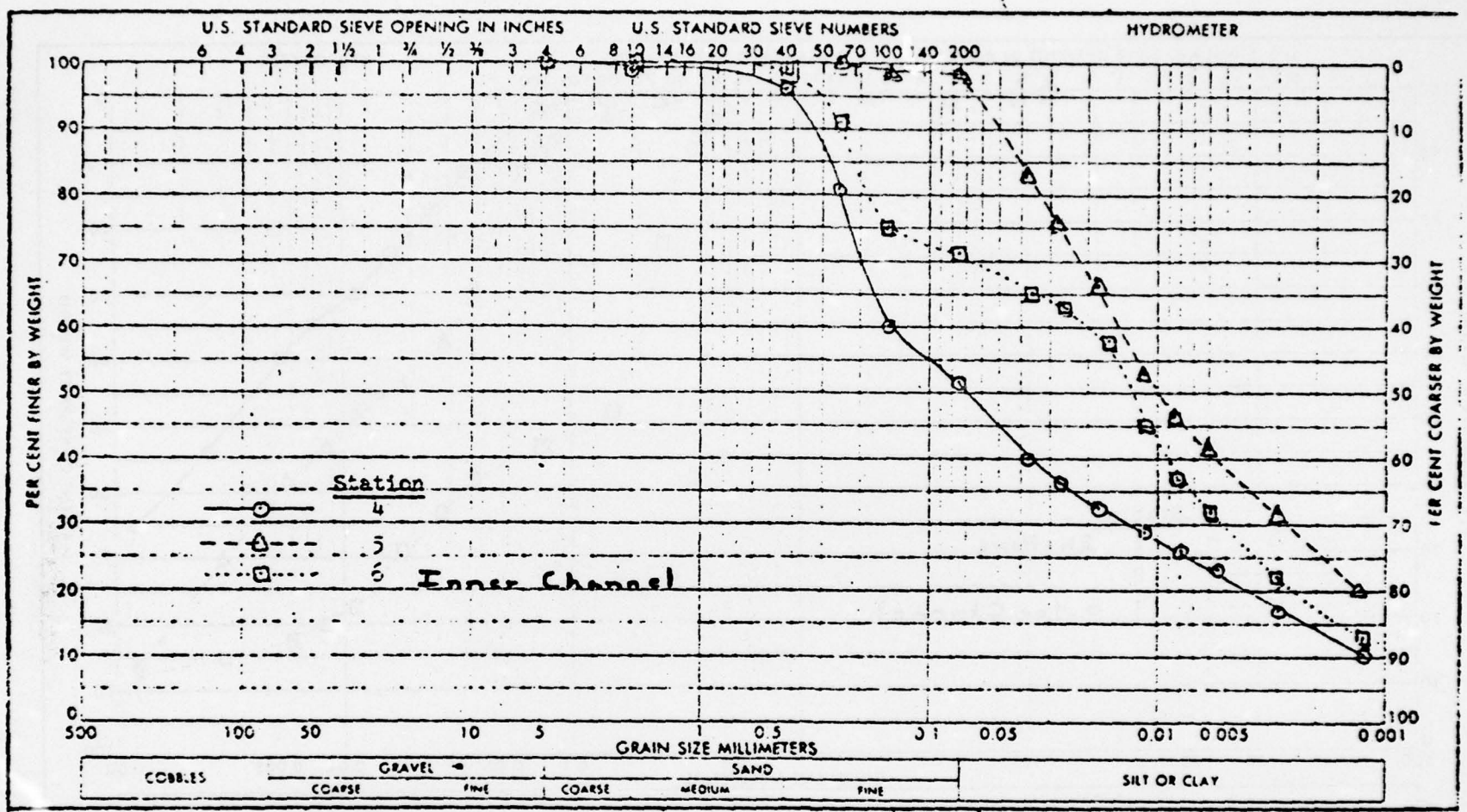
AREA

BORING NO

DATE September 1975

ENG FORM 2087
1 MAY 63

REPLACES WES FORM NO 1241, SEP 1962, WHICH IS OBSOLETE



SAMPLE NO	FROM TO DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

GRADATION CURVES

PROJECT OAKLAND OUTER HARBOR

AREA

BORING NO

DATE September 1975

ENG FORM 2087
1 MAY 63

REPLACES WES FORM NO 1241, SEP 1962, WHICH IS OBSOLETE.

PROJEC: [illegible] STA. 1 MAP NO. SHEET

PPE DREDGING - WHILE DREDGING - POST DREDGING -

TIDE: FLOOD 0.1 KT EBB SLACK WEATHER Clear-Warm

WINDSPEED 5 KT DIRECTION NW WAVE HEIGHT 6" [illegible] GP DATE 22 Mar 7

EQUIPMENT PROBLEMS None

TIME	DIST. FROM DREDGE	DREDGE HEAL.	CURR. VEL.	CURR. DIR.	COND.	SAL.	TUR.	FTU	TEMP.	DEPTH	D.O.	WET D.O.	PH
1020			0.1 K	360°	34.84	29.20	74.0	10	13.15	3.3M	8.77		8.70

PRE DREDGING - WHILE DREDGING - POST DREDGING -

TIDE: FLOOD X EBB SLACK WEATHER

WINDSPEED 5 KT DIRECTION NW WAVE HEIGHT 6" [illegible] GP DATE 22 Mar 76

EQUIPMENT PROBLEMS None

TIME	DIST. FROM DREDGE	DREDGE HEAL.	CURR. VEL.	CURR. DIR.	COND.	SAL.	TUR.	FTU	TEMP.	DEPTH	D.O.	WET D.O.	pH
1110	-	-	0.1 KT	230°	34.76	29.00	74.2	12	12.00	8.9	7.96		8.65

PROJECT [illegible] STA. - MAP NO. SHEET

PRE DREDGING - WHILE DREDGING - POST DREDGING -

TIDE: FLOOD ____ EBB X SLACK ____ WEATHER Clear-Warm

WINDSPEED 2 KT DIRECTION NW WAVE HEIGHT 1.0' [illegible] GP DATE 22 Mar 76

EQUIPMENT PROBLEMS None

TIME	DIST. FROM DREDGE	DREDGE HEAL.	CURR. VEL.	CURR. DIR.	COND.	SAL.	TUR. FTU	TEMP.	DEPTH	D.O.	WET D.O.	PH
1330	-	-	0.25	230°	35.00	29.74	63.7	12	12.73	15.6	8.51	8.58

PRE DREDGING - WHILE DREDGING - POST DREDGING -

TIDE: FLOOD ____ EBB ____ SLACK X WEATHER Clear-Warm

WINDSPEED 7 KT DIRECTION NW WAVE HEIGHT 1.0 [illegible] GP DATE 22 Mar 76

EQUIPMENT PROBLEMS None

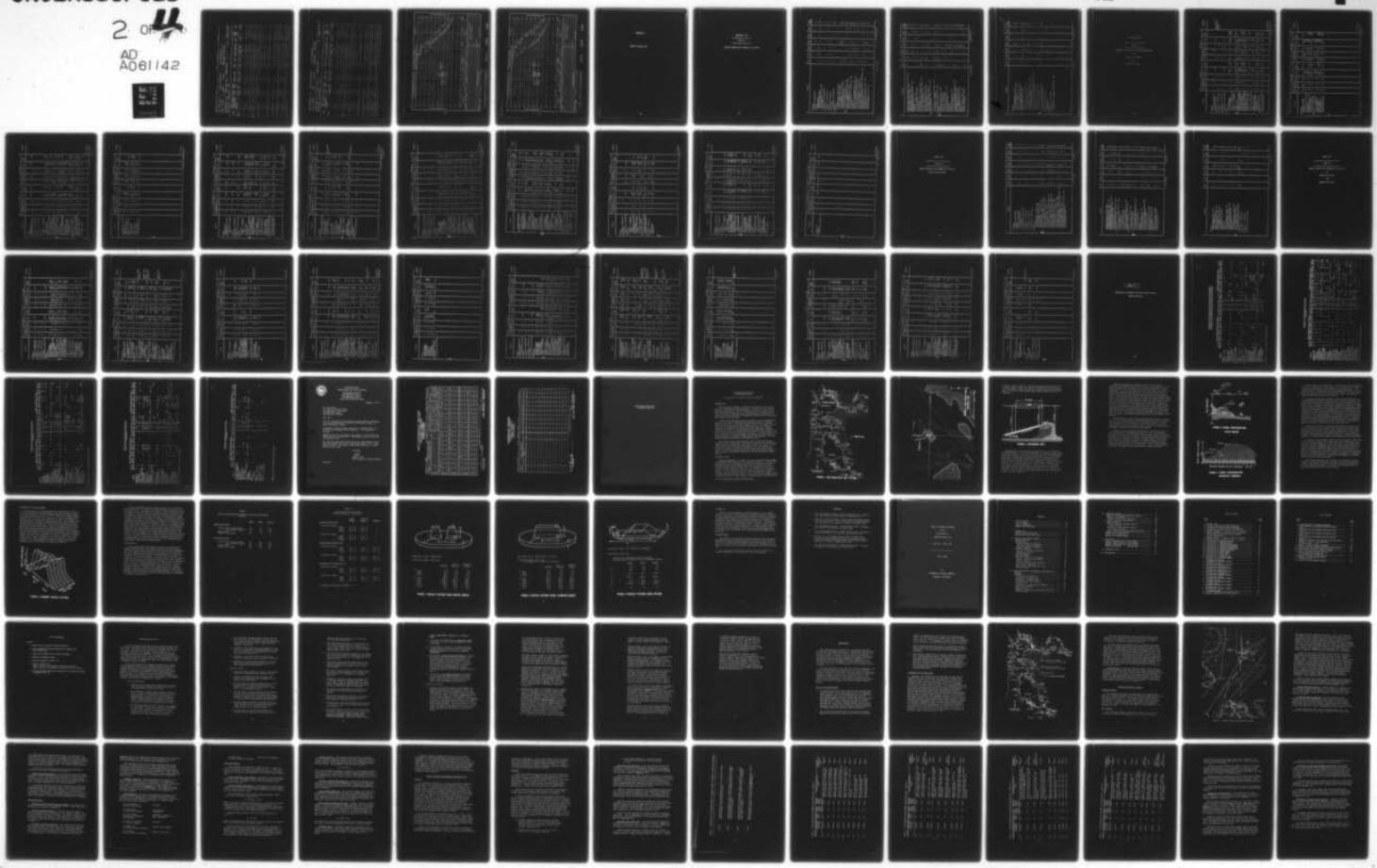
TIME	DIST. FROM DREDGE	DREDGE HEAL.	CURR. VEL.	CURR. DIR.	COND.	SAL.	TUR.	FTU	TEMP.	DEPTH	D.O.	WET D.O.	PH
1220	-	-	0.2KT	160°	34.82	29.20	75.5	10	13.19	10.0	8.16		8.68

AD-A061 142 CORPS OF ENGINEERS SAN FRANCISCO CALIF SAN FRANCISCO--ETC F/G 13/3
DREDGE DISPOSAL STUDY, SAN FRANCISCO BAY AND ESTUARY, APPENDIX --ETC(U)
SEP 78

UNCLASSIFIED NL

2 OF 4

AD A061142



PROJECT BENTHIC STUDY STA. 5 MAP NO. SHEET

PRE DREDGING - WHILE DREDGING - POST DREDGING -

TIDE: FLOOD ____ EBB x SLACK ____ WEATHER Clear-Warm

WINDSPEED 5 KT DIRECTION NW WAVE HEIGHT - [illegible] GP DATE 23 Mar 7

EQUIPMENT PROBLEMS None

TIME	DIST. FROM DREDGE	DREDGE HEAL.	CURR. VEL.	CURR. DIR.	COND.	SAL.	TUR.	FT U	TEMP.	DEPTH	D.O.	WET D.O.	PH
0955	-	-	0.1KT	90°	35.27	30.25	63.3	17	12.38	9.3	7.41		8.56

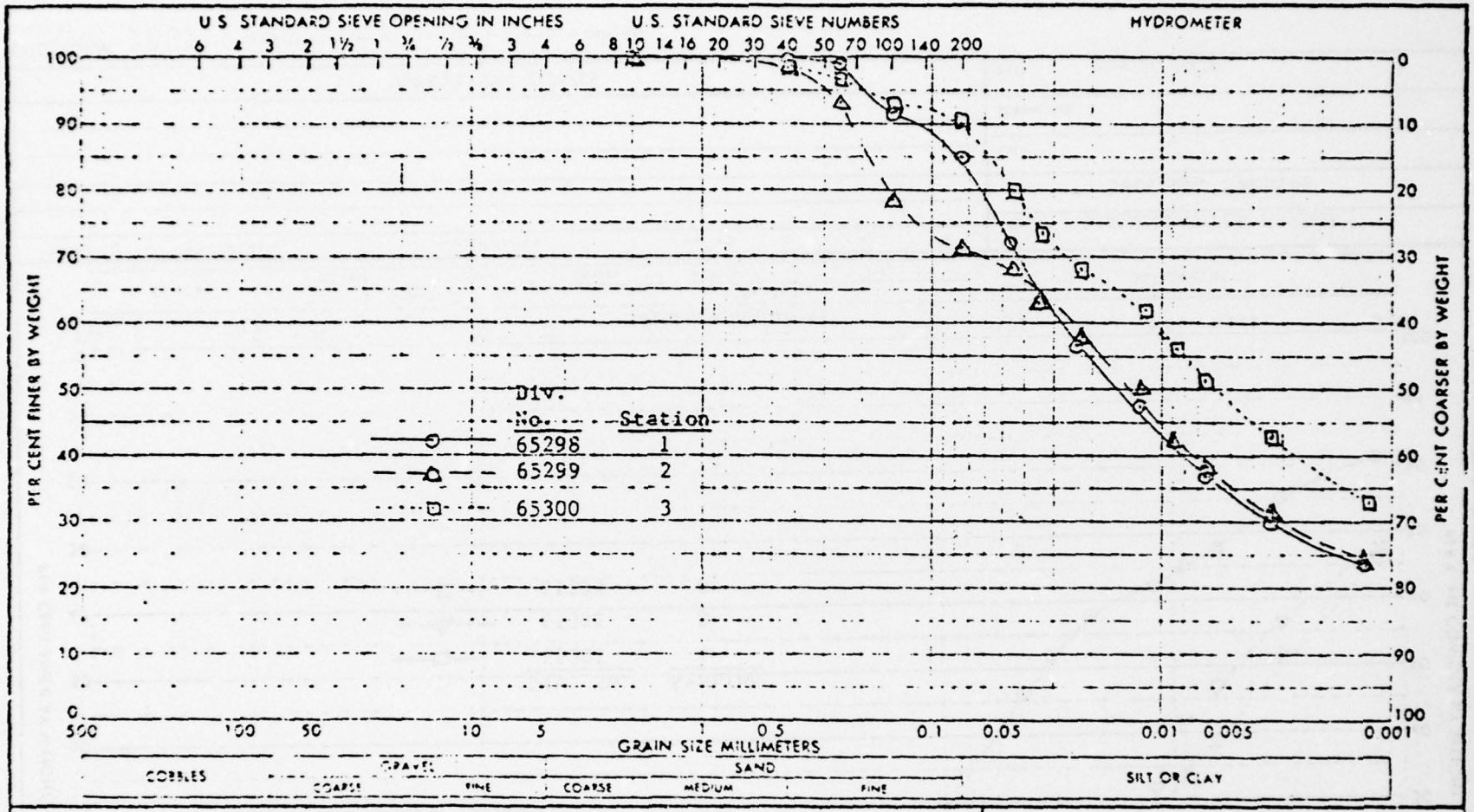
PRE DREDGING - WHILE DREDGING - POST DREDGING -

TIDE: FLOOD ___ EBB X SLACK ___ WEATHER Clear-Warm

WINDSPEED 5 KT DIRECTION NW WAVE HEIGHT ___ [illegible] GP DATE 23 Mar 76

EQUIPMENT PROBLEMS None

TIME	DIST. FROM DREDGE	DREDGE HEAD.	CURR. VEL.	CURR. DIR.	COND.	SAL.	TUR.	FTU	TEMP.	DEPTH	D.O.	WET D.O.	PH
1110	-	-	0.03KT	270°	34.72	29.95	77.7	10	12.74	9.2	8.63		8.55

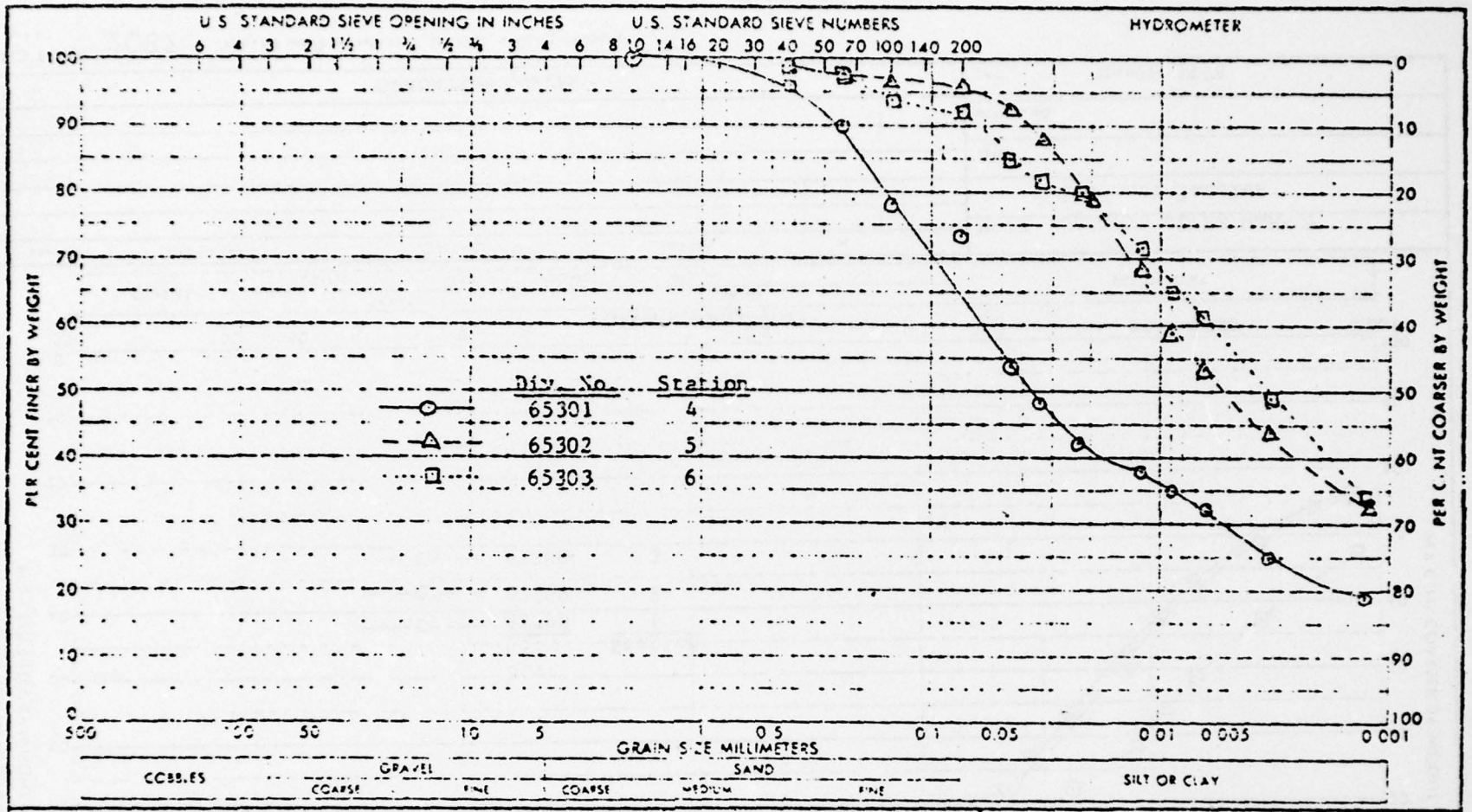


SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

GRADATION CURVES

PROJECT OAKLAND OUTER HARBOR
Sediment Samples
AREA
BORING NO
DATE March 1976

ENG FORM 2087 1 MAY 63 REPLACES WES FORM NO 1241, SEP 1962, WHICH IS OBSOLETE



SAMPLE NO.	ELEV. TO DEPTH	CLASSIFICATION	NAT. W%	LL	PL	PI

GRADATION CURVES

PROJECT OAKLAND OUTER HARBOR
Sediment Samples
AREA
BORING NO.
DATE March 1976

ENG FORM 2087 REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE
1 MAY 63

APPENDIX C

BENTHIC INFUANA DATA

SEPTEMBER 1975

TABLE C-1

BENTHIC SPECIES AND ABUNDANCE BY STATION

SPECIES	STN. 1	STN. 2	STN. 3	STN. 4	STN. 5	STN. 6	TOT. ABUND.
PORIFERA							
Porifera, unidentified				P			P
CNIDARIA							
Hydractinia sp.		2	6				8
Hydrozoa, unidentified	P	P	P	P	P	P	P
Stylatula elongata (Gabb, 1863)	1						1
PLATYHELMINTHES							
?Turbellaria, unidentified			1				1
NEMERTEA							
Nemertea, unidentified	P	P		P		P	P
NEMATODA							
Nematoda, unidentified	P	P	P	P			P
SIPUNCULIDA							
Sipunculida, unidentified	1		7		2		10
ANNELIDA							
POLYCHAETA							
Anaitides mucosa (Oersted, 1843)				1			1
Eumida brevis (Moore, 1906)				11			11
Asychis elongata (Verrill, 1873)	19			22			41
Capitella capitata (Fabricus, 1780)	4			2			6
Capitellidae, unidentified	P						P
Cossura cf. pygodactylata Jones, 1956	6	5	8		1	13	33
Dorvillea rudolphi (delle Chiaje, 1828)				1			1
Euchone limnicola Reish, 1959		15				3	18
Exogone lourei Berkeley and Berkeley, 1938	133	1	3	65			202
Glycera sp.			1				1
Glycinde cf. polygnatha Hartman, 1950	1	6	13	4		5	29
Gyptis brevipalpa (Hartmann-Schroeder, 1959)		3	2				5
Harploscolepos elongatus (Johnson, 1901)	1	2	4	1		10	18
Harmothoe imbricata (Linnaeus, 1767)	2						2
Heteromastus filiformis (Claperede, 1864)	11						11
Heteromastus filobranchus Berkeley and Berkeley, 1932	8	1		5	3	4	21
Heteromastus sp.	1	2		1			4
Mediomastus californiensis Hartman, 1944	9		2	36			47
Mediomastus sp.				2	1	1	4
Nephtys caecoides Hartman, 1938			1				1

P=not counted

SEPTEMBER 1975

SPECIES	STN. 1	STN. 2	STN. 3	STN. 4	STN. 5	STN. 6	TOT. ABUND
Nephtys cornuta franciscana Clark and Jones, 1955	1	34	75	4	5	4	123
Nephtys parva Clark and Jones, 1955		2					2
Owenia collaris Hartman, 1955				1			1
Pectinaria californiensis Hartman, 1941		3	29	1		1	34
Polydora sp. A						1	1
Polynoidae, unidentified		1		1	1	1	4
Prionospio cirrifera Wiren,1883			7		2	2	11
Prionospio sp.		1					1
Pseudopolydora kempi (Southern, 1921)	1	1					2
Pseudopolydora paucibranchiata (Okuda, 1937)	119	3		1		1	124
Spionidae, unidentified		1					1
Spiophanes fimbriata Moore, 1923			1				1
Streblospio benedicti Webster, 1879	11	20		4		14	49
Tharyx parvus, Berkeley, 1929				10			10
Trochochaeta franciscanum (Hartman, 1947)			P			2	2
ANNELIDA (continued)							
OLIGOCHAETA							
Monoyliephorous irroratus (Verrill, 1873)		54	74		34	8	170
Oligochaeta, unidentified	2	2		3		2	9
Peloscolex gabriellae Marcus, 1950	64	53	18	10	2	3	150
ARTHROPODA							
Ampelisca milleri Barnard, 1954	719	5		44		2	770
Calanoida, unidentified	1		1				2
Caprellidae, unidentified	1						1
Cirripedia, unidentified		P	P	P			P
Corophium acherusicum Costa, 1857				6			6
Corophium sp.	2	1		39			42
Cumella sp.				1			1
Eudorella pacifica Carl, 1930	1	1	93	2	1		98
Gammaridea, unidentified				1			1
Grandidierella japonica Stephenson, 1938	12			6			18
Leptochelia dubia (Kroyer, 1842)	33		1	32			66
Melita dentata (Kroyer, 1842)				20			20
Photis brevipes Shoemaker, 1942				2			2
Photis sp.				202			202
Pinnixia schmitti Rathbun, 1918				3			3
Sarsiella costericola Cushman	31	7	12	24		2	76

P=not counted

SEPTEMBER 1975

SPECIES	STN. 1	STN. 2	STN. 3	STN. 4	STN. 5	STN. 6	TOT. ABUND.
MOLLUSCA							
Adula diegensis (Dall, 1911)		2	7	23			32
Alvinia californica (Bartsch, 1911)				11			11
Bivalvia, unidentified	1						1
Clinocardium nuttalli (Conrad, 1837)				2			2
Lyonsia californica Conrad, 1837	1						1
Macoma nasuta (Conrad, 1837)	6	9	5		2	13	35
Macoma sp.		55	26	20	3	3	107
Nuculana penultata (Benson, 1842)	3		1				4
Mya arenaria Linnaeus, 1758			3				3
Mytilus edulis Linnaeus, 1758	1	5	3	180			187
Nemocardium centrifilosum (Carpenter, 1864)			1				1
Nuculoranella, unidentified			1				1
Odostomia (Evalea) cf. franciscana Bartsch, 1917				1			1
Protothaca staminea (Conrad, 1837)				4			4
Tellina bodega Hinds, 1843				2			2
Tellina modesta (Carpenter, 1864)		2	4				6
Tellinidae, unidentified				1			1
Transennella tantilla (Gould, 1853)	144	9	286	311			750
Yoldia nuttalli (Conrad, 1837)				4			4
ECTOPROCTA							
Ectoprocta, unidentified			P	P		P	
Triticella sp.			P				
PHORONIDA							
Phoronida, unidentified			1	1			2
ECHINODERMATA							
Amphipholis cf. squamata (delle Chiaje, 1829)				1			1

P=not counted

SEPTEMBER 1975

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TABLE C-2

BENTHIC SPECIES AND ABUNDANCE BY REPLICATE

IN

NUMBERS PER SAMPLE

AND

NUMBERS PER LITER

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
CNIDARIA											
Hydrozoa, unidentified		P					P				
Stylatula elongata	1	0	0	.333		0.2	0	0	.067		Other specir observed by divers
NEMERTEA											
Nemertea, unidentified	P		P			P		P			
NEMATODA											
Nematoda, unidentified	P		P			P		P			
SIPUNCULIDA											
Sipunculida,unidentified	0	0	1	.333		0	0	0.2	.067		
ANNELIDA											
POLYCHAETA											
Asychis elongata	6	6	7	6.33	.577	1.4	1.4	1.6	1.46	0.115	
Capitella capitata	3		1	1.33	1.53	0.7			0.233	0.404	
Capitellidae,unidentified		P					P				
Cossura c.f. pygodactylata	1	2	3	2.00	1.00	0.2	0.5	0.7	.467	0.252	
Exogone lourei	43	32	62	45.67	15.18	9.8	7.3	14.1	10.4	3.44	
Glycinde c.f. polygnatha	1	0	0	.333		0.2	0	0	.067		
Haploscolopos elongatus	1	0	0	.333		0.2	0	0	.067		
Harmothoe imbricata		2		.666	1.15		0.5		.167	.289	
Heteromastus filiformis	3	2	6	3.67	2.08	0.7	0.5	1.4	.867	.472	
Heteromastus filobranchus	5	1	2	2.66	2.08	1.1	0.2	0.5	1.00	.458	
Heteromastus sp.	0	1	0	.333		0	0.2	0	.067		
Mediomastus californiensis	7		2	3.00	3.61	1.6		0.5	.700	.818	
Nephtys cornuta franciscana	0	1	0	.333		0	0.2	0	.067		
Pseudopolydora kempi	1	0	0	.333		0.2	0	0	.067		
Pseudopolydora paucibranchiata	43	46	30	39.7	8.50	9.8	10.5	6.8	9.03	1.96	
Streblospio benedicti	6	3	2	3.67	2.08	1.4	0.7	0.5	.866	.472	
OLIGOCHAETA											
Oligochaeta,unidentified	0	0	2	.666	1.15	0	0	0.5	.167	.289	
Peloscolex gabrielliae	15	29	20	21.33	7.09	3.4	6.6	4.5	4.83	1.62	
											P = Not coun

STATION 1 SEPTEMBER 1975

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
ARTHROPODA											
Ampelisca milleri	293	253	181	242	56.76	65.2	57.0	41.1	54.4	12.2	
Calanoida	0	1	0	.333		0	0.2	0	.067		
Caprellidae, unidentified	0	1	0	.333		0	0.2	0	.067		
Corophium sp.	1	0	1	.666		0.2	0	0.2	.133		
Grandidierella japonica	7	4	1	4.00	3.00	1.6	0.9	0.2	.900	.700	
Leptocheila dublia	20	5	7	10.66	8.14	4.8	1.1	1.6	2.50	.201	
Sarsiella zostericola	13	12	6	10.33	3.78	3.0	2.7	1.4	2.37	.850	
MOLLUSCA											
Bivalvia, unidentified	0	1	0	.333		0	0.2	0	.067		
Lyonsia californica	0	1	0	.333		0	0.2	0	.067		
Macoma nasuta	2	2	2	2.00	.000	0.4	0.4	0.4	.400	.000	
Musculus senhousia	2		1	1.00	1.00	0.4		0.2	.200	.200	
Mytilus edulis	1	0	0	.333		0.2	0	0	.067	.115	
Transennella tantilla	68	41	36	48.3	17.2	15.5	9.3	8.2	11.0	3.94	

P = Not cour

STATION 1 SEPTEMBER 1975

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
CNIDARIA											
Hydractinia sp.				.667	1.55		1.2		.400	.693	
Hydrozoa, unidentified	P	P	P			P	P	P			
NEMERTEA											
Nemertea, unidentified			P					P			
NEMATODA											
Nematoda, unidentified			P					P			
ANNELIDA											
POLYCHAETA											
Cossura c.f. pygodactylata	1	3	1	1.67	1.15	0.2	1.0	0.6	.600	.400	
Euchone limnicola	5	4	6	5.00	1.00	1.1	1.4	3.5	2.00	1.31	
Exogone lourei	0	0	1	.333		0	0	0.6	.200		
Glycinde c.f. polygnatha	1	4	1	2.00	1.73	0.2	1.4	0.6	.733	.611	
Gyptis brevipalpa		3		1.00	1.73		1.0		.333	.577	
Haploscoloplos elongatus	1	0	1	.667		0.2	0	0.6	.267		
Heteromastus filobranchus	1	0	0	.333		0.2	0	0	.067		
Heteromastus sp.	2	0	0	.667	1.55	0.5	0	0	.167	.289	
Nephtys cornuta franciscana	14	14	6	11.3	4.62	3.2	4.8	3.5	3.83	.850	
Nephtys parva	1	0	1	.667		0.2	0	0.6	.267		
Pectinaria californiensis	1	1	1	1.00	.000	0.2	0.3	0.6	.367	.208	
Polynoidae, unidentified	0	0	1	.333		0	0	0.6	.200		
Prionospio sp.	1	0	0	.333		0.2	0	0	.067		
Pseudopolydora kempi	0	1	0	.333		0	0.3	0	.100		
Pseudopolydora paucibranchiata			3	1.00	1.73			1.8	.600	1.04	
Spionidae, unidentified	0	1	0	.333	.577	0	0.3	0	1.00	.173	
Streblospio benedicti	4	14	2	6.67	6.43	0.9	4.8	1.2	2.30	2.17	
OLIGOCHAETA											
Monopylephorous irroratus		54		18	31.2		18.6		6.20	10.73	
Oligochaeta, unidentified			2	.667	1.55			1.2	.400	.693	
Peloscolex gabriellae	32	1	20	17.7	15.6	7.3	0.3	11.8	6.47	5.80	
ARTHROPODA											
Ampelisca milleri	1	3	1	1.67	1.15	0.2	1.0	0.2	.467	.462	

P = Not cou

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
Cirripedia, unidentified	P					P					
Corophium sp.	0	0	1	.333		0	0	0.2	.067		
Eudorella pacifica	1	0	0	.333		0.2	0	0	.067		
Sarsiella zostericola	2	2	3	2.33	.577	0.5	0.7	1.8	1.00	.700	
MOLLUSCA											
Adula diegensis	0	1	2	1.5	.707	0	0.3	1.2	.500	.624	
Macoma nasuta	2	4	3	3.00	1.00	0.5	1.4	1.8	1.23	.666	
Macoma sp.	10	27	18	18.3	8.50	2.3	9.3	10.6	7.4	4.46	
Mytilus edulis	0	1	1	.667		0	0.3	0.6	.300		
Tellina modesta	0	1	1	.667		0	0.3	0.6	.300		
Transennella tantilla	3	3	3	1.00	.000	0.7	1.0	1.8	1.17	.569	

P = Not cou

STATION 2 SEPTEMBER 1975

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
CNIDARIA											
Hydractina sp.	2		4	2.00	2.00	0.6		1.7			
Hydrozoa, unidentified	P	P	P			P	P	P	.767	.862	
PLAYTHELMINTHES											
? Turbellaria, unidentified	1	0	0	.333		0.3	0	0	.100		
NEMATODA											
Nematoda, unidentified	P					P					
SIPUNCULIDA											
Sipunculida, unidentified		4	3	2.33	2.08		1.6	1.3	.967	.850	
ANNELIDA											
POLYCHAETA											
Cossura c.f. pygodactylata	2	1	5	2.67	2.08	0.6	0.4	2.2	1.07	.987	
Exogone lourei	1	1	1	1.00	.000	0.3	0.4	0.4	.367	0.058	
Glycera sp.	0	0	1	.333		0	0	0.4	.133		
Glycinde c.f. polygnatha	5	3	5	4.33	1.15	1.4	1.2	2.2	1.60	.529	
Gyptis brevipalpa	2			.667	1.15	0.6			.200	.346	
Haploscoloplos elongatus	3		1			0.8		0.4	.400	.400	
Mediomastus californiensis	1	0	1	.666		0.3	0	0.4	.200		
Nephtys caecoides	0	0	1	.333		0	0	0.4	.133		
Nemtys cornuta franciscana	19	32	24	17.7	15.0	5.3	12.8	10.4	9.50	3.83	
Pectinaria californiensis	5	11	13	9.67	4.16	1.4	4.4	5.7	3.83	2.20	
Prionospio cirrifera	4		3	2.33	2.08	1.1		1.3	.800	.700	
Spiophanes fimbriata	0	0	1	.333		0	0	0.4	.133		
Streblospio benedicti	1		2	1.00	1.00	0.3		0.9	.400	.458	
Trochochaeta franciscanum	P					P					
OLIGOCHAETA											
Monopylephorous irroratus	17	21	36	24.7	10.0	4.7	8.4	15.7	10.8	5.11	
Pelosco.ex gabriellae	2	5	11	6.00	4.58	0.6	2.0	4.8	2.47	2.14	

P = Not coun

STATION 3 SEPTEMBER 1975

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
ARTHROPODA											
Calanoida, unidentified	0	0	1	.333		0	0	0.4	.133		
Cirripedia, unidentified		P					P				
Eudorella pacifica	43	33	17	16.7	17.7	11.9	13.2	7.4	10.8	3.04	Incl. ovigerc
Leptochelia dubia	0	0	1	.333		0	0	0.4	.133		female
Sarsiella costericola	10	1	1	4.00	5.20	2.8	0.4	0.4	1.20	1.39	
MOLLUSCA											
Adula diegensis	2	1		1.00	1.00	0.6	0.4		.333	.306	
Macoma nasuta	2		3	1.67	1.53	0.6		1.3	.633	.651	
Macoma sp.	8	9	9	8.67	.577	2.2	3.6	3.9	3.27	.850	
Musculus senhousia	0	1	0	.333		0	0.4	0	.133		
Mya arenaria	1	1	1	1.00	.000	0.3	0.4	0.4	.367	.057	
Mytilus edulis	4	3		2.33	2.08	1.1	1.2		.767	.666	
Nemocardium centrifilosum	0	1	0	.333		0	0.4	0	.133		
Nudibranchia, unidentified	1	0	0	.333		0.3	0	0	.100		
Tellina modesta		3	1	1.33	1.53		1.2	0.4	.533	.611	
Transennella tantilla	169	60	57	95.3	63.8	46.9	24.0	24.8	31.9	13.0	Brooding you
ECTOPROCTA											
Ectoprocta, unidentified	P	P	P			P	P	P			
Triticella sp.	P					P					
PHORONIDA											
Phoronida, unidentified	0	1	0	.333		0	0.4	0	.133		

P = Not coun

STATION 3 SEPTEMBER 1975

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
PORIFERA											
Porifera, unidentified			P					P			
CNIDARIA											
Hydrozoa, unidentified	P					P					
NEMERTEA											
Nemertea, unidentified	P	P	P			P	P	P			
NEMATODA											
Nematoda, unidentified	P		P			P		P			
ANNELIDA											
POLYCHAETA											
Anaitides mucosa	0	0	1	.333		0	0	0.2	.067		
Armandia brevis		6	5	3.67	3.21		1.4	1.1	.833	.737	
Asychis elongata	9	7	6	7.33	1.23	2.1	1.6	1.4	1.70	.360	
Capitella capitata			2	.667	1.15			0.5	.167	.287	
Eteone pycnolphi	1	0	0	.333		0.2	0	0	.067		
Eteone lourei	22	19	24	21.7	2.52	5.2	4.3	5.5	5.00	.624	
Glycinde c.f. polygnatha	2	1	1	1.33	.577	0.5	0.2	0.2	.300	.173	
Haplosclenos elongatus	0	1	0	.333		0	0.2	0	.067		
Heteromastus filobranchus	4		1	1.67	2.08	1.0		0.2	.400	.529	
Heteromastus sp.	1	0	0	.333		0.2	0	0	.067		
Mediomastus californiensis	6	15	15	12.0	5.20	1.4	3.4	3.4	2.73	1.15	
Mediomastus sp.	1	1	0	.666		0.2	0.2	0	.133		
Nephtys cornuta franciscana	2		2	1.33	1.15	0.5		0.5	.333	.289	
Owenia collaris	1	0	0	.333		0.2	0	0	.067		
Pectinaria californiensis	0	0	1	.333		0	0	0.2	.067		
Polynoidae, unidentified	1	0	0	.333		0.2	0	0	.067		
Pseudopolycora paucibranchiata	0	0	1	.333		0	0	0.2	.067		
Streblospio benedicti	2		2	1.33	1.15	0.5		0.5	.333	.289	
Tharyx parvus	3	1	6	3.33	2.52	0.7	0.2	1.4	.767	.603	
OLIGOCHAETA											
Oligochaeta, unidentified	1		2	1.00	1.00	0.2		0.5	.233	.252	

P = Not cour

STATION 4 SEPTEMBER 1975

SPECIES	PER SAMPLE					PER LITER					REMARK
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
Peloscolex gabriellae	5	5		3.33	2.89	1.1	1.1		.733	.635	
ARTHROPODA											
Ampelisca milleri	19	10	15	14.7	4.51	4.5	2.2	3.4	3.37	1.15	
Cirripedia, unidentified	P	P	P			P	P	P			
Corophium acherusicum	1	3	2	1.00	1.00	0.2	0.7	0.5	.467	.252	
Corophium sp.	17	8	14	13.00	4.58	4.0	1.8	3.2	3.00	1.11	
Cumella sp.	1	0	0	.333		0.2	0	0	.067		
Eudorella pacifica	1	1	0	.667		0.2	0.2	0	.133		
Gammaridia, unidentified	1	0	0	.333		0.2	0	0	.067		
Grandidierella japonica	3	1	2	1.00	1.00	0.7	0.2	0.5	.467	.252	
Leptochelia dubia	7	12	13	10.7	3.21	1.7	2.7	3.0	2.47	.681	
Melita dentata	6	12	2	6.67	5.03	1.4	2.7	0.4	1.50	1.15	
Photis brevipes	1	0	1	.667		0.2	0	0.2	.133		
Photis sp.	76	67	60	67.7	8.02	18.1	15.2	13.4	15.6	2.37	
Rhepoxia schmitti	3			1.00	1.73	0.7			.233	.404	
Tarsiella tostericola	8	9	7	1.00	1.00	1.9	2.0	1.6	1.83	.208	
MOLLUSCA											
Adula diegensis	10	5	8	7.67	2.52	2.4	1.1	1.8	1.77	.651	
Alvania californica		3	8	3.67	4.04		0.7	1.8	.500	.434	
Clinocardium nuttalli	2			.666	1.15	0.5			.167	.289	
Macoma sp.	5	13	2	6.67	5.69	1.2	3.0	1.5	1.90	.964	
Mytilus edulis	79	48	53	60.0	16.6	18.8	10.9	12.0	13.9	4.28	
Odostomia c.f. francis-cana	0	0	1	.333		0	0	0.2	.067		
Protothaca staminea	1	2	1	1.33	.577	0.2	0.5	0.2	.300	.173	
Tapes japonica	1	0	1	.667		0.2	0	0.2	.133		
Tellindae, unidentified	1	0	0	.333		0.2	0	0	.067		
Transennella tantilla	102	128	82	104	23.1	24.3	29.0	18.6	24.0	5.21	
Tresus nuttalli	1	0	3	1.33	1.53	0.2	0	0.7	.300	.360	
ECTOPROCTA											
Ectoprocta, unidentified			P					P			
PHORONIDA											
Phoronida, unidentified	1	0	0	.333		0.2	0	0	.067		
ECHINODERMATA											
Amphiodia c.f. squam-ata	0	0	1	.333		0	0	0.2	.067		

P = Not cc

STATION 4 SEPTEMBER 1975

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
CNIDARIA											
Hydrozoa, unidentified			P					P			
SIPUNCULIDA											
Sipunculida, unidentified	1	1		.667		0.3	0.3	0	.200		
ANNELIDA											
POLYCHAETA											
Cossura c.f. pygodactylata	0	1	0	.333		0	0.3	0	.100		
Heteromastus filobranchus	P	3		1.00	1.73	P	1.0		.333	.577	
Mediomastus sp.	1	0	0	.333		0.3	0	0	.100		
Nephtys cornuta franciscana	1		4	1.67	2.08	0.3		0.9	.400	.458	
Polynoidae, unidentified	0	0	1	.333		0	0	0.2	.067		
Prionospio cirrifera		2		.667	1.15		0.7		.233	.404	
OLIGOCHAETA											
Monopylephorous irroratus	0	22	12	11.3	11.0	0	7.5	2.7	3.40	3.80	
Periscolex gabriellae	2			.667	1.15	0.5			.167	.289	
ARTHROPODA											
Eudorella pacifica	0	1	0	.333		0	0.3	0	.100		
MOLLUSCA											
Macoma nasuta	1	1	0	.667		0.3	0.3	0	.200		
Macoma sp.	1		2	1.00	1.00	0.3		0.5	.267	.252	

P = Not cou

STATION 5 SEPTEMBER 1975

SPECIES	PER SAMPLE					PER LITER					REMARK
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
CNIDARIA											
Hydrozoa, unidentified	P					P					
NEMERTEA											
Nemertea, unidentified			P					P			
ANNELIDA											
POLYCHAETA											
Cossura c.f. pygodactylata	7	3	3	4.33	2.31	1.6	1.3	0.7	1.20	.458	
Euchone limnicola	1	1	1	1.00	.000	0.2	0.4	0.2	.266	.115	
Glycinde c.f. polygnatha	1	0	4	1.67	2.08	0.2	0	0.9	.367	.472	
Haploscolcpos elongatus	4	3	3	3.33	.577	0.9	1.3	0.7	.967	.306	
Heteromastus filobranchus	3		1	1.33	1.53	0.7		0.2	.300	.360	
Mediomastus sp.	1	0	0	.333		0.2	0	0	.067		
Nephtys cornuta franciscana	1		3	1.33	1.53	0.2		0.7	.300	.360	
Pectinaria californiensis	0	0	1	.333		0	0	0.2	.067		
Polydora sp. A	1	0	0	.333		0.2	0	0	.067		
Polynoidae, unidentified	0	0	1	.333		0	0	0.2	.067		
Prionospio cirrifera			2	.667	1.15			0.5	.167	.289	
Pseudopolydora paucibranchiata	1	0	0	.333		0.2	0	0	.067		
Streblospio benedicti	11	2	1	4.67	5.51	2.5	0.9	0.2	1.20	1.18	
Trochochaeta franciscanum			2	.667	1.15			0.5	.167	.289	
OLIGOCHAETA											
Monopylephorous irroratus	6	2		2.67	3.06	1.4	0.9		.767	.709	
Oligochaeta, unidentified		2		.667	1.15		0.9		.300	.520	
Peloscolex gabriellae	1	2		1.00	1.00	0.2	0.9		.367	.472	
ARTHROPODA											
Ampelisca milleri	1	1	0	.667		0.2	0.4	0	.200		
Sarsiella zostericola	2			.667	1.15	0.5			.167	.289	
MOLLUSCA											
Macoma nasuta	7	3	3	4.33	2.31	1.6	1.3	0.7	1.2	.458	

P = Not cou

STATION 6 SEPTEMBER 1975

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
Macoma sp.	1	2		1.00	1.00	0.2	0.9		.367	.472	
ECTOPROCTA											
Ectoprocta, unidentified	P		P			P		P			

P = Not coun

STATION 6 SEPTEMBER 1975

MARCH 1976

TABLE C-3

BENTHIC SPECIES AND ABUNDANCE BY STATION

OAKLAND OUTER HARBOR

SPECIES	STN. 1	STN. 2	STN. 3	STN. 4	STN. 5	STN. 6	TOT. ABUND.
PORIFERA							
Porifera, unidentified			P				P
CNIDARIA							
Anthozoa, unidentified	1						1
Hydrozoa, unidentified	P			P	P	P	P
PLATYHELMINTHES							
Turbellaria, unidentified				1			1
NEMERTEA							
Nemertea, unidentified	P	P		P		P	P
NEMATODA							
Nematoda, unidentified	P		P	P	P	P	P
SIPUNCULIDA							
Sipunculida, unidentified	1		4	1	1		7
ANNELIDA							
POLYCHAETA							
Amphareta labrops Hartman, 1961				1			1
Amaitides mucosa (Oersted, 1843)				1			1
Aspotis elongata (Verrill, 1873)	2			1			3
Capitella capitata (Fabricus, 1780)	20	3	2	5			30
Cossura cf. pygodactylata Jones, 1956	18	1	7	5	2	35	68
Dorvillea rudolphi (delle Chiaje, 1828)	2			2		2	6
Eteone cf. californica Hartman, 1936				7			7
Euchone limnicola Reish, 1959				1		1	2
Exogone lourei Berkeley and Berkeley, 1938	173	1	19	661		2	856
Glycinde cf. polygnatha Hartman, 1950	1	2	2	11	2	3	21
Gyptis brevipalpa (Hartmann-Schroeder, 1959)	3		1	8	4	1	17
Haploscoloplos elongatus (Johnson, 1901)	4	2	2	8	2	29	47
Harmothoe imbricata (Linnaeus, 1767)	2		1	5	2		10
Harmothoe lunulata (delle Chiaje, 1841)						6	6
Heteromastus filiformis (Claperede, 1864)	7	1	4	2	3	2	19
Heteromastus filobranchus Berkeley and Berkeley, 1932	6	2	1	6	4		19
Mediomastus californiensis Hartman, 1944	11	1		39		2	53
Nephtys caecoides Hartman, 1938					1	4	5
Nephtys cornuta franciscana Clark and Jones, 1955	2		3	8	1		14
Owenia collaris Hartman, 1955				9			9

P = Not counted

SPECIES	STN. 1	STN. 2	STN. 3	STN. 4	STN. 5	STN. 6	TOT. ABUND
Paleanotus bellis (Johnson, 1897)				8			8
Pectinaria californiensis Hartman, 1941	1		1	9		1	12
Prionospio cirrifera Wiren, 1883	3		4	6	1	1	15
Pseudopolydora paucibranchiata (Okuda, 1937)	1		1	12			14
Streblospio benedicti Webster, 1879	39			31	1	10	81
Tharyx parvus Berkeley, 1929				22	1	2	25
Trochochaeta franciscanum (Hartman, 1947)	1					8	9
OLIGOCHAETA							
Monopylephorous irroratus (Verrill, 1873)	71	3	28	7	10	18	137
Monopylephorous sp.			6				6
cf. *Monopylephorous* sp.	15						15
Nais communis Piguet, 1906	1						1
Oligochaeta, unidentified	11			3			14
Peloscolex apectinatus Brinkhurst, 1965	3						3
Peloscolex gabriellae Marcus, 1950	228		51	25	3	19	326
ARTHROPODA							
Ampelisca milleri Barnard, 1954	12		1	4			17
Branchiura, unidentified	1					1	2
Calanoida, unidentified	1						1
cf. *Callianassa californiensis* Dana, 1854	1						1
Caridea, unidentified				1			1
Cirripedia, unidentified				P			P
Cumella sp.				2		1	3
Eudorella pacifica Carl, 1930	34	1	7	321		1	364
Gammaridea, unidentified	2			1			3
Grandidierella japonica Stephenson, 1938				1			1
Harpactacoida, unidentified	6		2	1	3	2	14
Isopoda, unidentified	1						1
Leptochelia dubia (Kroyer, 1842)	15		3	313			331
Melita dentata (Kroyer, 1842)				1			1
Photis brevipes Shoemaker, 1942				16			16
Photis sp.			1	153			154
Sarsiella zostericola Cushman	53	1	7	104	1		166
Thalassinidea, unidentified						1	1
Unidentified larva	1						1

P = Not counted

MARCH 1976

SPECIES	STN. 1	STN. 2	STN. 3	STN. 4	STN. 5	STN. 6	TOT. ABUND.
MOLLUSCA							
Adula diegensis (Dall, 1911)	23		11	26			60
Bivalvia, unidentified				3			3
Lyonsia californica Conrad, 1837				4			4
Macoma acolasta Dall, 1921				1			1
Macoma balthica (Linnaeus, 1758)		1	3	5			9
Macoma nasuta (Conrad, 1837)	8		5	4	9	5	31
Macoma secta (Conrad, 1837)				13			13
Macoma sp.	1			4	3	4	12
Modiolus sp.			1				1
Musculus senhousia (Benson, 1842)				2			2
Mya arenaria Linnaeus, 1758			1				1
Mysella cf. tumida (Carpenter, 1864)	2			9			11
Mytilus edulis Linnaeus, 1758			1	3			4
Odostomia sp.	1						1
Panthothaca staminea (Conrad, 1837)				18			18
Tellina nipponica Desnayes, 1853				7			7
Tellina modesta (Carpenter, 1864)	1			3			4
Transennella tantilla (Gould, 1853)	64		57	4193	13		4327
ECTOPROCTA							
Ectoprocta, unidentified	P		P		P	P	P
PHORONIDA							
Phoronida, unidentified						6	6
CHORDATA							
Urochordata, unidentified				P		P	P

P = Not counted

MARCH 1976

TABLE C-4

BENTHIC SPECIES AND ABUNDANCE BY REPLICATE

IN

NUMBERS PER SAMPLE

AND

NUMBERS PER LITER

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
CNIDARIA											
Anthozoa, unidentified	1	0	0	.333		0.2	0	0	.067		
Hydrozoa, unidentified	P	P	P			P	P	P			
NEMERTEA											
Nemertea, unidentified	P	P	P			P	P	P			
NEMATODA											
Nematoda, unidentified	P	P	P			P	P	P			
SIPUNCULIDA											
Sipunculida, unidentified	1	0	0	.333		0.2	0	0	.067		
ANNELIDA											
POLYCHAETA											
Asychis elongata *	2			.667	1.15	0.2			.067	.115	
Capitella capitata	2	15	3	6.67	7.23	0.4	0.9	0.6	.633	.252	
Cossura c.f. pygodactylata	2	4	12	6.00	5.29	0.4	0.9	2.6	1.30	1.15	
Dorvillea rudolphi	0	1	1	.667		0	0.2	0.2	.133		
Exogone lourei	76	63	34	57.7	21.5	15.8	13.4	7.2	12.1	4.44	
Glycinde c.f. polygnatha	0	1	0	.333		0	0.2	0	.067		
Gyptis brevipalpa	1	0	2	1.00	1.00	0.2	0	0.4	.200	.200	
Haploscoloplos elongatus	2	1	1	1.33	.577	0.4	0.2	0.2	.266	.115	
Harmothoe imbricata	0	1	1	.667		0	0.2	0.2	.133		
Heteromastus filiformis			7	2.33	4.04			1.5	.500	.867	
Heteromastus filobranchus	1		5	2.00	2.64	0.2		1.1	.433	.586	
Mediomastus californiensis	7		4	3.67	3.51	1.5		0.9	.800	.755	
Nephtys comuta franciscana	0	1	1	.667		0	0.2	0.2	.113		
Pectinaria californiensis	0	0	1	.333		0	0	0.2	.067		
Prionospio cirrifera	3			1.00	1.73	0.6			.200	.346	
Pseudopolydora paucibranchiata	0	1	0	.333		0	0.2	0	.067		
Streblospio benedicti	10	18	11	13.0	4.36	2.1	3.8	2.3	2.73	.929	
Trochochaeta franciscanum	0	0	1	.333		0	0	0.2	.067		

* = Not counted

STATION 1 MARCH 1976

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
OLIGOCHAETA											
Monopylephorous irroratus		21	50	23.7	25.1		4.5	10.6	5.03	5.32	
c.f. Monopylephorous sp.	15			5.00	8.66	3.1			1.03	1.79	
Nais communis	0	0	1	.333		0	0	0.2	.067		
Oligochaeta, unidentified		11		3.67	6.35		2.3		.767	1.33	
Peloscolex apectinatus	3			1.00	1.73	0.6			.200	.346	
Peloscolex gabriellae	78	63	87	76.	12.1	16.3	13.4	18.5	16.1	2.56	
ARTHROPODA											
Ampelisca milleri	5	4	3	4.00	1.00	1.0	0.9	0.6	.833	.208	Incl. oviger females.
Branchiura, unidentified	1	0	0	.333		0.2	0	0	.067		
Calanoida, unidentified	0	0	1	.333		0	0	0.2	.067		
c.f. Cullianassa californiensis	0	1	0	.333		0	0.2	0	.067		Thorax, head only.
Eudorella pacifica	12	7	15	11.3	4.04	2.5	1.5	3.1	2.37	.808	Incl. oviger females.
Gammaridea, unidentified	1	1	0	.667		0.2	0.2	0	.133		
Harpactacoida, unidentified	6			2.00	3.46	1.3			.433	.750	
Isopoda, unidentified	1	0	0	.333		0.2	0	0	.067		
Leptochelia dubia	10	4	1	5.00	4.58	2.1	0.9	0.2	1.07	.961	
Sarsiella costericola	22	13	18	17.7	4.51	4.6	2.7	3.8	3.7	.954	Incl. oviger females.
Unidentified larva	1	0	0	.333		0.2	0	0	.067		
MOLLUSCA											
Adula diegensis	1	11	11	7.67	5.77	0.2	2.3	3.9	2.13	1.86	
Macoma nasuta	3	4	1	2.67	1.53	0.6	0.9	0.2	.567	.351	
Macoma sp.	0	1	0	.333		0	0.2	0	.067		
Mysella c.f. tumida	2			.667	1.15	0.4			.133	.231	
Odostomia sp.	1	0	0	.333		0.2	0	0	.067		
Tellina modesta	1	0	0	.333		0.2	0	0	.067		
Transennella tantilla											
ECTOPROCTA											
Ectoprocta, unidentified		P				P					

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
NEMERTEA											
Nemertea, unidentified			P					P			
ANNELIDA											
POLYCHAETA											
Capitella capitata	3			1.00	1.73	0.6			.200	.346	
Cossura c.f. pygodactylata	1	0	0	.333		0.2	0	0	.067		
Exogone lourei	0	1	0	.333		0	0.2	0	.067		
Glycinde c.f. polygnatha	1	0	1	.667		0.2	0	0.2	.133		
Haploscoplos elongatus		2		.667	1.15		0.4		.133	.231	
Heteromastus filiformis	0	0	1	.333		0	0	0.2	.067		
Heteromastus filobranchus			2	.667	1.15			0.4	.133	.231	
Mediomastus californiensis	0	1	0	.333		0	0.2	0	.067	.115	
OLIGOCHAETA											
Monoculophorous irroratus	2	1		1.00	1.00	0.4	0.2		.200	.200	
ARTHROPODA											
Eudorella pacifica	1	0	0	.333		0.2	0	0	.067		Ovigerous fem
Sarsiella zostericola	0	1	0	.333		0	0.2	0	.067		
MOLLUSCA											
Macoma balthica	1	0	0	.333		0.2	0	0	.067		

STATION 2 MARCH 1976

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
PORIFERA											
Porifera, unidentified	P					P					
NEMATODA											
Nematoda, unidentified	P		P			P		P			
SIPUNCULIDA											
Sipunculida, unidentified			4	1.33	2.31			0.9	.300	.520	
ANNELIDA											
POLYCHAETA											
Capitella capitata	2			.667	1.15	0.4			.133	.231	
Cossura c.f. pygodactylata	5		2	2.33	2.52	1.0		0.5	.500	.500	
Exogone lourei	7	2	10	6.33	4.04	1.5	0.4	2.3	1.40	.954	
Glycinde c.f. polygnatha	1	1	0	.667		0.2	0.2	0	.133		
Gyptis brevipalpa	0	0	1	.333		0	0	0.2	.067		
[illegible] elongatus	1	0	1	.667		0.2	0	0.2	.133		
Harmothoe imbricata	0	0	1	.333		0	0	0.2	.067		
Heteromastus filiformis	3		1	3.83	3.89	0.6		0.2	.267	.306	
Heteromastus filobranchus	0	0	1	.333		0	0	0.2	.067		
Nephtys cornuta franciscana			3	1.00	1.73			0.7	.233	.404	
Pectinaria californiensis	0	0	1	.333		0	0	0.2	.067		
Prionospio cirrifera		4		1.33	2.31		0.9		.300	.520	
Pseudopolydora paucibranchiata	0	0	1	.333		0	0	0.2	.067		
OLIGOCHAETA											
Monoplephorous irroratus			28	9.33	16.2			6.4	2.13	.370	
Monoplephorous sp.	4	2		2	2	0.8	0.4		.400	.400	
Peloscolex gabriellae	23	1	27			4.8	0.2	6.1	3.70	3.10	
ARTHROPODA											
Ampelisca milleri	0	1	0	.333		0	0.2	0	.067		
Eudorella pacifica	3		4	2.33	2.08	0.6		0.9	.500	.458	Incl. ovigerous females
Harpactacoida, unidentified	1	0	1	.667		0.2	0	0.2	.133		
Leptochelia dubia	1	2		1.00	1.00	0.2	0.4		.200	.200	
Photis sp.	0	0	1	.333		0	0	0.2	.067		
Sarsiella zostericola	6		1	2.33	3.21	1.3		0.2	.500	.700	Inc. ovigerous females.

STATION 3 MARCH 1976

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
MOLLUSCA											
Adula diegensis	1	5	5	3.67	2.31	0.2	1.1	1.1	.800	.520	
Macoma balthica			3	1.00	1.73			0.7	.233	.404	
Macoma nasuta	2	1	2	1.67	.577	0.4	0.2	0.5	.367	.153	
Modiolus sp.	0	0	1	.333		0	0	0.2	.067		
Mya arenaria	0	1	0	.333		0	0.2		.067		
Mytilus edulis	1	0	0	.333		0.2	0	0	.067		
Transennella tantilla	14	6	37	19.0	16.1	2.9	1.3	8.4	4.2	3.72	
ECTOPROCTA											
Ectoprocta, unidentified	P					P					

STATION 3 MARCH 1976

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
CNIDARIA											
Hydrozoa unidentified	P					P					
PLAYTHELMINTHES											
Turbellaria,unidentified	1	0	0	.333		0.2	0	0	.067		
NEMERTEA											
Nemertea, unidentified	P	P	P			P	P	P			
NEMATODA											
Nematoda, unidentified	P	P				P	P				
SIPUNCULIDA											
Sipunculida,unidentified	1	0	0	.333		0.2	0	0	.067		
ANNELIDA											
POLYCHAETA											
Ampharete labrops	1	0	0	.333		0.2	0	0	.067		
Anaitides mucosa	0	1	0	.333		0	0.2	0	.067		
Asychis elongata	0		1	.333		0	0	0.2	.067		
Capitella capitata	1	2	2	1.67	.577	0.2	0.4	0.4	.333	.115	
Cossura c.f. pygodactylata	1	2	2	1.67	.577	0.2	0.4	0.4	.333	.115	
Dorvillea rudolphi	1	1		.667	.577	0.2	0.2		.133	.115	
Etecne c.f. californica	3	3	1	2.33	1.15	0.6	0.6	0.2	.467	.231	
Eunoe limnicola			1	.333	.577			0.2	.067	.115	
Exogone lourei	132	320	209	220	94.5	26.9	66.7	44.5	46.0	19.9	
Glycinde c.f. polygnatha	4	4	3	3.67	.577	0.8	0.8	0.6	.733	.115	
Gyptis brevipalpa	1	4	3	2.67	1.53	0.2	0.8	0.6	1.2	.872	
Haploscolopos elongatus	5		5	2.67	2.52	0.6		1.1	.567	.551	
Harmothoe imbricata	2	1	2	1.67	.577	0.4	0.2	0.4	.333	.115	
Heteromastus filiformis	0	1	1	.667		0	0.2	0.2	.133		
Heteromastus filobranchus	2		4	2.00	2.00	0.4		0.9	.300	.520	
Mediomastus californiensis	20	12	7	13.0	6.56	4.1	2.5	1.5	2.70	1.31	
Nephtys cornuta franciscana	2	2	4	2.67	1.15	0.4	0.4	0.9	.567	.289	
Owenia collaris	3	5	1	2.00	2.00	0.6	1.0	0.2	.600	.400	
Paleanotus bellis	1	3	4	2.67	1.53	0.2	0.6	0.9	.567	.351	

P = Not counted

STATION 4 MARCH 1976

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
Pectinaria californiensis	2	4	3	1.00	1.00	0.4	0.8	0.6	.600	.200	
Prionospio cirrifera	3	1	2	1.00	1.00	0.6	0.2	0.4	.400	.200	
Pseudopolydora paucibranchiata	3	5	4	1.00	1.00	0.6	1.0	0.9	.833	.208	
Streblospio benedicti	8	17	6	10.3	5.86	1.6	3.5	1.3	2.13	1.19	
Tharyx parvus	7	10	5	7.33	2.52	1.4	2.1	1.1	1.53	.513	
ANNELIDA (continued)											
OLIGOCHAETA											
Monopylephorous irroratus			7	2.33	4.04			1.5	.500	.866	
Oligochaeta, unidentified		3		1.00	1.73		0.6		.200	.346	
Peloscolex gabriellae	5		20	8.33	10.4	1.0		4.3	1.77	2.25	
ARTHROPODA											
Ampelisca milleri	1		3	1.33	1.53	0.2		0.6	.266	.306	
Caridea, unidentified	1	0	0	.333		0.2	0	0	.067		Abdomen only recently sett le
Cirripedia, unidentified		P					P				
Cumella sp.			2	.667	1.15			0.4	.133	.231	
Eudorella pacifica	63	119	134	105	37.4	12.9	24.8	29.6	22.4	8.60	Incl. ovigerous females.
Gammaridea, unidentified	0	0	1	.333		0	0	0.2	.067		
Grandidierella japonica	0	0	1	.333		0	0	0.2	.067		
Harpacticoida, unidentified	1	0	0	.333		0.2	0	0	.067		
Leptocheliia dubia	58	139	116	104	41.7	11.8	29.0	24.7	21.8	8.95	Incl. ovigerous females.
Melita dentata	0	0	1	.333		0	0	0.2	.067		
Rhepis brevipes	7	7	2	5.33	2.89	1.4	1.5	0.4	1.10	.608	
Rhepis sp.	49	54	50	51.0	2.64	10.0	11.3	10.6	10.6	.651	
Sarsiella costericola	24	46	34	34.7	11.0	4.9	9.6	7.2	7.23	2.35	Incl. ovigerous females.
MOLLUSCA											
Adula diegensis	4	6	16	8.67	6.43	0.8	1.3	3.4	1.83	1.38	
Bivalvia, unidentified		3		1.00	1.73		0.6		.200	.346	
Lyonsia californica	0	1	0	.333		0	0.2	0	.067		
Macoma acolasta	0	1	0	.333		0	0.2	0	.067		

P = Not counted

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
MOLLUSCA (continued)											
Macoma balthica		5		1.67	2.89		1.0		.333	.577	
Macoma nasuta	3		1	1.33	1.53	0.6		0.2	.267	.306	
Macoma secta	3	3	7	4.33	2.31	0.6	0.6	1.5	.900	.520	
Macoma sp.	4			1.33	2.31	0.8			.266	.462	
Musculus senhousia	1	1	0	.667		0.2	0.2	0	.133		
Mysella c.f. tumida	5	1	3	3.00	2.00	1.0	0.2	0.6	.433	.427	
Mytilus edulis	1	2		1.00	1.00	0.2	0.4		.200	.200	
Prototheca staminea	4	7	7	6.00	1.73	0.8	1.5	1.5	1.27	.404	
Tapes japonica		4	3	2.33	2.08		0.8	0.6	.467	.416	
Tellina modesta	1	1	1	1.00	0.00	0.2	0.2	0.2	.2	.000	
Transennella tantilla	840	1601	1752	1398.	489.	171.4	333.5	372.8	292.6	106.8	Epiphytic hydroids.
CHORDATA											
Urochordata, unidentified	P		P			P		P			

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
CNIDARIA											
Hydrozoa, unidentified			P					P			
NEMATODA											
Nematoda, unidentified			P					P			
SIPUNCULIDA											
Sipunculida, unidentified	1	0	0	.333		0.2	0	0	.067		
ANNELIDA											
POLYCHAETA											
Cossura c.f. pygodactylata	2			.667	1.15	0.4			.133	.231	
Glycinde c.f. polygnatha	2			.667	1.15	0.4			.133	.231	
Gyptis brevipalpa	2		2	1.33	1.15	0.4		0.4	.267	.231	
Hadloscolepos elongatus	2			.667	1.15	0.4			.133	.231	
Harmothoe imbricata			2	.667	1.15			0.4	.133	.231	
Heteromastus filiformis	3			1.00	1.73	0.6			.200	.346	
Heteromastus filobranchus	3	1		1.33	1.53	0.6	0.2		.267	.305	
Nephtys caecoides	0	1	0	.333		0	0.2	0	.067		
Nephtys cornuta franciscana	1	0	0	.333		0.2	0	0	.067		
Polydora cirrifera	1	0	0	.333		0.2	0	0	.067		
Streblospio benedicti	0	1	0	.333		0	0.2	0	.067		
Tharyx parvus	0	1	0	.333			0.2		.067		
OLIGOCHAETA											
Monopylephorous irroratus	8	2		3.33	4.16	1.7	0.4		.700	.889	
Peloscolex gabriellae	1		2	1.00	1.00	0.2		0.4	.200	.200	
ARTHROPODA											
Harpactacoida, unidentified			3	1.00	1.73			0.6	.200	.346	
Sarsiella postericola	0	1	0	.333		0	0.2	0	.067		
MOLLUSCA											
Macoma nasuta	6	1	2	3.00	2.64	1.3	0.2	0.4	.633	.586	
Macoma sp.	3			1.00	1.73	0.6			.200	.346	
Transennella tantilla	10		3	4.33	5.13	2.1		0.6	.900	1.08	
ECTOPROCTA											
Ectoprocta, unidentified	P	P	P			P	P	P			

P = Not counted

STATION 5 MARCH 1976

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
CNIDARIA											
Hydrozoa, unidentified			P					P			
NEMERTEA											
Nemertea, unidentified		P					P				
NEMATODA											
Nematoda, unidentified	P	P	P			P	P	P			
ANNELIDA											
POLYCHAETA											
Cossura c.f. pygodactylata	6	21	8	11.7	8.14	1.3	4.4	1.7	2.47	1.69	
Dorvillea rudolphi		2		.667	1.15		0.4		.133	.231	
Euchone limnicola	0	0	1	.333	.577	0	0	0.2	.067	.115	
Exogone lourei	0	1	1	.666	.577	0	0.2	0.2	.133	.115	
Glycinde c.f. polygnatha	1		2	1.00	1.00	0.2		0.4	.200	.200	
[illegible]	0	1	0	.333		0	0.2	0	.067		
Haploscoloplos elongatus	4	13	12	9.67	4.93	0.8	2.7	2.6	2.03	1.07	
Harmothoe lunulata	3	1	2	2.00	1.00	0.6	0.2	0.4	.400	.200	
Heteromastus filiformis		2		.667	1.15		0.4		.133	.231	
Leodamas californiensis	1	0	1	.667		0.2	0	0.2	.133		
Nephtys caecoides		2	2	1.33	1.15		0.4	0.4	.266	.231	
Pectinaria californiensis	0	1	0	.333		0	0.2	0	.067		
Prionospio cirrifera	0	1	0	.333		0	0.2	0	.067		
Streblospio benedicti	5	3	2	3.33	1.53	1.0	0.6	0.4	.667	.306	
Tharyx tamus	1	1	0	.667		0.2	0.2	0	.133		
Trochochaeta franciscana	2	2	4	2.66	1.15	0.4	0.4	0.9	.567	.289	
OLIGOCHAETA											
Monoplephorous irroratus	7	9	2	6.00	3.60	1.5	1.9	0.4	1.27	.777	
Peloscolex gabriellae	1	14	4	6.33	6.81	0.2	2.9	0.9	1.33	1.40	

STATION 6 MARCH 1976

SPECIES	PER SAMPLE					PER LITER					REMARKS
	REPLICATES			MEAN	STD. DEV.	REPLICATES			MEAN	STD. DEV.	
	I	II	III			I	II	III			
ARTHROPODA											
Branchiura, unidentified	0	1	0	.333		0	0.2	0	.067		
Cumella	0	1	0	.333		0	0.2	0	.067		
Eudorella pacifica	0	0	1	.333		0		0.2	.067		
Harpactacoida, unidentified	0	1	1	.667		0	0.2	0.2	.133		
Thalassinidea, unidentified	0	1	0	.333		0	0.2	0	.067	.115	Abdomen only.
MOLLUSCA											
Macoma nasuta	1	1	3	1.66	1.15	0.2	0.2	0.7	.367	.289	
Macoma sp.	2	2		1.33	1.15	0.4	0.4		.267	.231	
ECTOPROCTA											
Ectoprocta, unidentified		P	P				P	P			
PHORONIDA											
Phoronida, unidentified		6		2.00	3.46		1.3		.433	.750	
CHORDATA											
Urochordata, unidentified		P					P				

TABLE C-5

COMPARISON OF SEPTEMBER AND MARCH BENTHIC FAUNAL SAMPLING RESULTS

COMPARISON OF SEPTEMBER AND MARCH BENTHIC FAUNAL SAMPLING RESULTS

EXPRESSED AS TOTAL NUMBERS AND NUMBERS PER LITER AT SIX STATIONS

Species	TOTAL NUMBERS OF ORGANISMS PER SAMPLE														NUMBERS OF ORGANISMS PER LITER											
	Sta 1		Sta 2		Sta 3		Sta 4		Sta 5		Sta 6		Total	Total	Sta 1		Sta 2		Sta 3		Sta 4		Sta 5		Sta 6	
	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar
PORIFERA																										
Porifera, unident*						P	P												P	P						
CNIDARIA																										
Anthozoa, unident*		1												1		<0.1										
Hydractinia sp.			2		6								8				0.2		0.7							
Hydroida, unident*	P	P	P		P		P	P	P	P	P	P			P	P	P		P		P	P	P	P	P	P
Stylatula elongata	1												1		<0.1											
PLATYHELMINTHES																										
Turbellaria, unident*								1						1								<0.1				
Turbellaria, unident*					1								1						0.1							
NEMERTEA																										
Nemertea, unident*	P	P	P	P			P	P			P	P			P	P	P	P			P	P			P	P
NEMATODA																										
Nematoda, unident*	P	P	P		P	P	P	P		P		P			P	P	P		P	P	P	P		P		P
SIPUNCULIDA																										
Sipunculida, unident*	1	1			7	4	-	1	2	1			10	7	<0.1	<0.1			0.8	0.5		<0.1	0.2	<0.1		
ANNELIDA POLYCHAETA																										
Ampharete labrops								1						1								<0.1				
Anaitides mucosa							1	1					1	1							<0.1	<0.1				
Armandia brevis							11						11								0.8					
Aryenis elongata	19	2					22	1					41	3	1.4	0.1					1.7	<0.1				
Capitella capitata	4	20		3		2	2	5					6	30	0.3	1.4		0.2		0.1	0.2	0.3				
Capitellidae, unident*	P														P											
Cossura c.f. pseudohetvlata	6	18	5	1	8	7		5	1	2	13	35	33	68	0.5	1.3	0.6	<0.1	1.0	0.5		0.3	<0.1	0.1	1.2	2.5
Dorvillea rudolphi		2					1	2				2	1	6		0.1					<0.1	0.1				
Eteone of californica								7						7								0.5				
Euchone limnicola			15					1			3	1	18	2			1.7					<0.1			0.3	<0.1

* organisms which do not count as a species in statistics

COMPARISON OF BENTHIC FAUNAL SAMPLING RESULTS
(continued)

Species	TOTAL NUMBERS OF ORGANISMS PER SAMPLE														NUMBERS OF ORGANISMS PER LITER											
	Sta 1		Sta 2		Sta 3		Sta 4		Sta 5		Sta 6		Total	Total	Sta 1		Sta 2		Sta 3		Sta 4		Sta 5		Sta 6	
	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar
Exogone lourei	133	173	1	1	3	19	65	661				2	202	856	10.1	12.2	0.1	<0.1	0.4	1.4	5.0	45.9				0.1
Glycera sp. A					1								1						0.1							
Glycinde cf. polygnatha	1	1	6	2	13	2	4	11		2	5	3	29	21	<0.1	<0.1	0.7	0.1	1.5	0.1	0.3	0.8		0.1	0.5	0.2
Gyptis brevipalpa		3	3		2	1		8		4		1	5	17		0.2	0.3		0.2	<0.1		0.6		0.3		<0.1
Hapleoscolopos elongatus	1	4	2	2	4	2	1	8		2	10	29	18	47	<0.1	0.3	0.2	0.1	0.5	0.1	<0.1	0.6		0.1	0.9	2.0
Harmothoe imbricata	2	2				1		5		2			2	10	0.2	0.1				<0.1		0.3		0.1		
Harmothoe tumulata												6		6												0.4
Heteromastus filiformis	11	7		1		4		2		3		2	11	19	0.8	0.5		<0.1		0.3		0.1		0.2		0.1
Heteromastus filobranchus	8	6	1	2		1	5	6	3	4	4		21	19	0.6	0.4	0.1	0.1		<0.1	0.4	0.4	0.3	0.3	0.4	
Heteromastus sp.*	1		2				1						4		<0.1		0.2				<0.1					
Mediomastus californiensis	9	11		1	2		36	39				2	47	53	0.7	0.8		<0.1	0.2		2.8	2.7				0.1
Mediomastus sp*							2		1		1		4								0.2		<0.1		<0.1	
Nephtys caecoides					1					1		4	1	5					0.1					<0.1		0 3
Nephtys cornuta franciscana	1	2	34		75	3	4	8	5	1	4		123	14	<0.1	0.1	3.8		8.9	0.2	0.3	0.6	0.4	<0.1	0.4	
Nephtys parva			2										2				0.2									
Owenia collaris							1	9					1	9							<0.1	0.6				
Paleanotus gallis								8						8								0.6				
Paraonella californiensis		1	3		29	1	1	9			1	1	34	12		<0.1	0.3		3.6	<0.1	<0.1	0.6			<0.1	<0.1
Polydora sp. A											1		1												<0.1	
Polynoidae, unident*			1		1				1		1		4										<0.1		<0.1	
Prionospio cirrifera		3			7	4		6	2	1	2	1	11	15		0.2			0.8	0.3		0.4	0.2	<0.1	0.2	<0.1
Prionospio sp.*			1										1				0.1									
Pseudopolydora kempi	1		1										2		<0.1		0.1									
Pseudopolydora paucibranchiata	119	1	3			1	1	12			1		124	14	9.0	<0.1	0.3			<0.1	<0.1	0.8			<0.1	
Spionidae, unident*			1										1				0.1									
Spiophanes fimbriata					k								1						0.1							

* organisms which do not count as a species in statistics

COMPARISON OF BENTHIC FAUNAL SAMPLING RESULTS
(continued)

TOTAL NUMBERS OF ORGANISMS PER SAMPLE

Species	Sta 1 Sep	Sta 1 Mar	Sta 2 Sep	Sta 2 Mar	Sta 3 Sep	Sta 3 Mar	Sta 4 Sep	Sta 4 Mar	Sta 5 Sep	Sta 5 Mar	Sta 6 Sep	Sta 6 Mar	Total Sep	Total Mar
Streblospio benedicti	11	39	20				4	31		1	14	10	49	81
Tharyx parvus							10	22		1		2	10	25
Trochochaeta franciscanum		1									2	8	2	9
OLIGOCHAETA														
Monoyleptherous antennatus		71	54	3	74	28		7	34	10	8	18	170	137
Monoyla procrous sp*						6								6
cf. Monoyleptherous sp*		15												15
Nais communis		1												1
Oligochaeta, unident*	2	11	2				3	3			2		9	14
Peloscolex apectinatus		3												3
Peloscolex rantiellae	64	228	53		18	51	10	25	2	3	3	19	150	326
ARTHROPODA														
Ampelisca milleri	719	12	5			1	44	4			2		770	17
Brachiura, unident*		1									1			2
Calanoida, unident*	1	1			1								2	1
cf. Callianassa californiensis		1												1
Caprella, unidentified*								1						1
Caprellidae, unidentified*	1												1	
Cirripedia, unidentified*			P		P		P	P						
Corophium acherusicum							6						6	
Corophium sp*	2		1				39						42	
Cumella sp*							1	2				1	1	3
Eudorella pacifica	1	34	1	1	93	7	2	321	1			1	98	364
Gammaridea, unidentified*		2					1	1					1	3

NUMBERS OF ORGANISMS PER LITER

Species	Sta 1 Sep	Sta 1 Mar	Sta 2 Sep	Sta 2 Mar	Sta 3 Sep	Sta 3 Mar	Sta 4 Sep	Sta 4 Mar	Sta 5 Sep	Sta 5 Mar	Sta 6 Sep	Sta 6 Mar
Streblospio benedicti	0.8	2.7	2.2				0.3	2.2		<0.1	1.3	0.7
Tharyx parvus							0.8	1.5		<0.1		0.1
Trochochaeta franciscanum		<0.1			0.1						0.2	0.6
OLIGOCHAETA												
Monoyleptherous antennatus		0.5	6.0	0.2	8.8	2.0		0.5	3.0	0.7	0.7	1.3
Monoyla procrous sp*						0.4						0.4
cf. Monoyleptherous sp*		1.1										
Nais communis		<0.1										
Oligochaeta, unident*	0.2	0.8	0.2				0.2	0.2			0.2	
Peloscolex apectinatus		0.2										
Peloscolex rantiellae	4.8	16.1	5.9		2.1	3.7	0.8	1.7	0.2	0.2	0.3	1.3
ARTHROPODA												
Ampelisca milleri	54.2	0.8	0.6			<0.1	3.2	0.3			0.2	
Brachiura, unident*		<0.1										<0.1
Calanoida, unident*	<0.1	<0.1			<0.1							
cf. Callianassa californiensis		<0.1										
Caprella, unidentified*								<0.1				
Caprellidae, unidentified*	<0.1											
Cirripedia, unidentified*			P		P		P	P				
Corophium acherusicum							0.5					
Corophium sp*	0.2		0.1				3.0					
Cumella sp*							<0.1	0.1				<0.1
Eudorella pacifica	<0.1	2.4	0.1	<0.1	11.0	0.5	0.2	22.3	<0.1			<0.1
Gammaridea, unidentified*		0.1					<0.1	<0.1				

* organisms which do not count as a species in statistics

COMPARISON OF BENTHIC FAUNAL SAMPLING RESULTS
(continued)

Species	TOTAL NUMBERS OF ORGANISMS PER SAMPLE												Total	Total	NUMBERS OF ORGANISMS PER LITER											
	Sta 1		Sta 2		Sta 3		Sta 4		Sta 5		Sta 6				Sta 1		Sta 2		Sta 3		Sta 4		Sta 5		Sta 6	
	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar
Grandidierella japonica	12						6	1					18	1	0.9						0.5	<0.1				
Harpacticoida unidentified*		6				2		1		3		2		14		0.4				0.1		<0.1		0.2		0.1
Isopoda unidentified*		1												1		<0.1										
Lamprops quadriplicata	33	15			1	3	32	313					66	331	2.4	1.1			0.1	0.2	2.5	21.7				
Melita dentata							20	1					20	1							1.5	<0.1				
Monoculodes packardi							2	16					2	16							0.2	1.1				
Ampelisca sp*						1	202	153					202	154						<0.1	15.5	10.6				
Pleustes schmitti							3						3								0.2					
Spiophanes bombyx	31	53	7	1	12	7	24	104		1	2		76	166	2.3	3.7	0.8	<0.1	1.4	0.5	18	7.2		<0.1	0.2	
Thalassinidea, unidentified*												1		1												<0.1
Unidentified larva*		1												1		<0.1										
MOLLUSCA																										
Adula diegensis		23	2		7	11	23	26					32	60		1.6	0.2		0.8	0.8	1.8	1.8				
Axinopsida serricata							11						11								0.8					
Bivalvia, unidentified*	1							3					1	3	0.2							0.2				
Clinocardium nuttalli							2						2								0.2					
Macoma calcarea	1							4					1	4	<0.1							0.3				
Macoma obliqua								1						1								<0.1				
Macoma carlottensis				1			3							9				<0.1		0.2		0.3				
Macoma inquinata	6	8	9		5	5		4	2	9	13	5	35	31	0.4	0.6	1.0		0.6	0.4		0.3	0.2	0.6	1.2	0.4
Macoma secta								13						13								0.9				
Macoma sp*		1	55		26		20	4	3	3	3	4	107	12		<0.1	6.1		3.1		1.5	0.3	0.3	0.2	0.3	0.3
Mitrella sp A						1								1						<0.1						
Nucula tenuis	3		1					2					4	2	0.2							0.1				
Nuculana minuta					3	1							3	1					0.4	<0.1						
Nuculana cf. tumida		2						9					11			0.1						0.6				
Solidula solidula	1		3		3	1	180	3					187	4	<0.1		0.3		0.4	<0.1	12.6	0.2				

* Organisms which do not count as a species in statistics

COMPARISON OF BENTHIC FAUNAL SAMPLING RESULTS
(continued)

Species	TOTAL NUMBERS OF ORGANISMS PER SAMPLE												Total	Total	NUMBERS OF ORGANISMS PER LITER											
	Sta 1		Sta 2		Sta 3		Sta 4		Sta 5		Sta 6				Sta 1		Sta 2		Sta 3		Sta 4		Sta 5		Sta 6	
	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar
Nemocardium centrifilosum					1								1						0.1							
Nudibranchia, unidentified*					1								1						0.1							
Odostomia (Evalea) cf. franciscana							1						1								<0.1					
Odostomia sp*		1												1		<0.1										
Protothaca staminea							4	18					4	18							0.3	1.3				
Saxos japonica							2	7					2	7							0.2	0.5				
Tellina nuculoides		1	2		4			5					6	4		<0.1	0.2		0.5			0.2				
Tellinidae, unidentified*							1						1								0.2					
Transennella tantilla	144	64	9		286	57	311	4193		13			750	4327	0.9	4.5	1.0		34.0	4.1	23.9	291.2		0.9		
Tresus nuttalli							4						4								0.3					
ECTOPROCTA																										
Ectoprocta, unidentified*		P				P				P		P				P				P				P		P
PHORONIDA																										
Phoronida, unidentified*					1		1					6	2	6												0.4
ECHINODERMATA																										
Amphipholis cf. squamata							1						1								<0.1					
CHORDATA																										
Urochordata, unidentified*								P				P										P				P

* organisms which do not count as a species in statistics

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Conservation Division
Area Geologist's Office
345 Middlefield Road
Menlo Park, California 94025

December 7, 1977

Mr. John Sustar
San Francisco District Office
U.S. Army Corps of Engineers
100 McAllister Street
San Francisco, CA 94102

Dear John:

This is in reference to the phosphatic nodule sample you collected from the COE Ocean Study Area east of the Farallon Islands, in about 100 fathoms of water.

As promised, I had the sample prepared as a "standard head" and analyzed spectrographically and chemically. The results are enclosed.

Because of the low (0.5 percent) P_2O_5 content, I did not think the sample merited a mineralogical or petrographic analysis and so did not proceed further.

Does the value seem surprisingly low for the area sampled? Do you have other samples which show a higher P_2O_5 content? If so, what range of values is indicated or suspected for that area? I would appreciate your views.

Sincerely,

Harold D. Hess
Staff Geologist, Offshore Minerals

Enclosures

SPECTROGRAPHIC REPORT

ANALYTICAL LABORATORY
BUREAU OF MINES
ALBANY, OREGON

REPORT TO (Rule) DATE 10-14-77 CHART/PLATE # 1-5628 REPORT # ME-32509-SCG

	LAB #	SAMPLE DESCRIPTION	
1	7-7101	San Francisco Marine Phos. Head	3182
2			
3			
4			
5			

ESTIMATES FROM QUALITATIVE ANALYSIS					
A+	10 to 100%	C+	.1 to 1%	E+	.001 to .01%
A	3 to 30	C	.03 to 3	E	.0003 to .003
B+	1 to 10	D+	.01 to 1	F+	.0001 to .001
B	.3 to 3	D	.003 to .03	F	.00003 to .0003
-NOT DETECTED		≠NOT DETECTED AT THIS VALUE			

	Ag	Al	As	Au	B	Ba	Be	Bi	Ca	Cb	Cd	Co	Cr	Cs	Cu	Fe	Ga	Ge	Hf
1	-	B+	-		-	-	-	-	C+	-	-	-	E+		F+	B	-	-	-
2																			
3																			
4																			
5																			

	Hg	In	Ir	K	Li	Mg	Mn	Mo	Na	Ni	Os	P	Pb	Pd	Pt	Rb	Re	Rh	Ru
1					-	B	D	-	B	D		-	-	-	-				
2																			
3																			
4																			
5																			

	S	Sc	Se	Si	Sn	Sr	Ta	Te	Ti	Tl	V	W	Zn	Zr
1				At	-	-	-		C		D			
2														
3														
4														
5														

	Sc	Y	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Th	O
		-	.														

Values reported as _____

M. J. Russell
SUPERVISOR

A. J. Mackie
CHIEF-ANALYTICAL LABORATORY

LABORATORY REPORT

ANALYTICAL LABORATORY
BUREAU OF MINES
ALBANY, OREGON

REPORT TO Rule DATE 11-9-77 CHART/PLATE# _____ REPORT# ME-32509-SCG

LAB#	SAMPLE DESCRIPTION		P_2O_5	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	CO_2	F	U	S
7-7101	ME1112 San Francisco Marine Phos. Head	3182	0.50	1.34	2.97	54.3	13.3	9.25	5.64	0.35	51PPM	0.145

values reported as %

W. P. Rasnick
SUPERVISOR

A. J. Mackiw
CHIEF-ANALYTICAL LABORATORY

SEDIMENT DISPERSION FROM A SUBMERGED PIPELINE

SEDIMENT DISPERSION FROM A SUBMERGED PIPELINE

J.F. Sustar,[1/] G. Perry[1/] and T.H. Wakeman[1/]

INTRODUCTION

The maintenance dredging of navigation facilities in the coastal zone is a continuing economic necessity. Unfortunately, for the past few years the disposal of dredged sediments has been viewed as an adverse environmental practice or a conflicting use of coastal and estuarine resources. Developing greater understanding of the physics of disposal operations will help to eliminate the potential for conflicting uses caused by this practice.

Extensive investigations have been recently conducted nationwide to describe the physical, chemical and biological aspects of sediment disposal operations. Since most disposal occurs in low energy environments, the major emphasis of these studies has been the mounding of sediments in a limited area rather than their dispersal. However, because of the nature of the San Francisco Bay environment, disposal operations by policy are characterized by dispersion, and studies in the Bay are directed towards quantifying this aspect. Previous studies have been conducted to delineate sediment release patterns associated with hopper dredging and clamshell dredging with barge transport. The work included both field monitoring and laboratory tests.

Open water pipeline disposal has not been a practiced method of disposal in San Francisco Bay. This method, however, was used during a recent maintenance operation. This paper presents the results of water column monitoring at the pipeline discharge site. The results are compared with previous studies on hopper dredge and barge releases in terms of effective sediment volumes and initial water mixing volumes. These volumes may be used for evaluation of water quality and organism impacts.

PIPELINE DISPOSAL

Disposal Operation. At present there are three established dredged disposal sites in San Francisco Bay as shown on Figure 1. Between July and September 1977, a dredging contractor doing work for the Corps of Engineers, dredged about 500,000 cubic meters of sediment from the Petaluma Channel across San Pablo Bay. The sediments, classified as clayey-silt, were dredged using two sixteen-inch hydraulic cutterhead dredges. As the distance of slurry transport increased, the second dredge was used as a pumping facility. The sediments were pumped to the San Pablo Bay Disposal Site, shown in Figure 2, with the sediments being released to the water column through a submerged diffuser suspended from

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1/ U.S. Army Engineer District San Francisco.

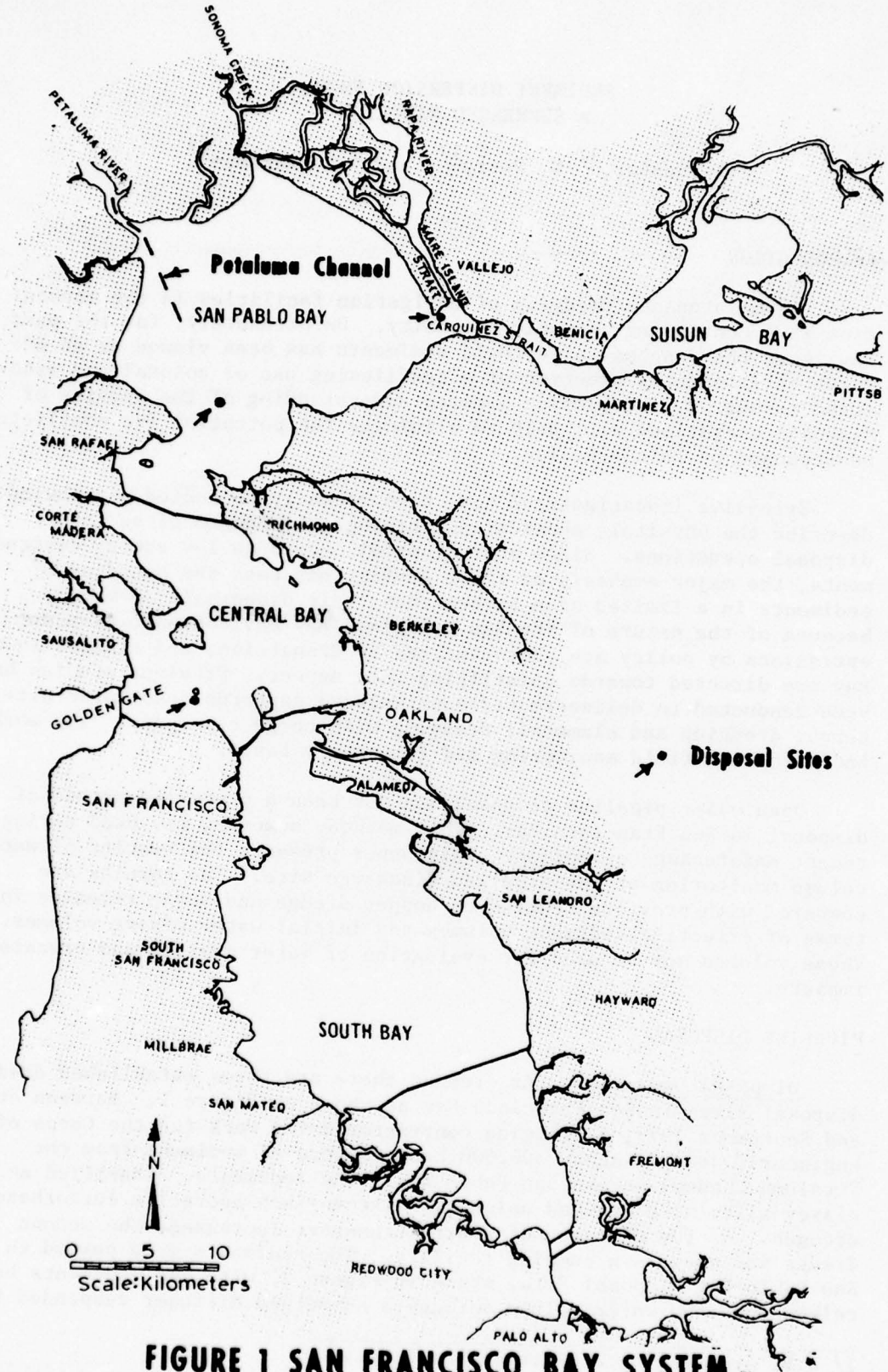


FIGURE 1 SAN FRANCISCO BAY SYSTEM

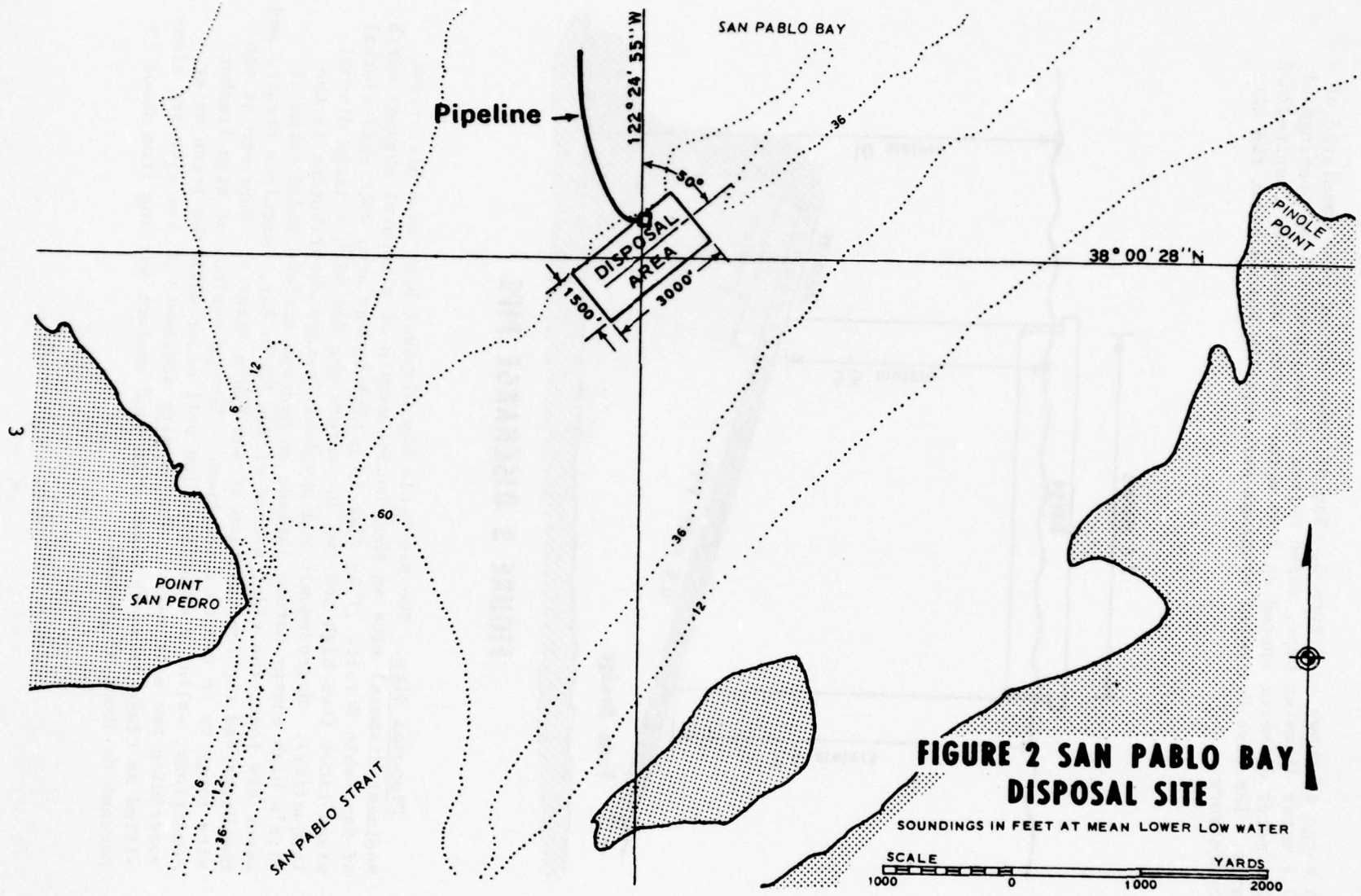


FIGURE 2 SAN PABLO BAY DISPOSAL SITE

SOUNDINGS IN FEET AT MEAN LOWER LOW WATER

a barge as shown in Figure 3. The diffuser outlet pipe consisted of a 0.4 meter diameter pipe, three meters in length with five openings of 0.1 meter diameter spaced on 0.45 meter centers along the longitudinal axis. The five 0.1 meter openings were equally spaced about the circumference.

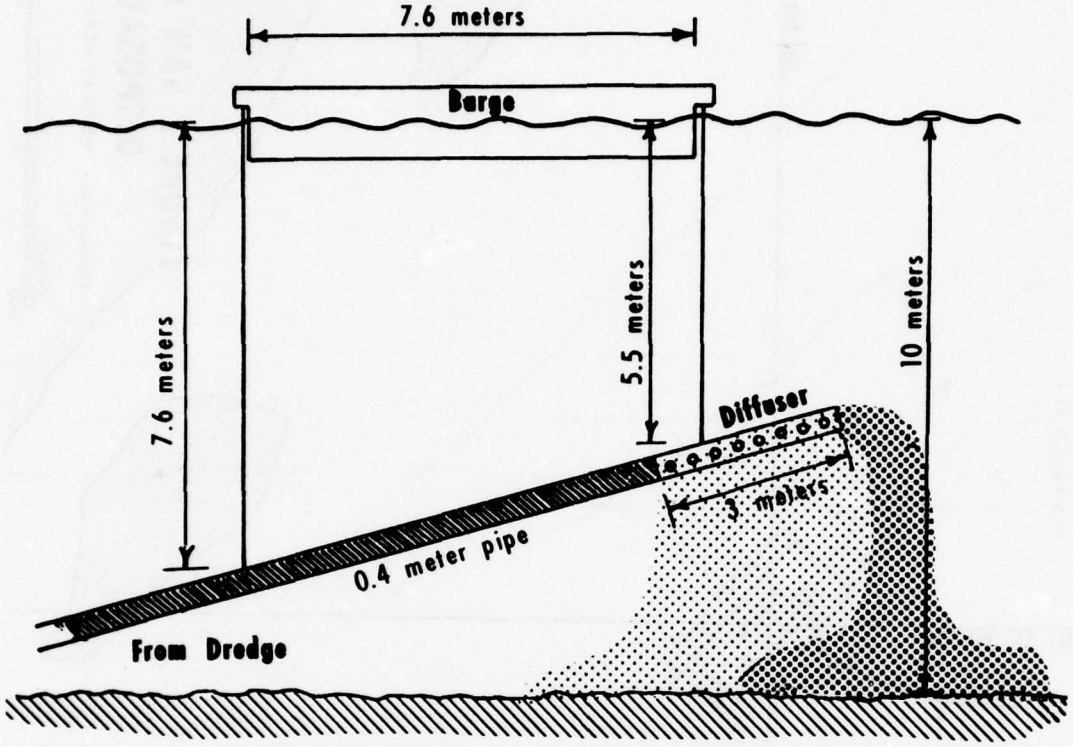


FIGURE 3 DISCHARGE PIPE

Disposal Site. The San Pablo Bay Disposal Site is a historical sediment disposal site on the channel margin of a natural channel north of San Pablo Strait. This site is a high energy area with semi-diurnal mixed tides (two high and two low waters per day with a large diurnal inequality). Hydrodynamic and physical factors contributing to the site's high energy nature include an average extreme tidal range of about six feet, the tidal prisms of San Pablo Bay, Carquinez Straits and the Delta and the constriction of San Pablo Straits. Currents at the site range up to two to three knots. During periods of high freshet conditions, salinity stratification will occur with the fresh water overriding the salt water. The in situ sediments at the site are classified as clays or sandy clays with sand content varying from about 10 percent to about 45 percent.

Monitoring Procedures. During the course of the disposal operation, the sediment loading in the water column was monitored. The monitoring program was conducted from the Corps of Engineers' survey vessel GRIZZLY. Depth was determined with a Ross Fine-Line Recording Fathometer. Instrument packages were raised and lowered using a 0.7 metric ton hydraulic winch on the port side of the vessel. Current velocity and direction were measured with Bendix Q-15 ducted-impeller meter. Water quality monitoring was performed with an InterOceans water quality survey system, Model 500, with digital and analog readout, Model 514A. The instrument gives continuous readout of temperature, dissolved oxygen, turbidity, pH, conductivity, salinity and depth. The instruments were calibrated with the appropriate equipment or standard solutions at the beginning of each monitoring period. The dissolved oxygen probe was calibrated and continuously checked by Wrinkler Titrations. Over 200 samples for suspended solids were collected by a surface pumping system using PAR heavy duty diaphram bilge pumps, Model No. 36600-0000, 12 volt DC. The pumps are rated at 0.50 liters per second. The water was pumped through Mayton vinyl tubing with a 19-millimeter inside diameter.

The monitoring of these various parameters was conducted at depths of 1, 2.5, 5, 7.5 meters and at the bottom (about 10 meters), along five lines parallel with the direction of the primary currents. The five lines included a centerline (based on point of release) and lines 30 meters and 90 meters to each side of the centerline. The monitoring was supplemented with diver observations and sampling.

Results. Based on the diver observations, the diffuser was noted to be ineffective in destroying the integrity of the discharge mass. Only 10 to 20 percent of the discharge was observed leaving through the openings in the three meter section. With the released mass maintaining its integrity and density, the resultant plume descended through the water column and impacted the bottom. Following impact, major differences in plume development between slack water and moderate current conditions were observed. The highest current velocities encountered during the monitoring were 1.4 to 1.6 knots. Figures 4 and 5 graphically depict the plume during slack water and current conditions.

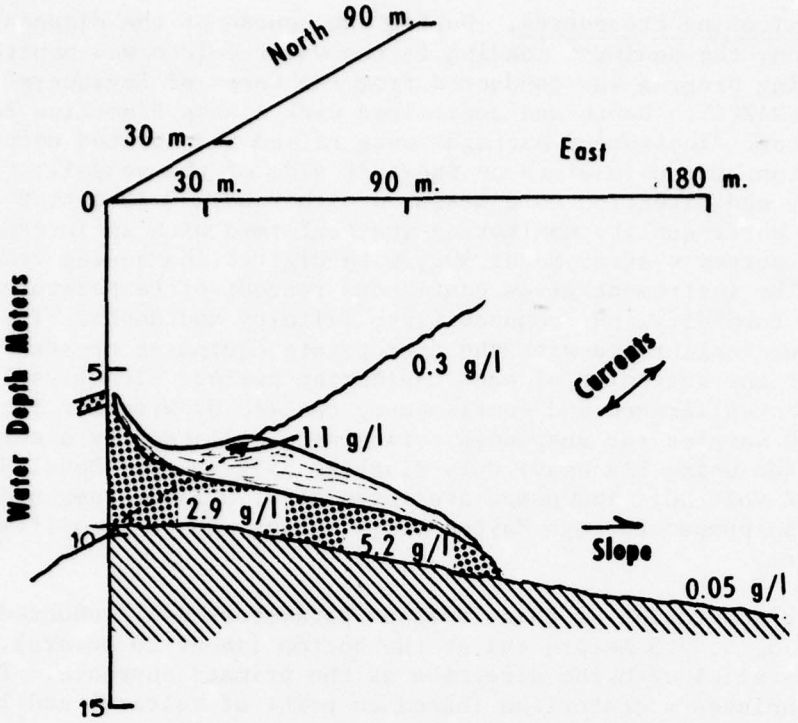


FIGURE 4 PLUME CONFIGURATION

SLACK WATER

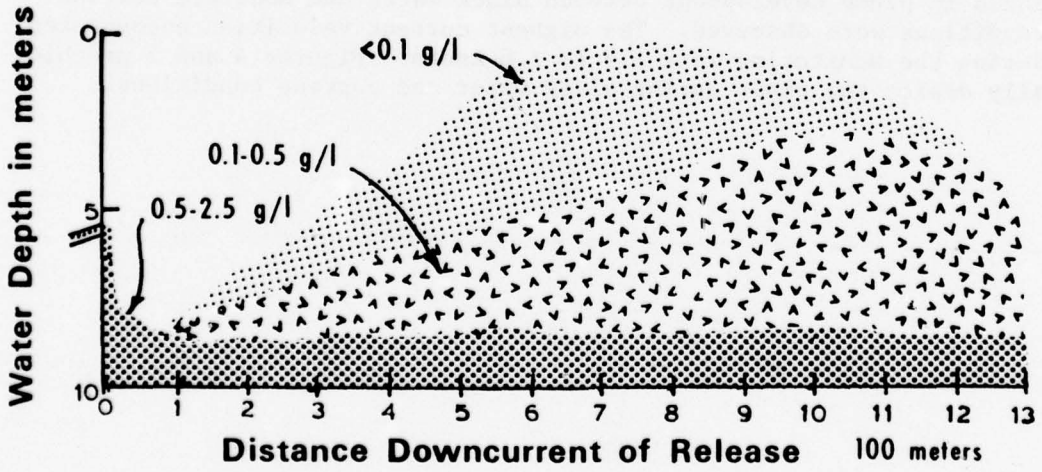


FIGURE 5 PLUME CONFIGURATION

MODERATE CURRENTS

During slack current conditions, no measurable sediment loading was found in the upper water column (depths of 7.5 meters or less) except in the zone surrounding the initial descent of the released mass. Suspended solids at the bottom of the water column ranged from 1.1 to 5.2 grams per liter. This zone of high suspended solids was quite restricted to the immediate vicinity of the point of impact. The zone was skewed in the direction of the bottom slope.

Measurements made during moderate current conditions produced an entirely different release pattern than that of slack conditions. The initial plume during descent remained intact but was distorted in the direction of the current. There was no measurable loading of the upper water column occurring in the immediate vicinity of the release. Transport in the lower portion of the water column was measured with concentrations varying from 0.5 to 2.5 grams per liter at a distance of over 1,300 meters. Within this transport distance, a turbidity cloud grew vertically from the lower water column and surfaced at a distance about 600 meters from the release point. It extended for about 300 meters downcurrent. The surface turbidity was detectable with the background suspended solids level less than 50 milligrams per liter. Concentrations in the upper portions of this surface turbidity cloud generally were less than 100 milligrams per liter. The width of the plume was generally confined to the 180 meter wide monitoring area.

Although the hydraulic cutterhead dredge added and mixed water to the dredged sediments and currents existed at the disposal site, the plume retained its integrity in the water column and descended intact. The density of the plume, however, was not sufficient to form a base surge cloud during the dynamic collapse phase (ie., second phase of transport characterized by collapse of cloud with subsequent horizontal spreading) as evident from the data taken during slack water conditions.

The density of the sediment mass was such that control of the plume in the lower water column was external rather than internal with the inertia of the descending mass. The bottom slope of the channel margin controlled plume distribution during slack water conditions with the currents being the predominent force during other periods in the tidal cycle. Although an equipment malfunction precluded bottom profile characterization of the site at the conclusion of the operation, divers did observe mounding at the point of release during the last monitoring period. The mounding was due to the gradual accumulation of sediments during slack water conditions. Ultimately all transport of sediments from the site was current dependent.

As previously mentioned, the influence of the moderate currents resulted in turbulent mixing with the turbidity cloud surfacing downcurrent. The extent to which the turbidity surfaced was dependent on the concentration distribution - a function of flocculation and the resulting settling velocity of the particles.

COMPARISON OF RELEASE PATTERNS

Previous studies of release patterns in San Francisco Bay dealt with the discharges of sandy sediments during hopper dredge operations (1, 2) and discharges of cohesive sediments during both hopper dredge and clamshell-barge operations (3, 4, 5). The type of dredged sediment and the degree to which it was disturbed were found to determine the immediate release pattern during discharge at open water disposal sites. The disturbance, including the adding and mixing of water, depended on the type and size of dredge, the efficiency of operation and the configuration of the dredged shoal. It was found that the type of sediment, water content and the liquid limit (an engineering test of sediment flow) were main parameters in predicting release pattern form. With cohesive sediments, the release pattern (degree of initial dispersion or mounding) was correlated with the liquid limit and the moisture content of the sediment. The degree of initial dispersion or mounding depends on whether the sediments act as a solid, a liquid or a transitional slurry. Cohesive sediments lose their integrity as water is added whereas; sands, regardless of water content, act as individual particles. The relationship of the degree of dispersion based on sediment type and water content is depicted on Figure 6.

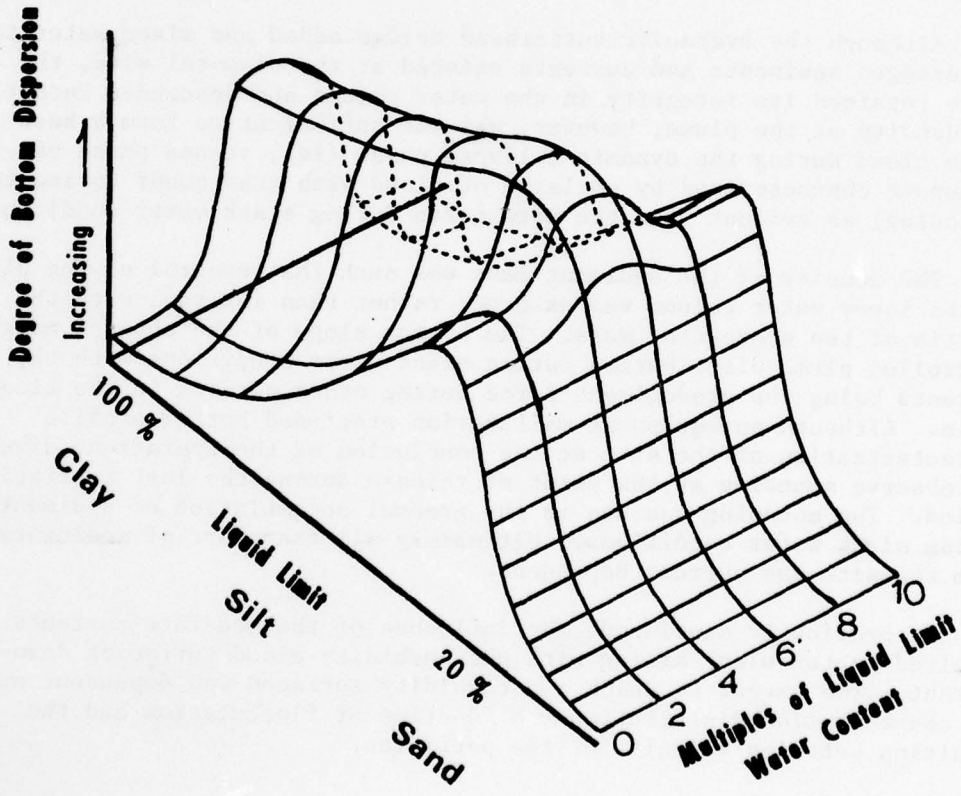


FIGURE 6 SEDIMENT RELEASE PATTERN

With the submerged pipeline disposal operation at the San Pablo Bay Disposal Site, the descent and collapse phases were similar to the previous work (5). The lower mass density of the discharged sediments, as compared to the mass density of previously studied discharges, and the method of release resulted in decreased inertia, permitting other characteristics (currents and bottom slope) to influence and, during transport, to control the pattern. Initially, the discharged sediments remained intact despite the diffuser. Collapse was characterized by a spreading cloud with very little energy available for translation from the vertical descent phase to horizontal transport. The initial transport, rather than a function of inertial forces of the descending mass, was generated by the currents or gravitational force with the bottom slope. The lower mass density during bottom transport was more susceptible to the influence of currents resulting in turbulent mixing. This mixing was responsible for bringing the turbidity cloud to the surface. The data suggest that a upper boundary of dispersion in Figure 6, occurs at levels of four to six times the liquid limit if currents are not present. The upper limit without currents would be defined by the maximum amount of vertical inertia force of the descending mass translatable to horizontal transport modes.

MIXING VOLUMES

In assessing chemical and biological effects as controlled by disposal characteristics, the studies indicate that the evaluation should take into account the effective volume of sediment as opposed to the total sediment volume released and the volume of water impacted. The water volume impacted should also be divided into the upper water column and the lower water column. The lower water column here is defined as the bottom two meters of the water column. Based on studies in San Francisco Bay, the estimated percentage of the total sediment volume which effectively interacts with the water column is presented in Table 1. Table 2 presents estimates of the impacted water volume at each of the three established disposal sites in the Bay. Figures 7 through 9 show the calculations used to generate the water volumes presented in Table 2. Tables 1 and 2 enable qualitative estimates of sediment loading caused by various disposal operations. These zones represent the mixing volumes in which potential release of contaminants may occur prior to their reassociation which particulates or formation of insoluble complexes (6).

TABLE 1

EFFECTIVE SEDIMENT VOLUME EXPECTED TO MIX WITH WATER COLUMN
(Percent)

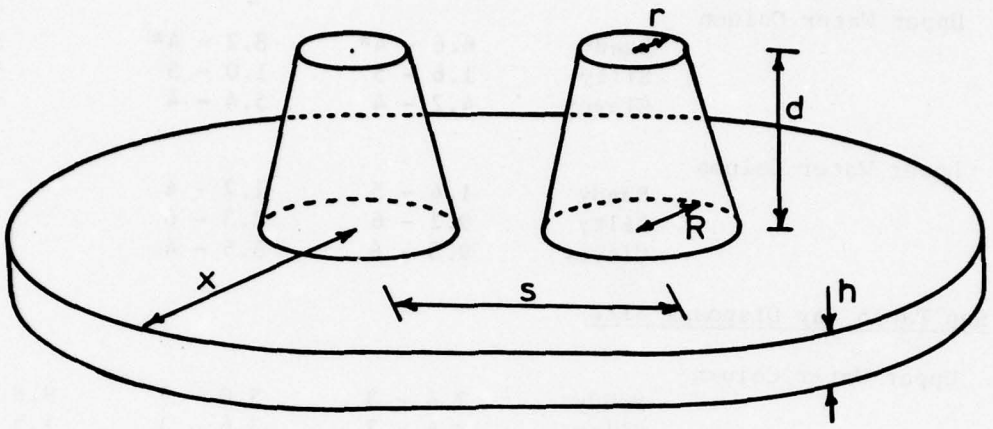
	Sandy	Silty	Clayey
Upper Water Column			
Pipeline with Surface Release	20	70	60
with Submerged Release	10	40	30
Hopper Dredge	10	5	2
Clamshell with Barge	10	3	1
Lower Water Column			
Pipeline with Surface Disposal	20	100	90
with Submerged Disposal	20	100	90
Hopper Dredge	20	70	50
Clamshell with Barge	20	60	10

TABLE 2

SHORT TERM MIXING WATER VOLUMES
(Scientific Notation - Cubic Meters)

		Hopper Dredge	Clamshell/ Barge	Pipeline
Alcatraz Disposal Site				
Upper Water Column				
	Sandy	6.6 - 4*	8.2 - 4*	-
	Silty	1.6 - 5	1.0 - 5	-
	Clayey	4.2 - 4	5.4 - 4	-
Lower Water Column				
	Sandy	1.4 - 5	1.2 - 4	-
	Silty	9.2 - 6	2.3 - 6	-
	Clayey	9.3 - 6	5.6 - 4	-
San Pablo Bay Disposal Site				
Upper Water Column				
	Sandy	2.4 - 3	5.0 - 3	9.8 - 4*
	Silty	2.4 - 3	3.6 - 3	1.5 - 6
	Clayey	2.4 - 3	4.3 - 3	1.5 - 6
Lower Water Column				
	Sandy	4.7 - 4	3.7 - 4	3.8 - 5
	Silty	4.1 - 6	6.1 - 5	7.5 - 5
	Clayey	4.1 - 6	1.8 - 4	7.5 - 5
Carquinez Strait Disposal Site				
Upper Water Column				
	Sandy	2.8 - 3	5.8 - 3	9.8 - 4
	Silty	2.8 - 3	4.2 - 3	1.5 - 6
	Clayey	2.8 - 3	5.0 - 3	1.5 - 6
Lower Water Column				
	Sandy	4.7 - 4	3.7 - 4	3.8 - 5
	Silty	4.1 - 6	6.1 - 5	7.5 - 5
	Clayey	4.1 - 6	1.8 - 4	7.5 - 5

(* indicates the exponent of "x10")

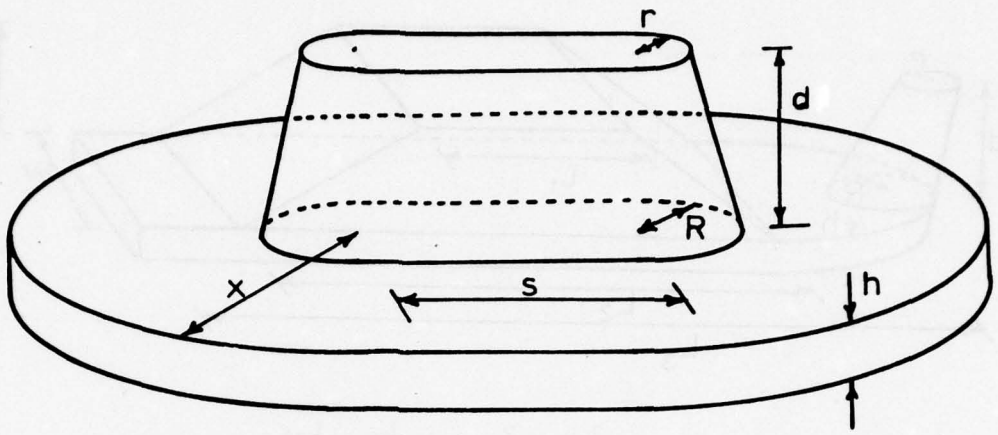


Upper Water Column $\frac{2\pi d}{3}(R^2+Rr+r^2)$

Lower Water Column $\pi x^2 h + 2xsh$

		Alcatraz	San Pablo Bay	Carquinez Strait
r		7 m	7 m	7 m
R	Sandy	24 m	9 m	9 m
	Silty	40 m	9 m	9 m
	Clayey	18 m	9 m	9 m
d		40 m	6 m	7 m
x	Sandy	120 m	60 m	60 m
	Silty	1,200 m	800 m	800 m
	Clayey	1,200 m	800 m	800 m
s	Sandy	100 m	100 m	100 m
	Silty	40 m	40 m	40 m
	Clayey	50 m	50 m	50 m
h		2 m	2 m	2 m

FIGURE 7 RELEASE PATTERN FROM HOPPER DREDGE



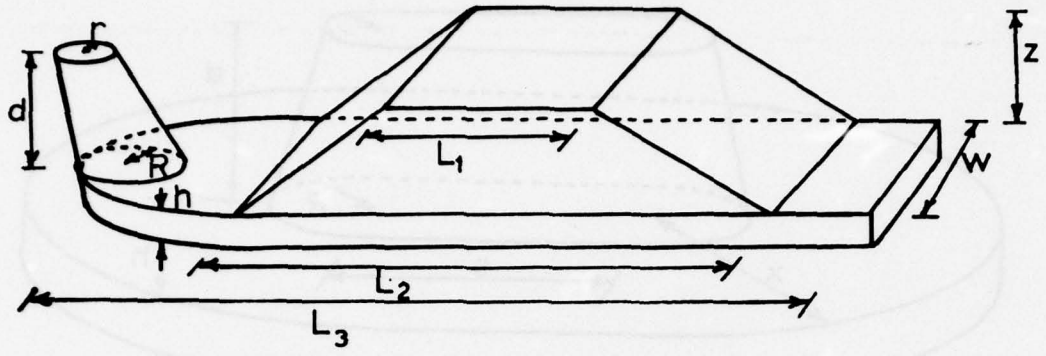
Upper Water Column $\frac{\pi d}{3}(R^2 + Rr + r^2) + ds\,(R+r)$

Lower Water Column $\pi x^2 h + 2xsh$

*s is combination of vessel size and speed

		Alcatraz	San Pablo Bay	Carquinez Strait
r		5 m	5 m	5 m
R	Sandy	20 m	7 m	7 m
	Silty	30 m	7 m	7 m
	Clayey	15 m	7 m	7 m
d		40 m	6 m	7 m
x	Sandy	120 m	60 m	60 m
	Silty	600 m	300 m	300 m
	Clayey	80 m	40 m	40 m
s	Sandy	60 m	60 m	60 m
	Silty	40 m	40 m	40 m
	Clayey	50 m	50 m	50 m
h		2 m	2 m	2 m

FIGURE 8 RELEASE PATTERN FROM CLAMSHELL/BARGE



Upper Water Column $\frac{\pi d}{3}(R^2+Rr+r^2) + zw(\frac{L_1 + L_2}{2})$

Lower Water Column hwL_3

Alcatraz not considered feasible for pipeline.
San Pablo Bay and Carquinez Strait are considered similar.

	Sandy	Silty	Clayey
r	3 m	3 m	3 m
R	6 m	6 m	6 m
d	3 m	3 m	3 m
L_1	300 m	400 m	400 m
L_2	1,000 m	1,600 m	1,600 m
w	75 m	150 m	150 m
z	2 m	10 m	10 m
L_3	2,500 m	2,500 m	2,500 m
h	2 m	2 m	2 m

FIGURE 9 RELEASE PATTERN FROM PIPELINE

CONCLUSION

Studies of release patterns associated with open water sediment disposal have taken different approaches depending upon the experience of the investigators. The apparent discrepancies between investigator's findings develop because of the complex nature of the release pattern. The plume pattern depends on the type of sediment and the degree of disturbance during the dredging and disposal operation. The sediments may act as a solid, a transitional slurry or a liquid. Very little is presently known about the transition zones. Based on studies conducted in San Francisco Bay, general estimates of the sediment-water interaction have been developed for the various types of dredging/disposal operations, types of sediment and the three established disposal sites in the Bay.

ACKNOWLEDGEMENT

The material in this paper is based on observations by the authors during studies by the San Francisco District of the U.S. Army Corps of Engineers of dredged sediment disposal in San Francisco Bay. Publication of this paper has been approved by the Corps of Engineers but any views, interpretations or conclusions developed are those of the writers only.

Use or mention of products in this paper does not constitute an official endorsement of the products by the U.S. Government.

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SURVEY OF BENTHIC MACROFAUNA

AT THE

SAN PABLO BAY

DREDGE DISPOSAL SITE

JULY 1977 - APRIL 1978

FINAL REPORT

by

UNDERWATER BIOLOGICAL RESEARCH

MONTEREY, CALIFORNIA

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SUMMARY AND CONCLUSIONS

A survey of benthic macrofauna at the San Pablo Bay dredge disposal site was conducted during a ten month period from July 1977 to April 1978. The primary study objective was to define and quantify the benthic infauna of the disposal site and adjacent areas. A secondary objective was to determine, wherever possible, species and population dynamics prerequisite to a general ecological baseline summary of the study area. This information was provided to the Corps of Engineers, San Francisco District, as one element of a more comprehensive effort to evaluate the impact of dredge disposal using a submerged pipeline discharge.

Infaunal invertebrates were sampled at three stations before, during, immediately after, and six months following the July 1977 through September 1977 disposal of dredge spoils which had been removed from the mouth of the Petaluma River and across-the-flats channel. The results of an epifaunal survey conducted during the same period and in the same area as this study are presented in latter sections of this report but were not analyzed in terms of the findings of the benthic infaunal survey. The findings of the benthic infaunal investigation are summarized as follows:

1. Station Descriptions

    a. Sediments in the study area were described as ranging from a relatively homogeneous, plastic silt-clay to a heterogeneous mix of sand, silt or clay.

    b. The northernmost infaunal sampling station (Station Three), located on the edge of the natural bay channel at approximately 32' water depth, was described as composing loose clayey-silts and plastic silty-clays. Organic filamentous masses also characterized this station. During dredging this station was closest to the disposal outfall pipe (approximately 300 yards).

    c. The infaunal sampling station in center of the disposal site quadrangle (Station Two), located at approximately 38' water depth, was described as primarily a sand station with a component of clayey-silt. During dredging this station was the second closest to the disposal outfall pipe (approximately 400 yards).

d. The southernmost infaunal sampling station (Station One), located at approximately 40' water depth, was described as having the most heterogeneous compositions of clayey-silts and fine sands. Plant debris was common at this station.

e. Sediments in the dredge source area across the flats near the Petaluma River mouth (approximately 4' water depth) were described as predominantly fine clayey-silt with high clay content.

f. Sediments in the Pinole Shoal channel area were described as primarily sand with moderate clayey-silt.

g. Sediments in the dredge spoils material at the disposal outfall were described as mainly silt with minor components of clay and sand.

2. Benthic Infauna

a. Infaunal replicate samples (3) taken by scuba divers consistently contained maximum volumes (3 liters).

b. Totals of 52 species and 7370 individuals were identified and enumerated from 36 samples over the course of the study period.

c. The mean number of species observed during all four periods within the study area ranged from 9.3 (range 8-11) at the center station to 17.0 (range 9-30) at the northernmost station.

d. The mean number of species observed at all stations over the entire course of study ranged from 11.3 (range 8-15) during Period II (shortly after dredge disposal had begun) to 16 (range 8-30) during Period III (shortly after dredge disposal had terminated).

e. The mean number of individuals observed within the study area during all four sampling periods from 92 (range 34-119) at the center station to 1174.5 (range 40-3159) at the southern station.

f. The mean number of individuals observed at all stations over the course of study ranged from 213

(range 40-480) during Period IV to 1161 (range 105-3159) during Period III.

g. Mean Shannon-Wiener diversity (H') observed within the study area ranged from 1.10 (range .53 to 1.57) at the southern station to 1.39 at both the center station (range .68 to 1.71) and the northern station (range .83 to 1.82).

h. Mean Shannon Wiener species diversity at all stations over the entire study period ranged from .98 (range .68-1.44) during Period I to 1.66 (range 1.57-1.71) during Period IV.

i. Mean Pielou species evenness observed within the study area ranged from .43 (range .19-.71) at the southern station to .62 (range .35-.76) at the center station.

j. Mean Pielou species evenness at all stations over the course of study ranged from .39 (range .27-.55) during Period I to .67 (range .59-.71) during Period IV.

k. Arthropods, annelids and molluscs comprised 99.9% of the total number of individuals and 96% of the total number of species observed during the study period. Arthropods and annelids alone constituted over 96% of the total number of individuals.

l. The annelids were represented by 26 species, the arthropods by 15 species and the molluscs by 9 species.

m. Arthropods were numerically dominant at the southernment and northernmost stations and annelids were dominant at the center station.

n. Arthropods were numerically dominant during Periods I, II and III. Annelids were numerically dominant during Period IV.

o. Ten species accounted for 95.3% of the total faunal abundance during the study period. The species are as follows: Ampelisca milleri, Exogone lourei, Peloscolex gabriellae, Sarsiella zostericola, Polydora brachycephala, Leptochelia dubia, Tharyx

parvus, Gemma gemma, Hesionura sp.A, Polydora ligni.

p. One of the ten dominant species, Ampelisca milleri constituted 71% of the total abundance with 5208 individuals.

q. A high positive correlation in relative abundance was described by the association of the amphipod, Ampelisca milleri and the ostracod, Sarsiella zostericola.

r. The hesionid, ?Heteropodarke heteromorpha, collected during the study (28 individuals), primarily from the center sand station, was described as a new member of Northern California's benthic infauna being reported here the first time in this area and because of its positive abundance correlation with the phyllodocid Hesionura sp., commonly abundant in sandy San Francisco Bay habitats, it is suggested that it will soon be a common occurrence here.

s. The tubificid, Peloscolex gabriellae was abundant in the study area (primarily at the northernmost station before and after dredging) and has been shown in the literature to be tolerant of lower salinity and high organic pollution levels.

3. General Conclusions

a. Spacially, the greatest number of individuals and species were found at the southernmost station, the deeper channel station, the sediments of which were composed of the most heterogeneous mixture of clayey-silts and fine sands. The impact of Ampelisca milleri on the infaunal community is significant at this station not only because of the numbers of the amphipod alone but by its modification of coarse to fine sediments which in turn offer more desireable habitat to other annelids and anthropods. This is also reflected by the lowest species diversity and evenness values. In other words, the number of individuals are not distributed evenly among the species present to a significant degree.

The northernmost station, located on the mud edge of the sand channel where A. milleri had less than half the population than at the southern station supported approximately the same number of individuals and species as the southern station. This is due to the naturally fine sediments found here. Higher species diversity and evenness values indicate that the number of individuals are distributed much more evenly among the species present.

The center station, composed of the coarsest sediments, was found to have far less the number of individuals and about half the number of species. Species diversity and evenness values are the highest indicating that the number of individuals in the community are most evenly distributed among the species present.

A final note is that the species similarity is highest between the southernmost and center stations. This is especially interesting in that it suggests long term sediment similarities. And, in fact, the literature indicates that the fine sediments created by A. milleri populations are highly unstable and hence short term. This also suggests that the A. milleri modified sediments, while offering habitat for a greater number of individuals and species, does not significantly affect the specific makeup of a seral community in sediments with a high degree of dynamic instability.

b. Temporally the number of individuals found in samples from the study area was the greatest during Sampling Period III (November 1977, one month following the completion of dredge disposal) and was the lowest during Sampling Period IV (April 1978, six months following the completion of dredge disposal). Populations of the amphipod Ampelisa milleri contributed most significantly to the total number of individuals and to the fluctuations which occurred between the sampling periods. The greatest number of species was found during Sampling Period III, the least during Sampling Period II in August while dredge disposal was underway. Species diversity and evenness is lowest during Sampling Period I in July prior to dredge disposal and greatest during Sampling Period IV. In other words, the lower number of individuals

observed in Period IV were distributed significantly more evenly among approximately the same number of species present as were found in Period I.

Between Periods I and II the number of individuals and species decreased proportionately, but the number of individuals became more evenly distributed among the species present. The specific composition was moderately similar.

Between Periods II and III the number of individuals more than doubled, while the number of species increased only moderately. The evenness of distribution of individuals decreased somewhat but still remained much greater than in Period I. The similarity of species make-up was lower than between Periods I and II.

Between Periods III and IV the number of individuals decreased significantly with a slight decrease in the number of species. The species composition was moderately similar between the two periods. However, the species similarity between Periods IV and I was relatively low, indicating that during the course of the study, there had been a shift in specific composition within the infaunal community.

It is again noted that the total number of individuals found in the study area was significantly affected by the population of Ampelisa milleri and its associated modified sediments. The significant decrease in numbers of individuals between Periods III and IV occurred at Station One, the deeper channel station with the most heterogeneous sediments during the first three periods. The number of individuals actually increased slightly between Periods III and IV at Station Three, the shallow mud station on the edge of the sand channel.

The fluctuations of the major infaunal parameters between Periods III and IV may be explained by flood flows from the California delta waterways caused by major storms which occurred during the winter of 1977-78. The resultant decrease of salinity and

increase of sediment transport may account for decreases in populations and the observed shift in specific makeup. Benthic samples taken from Station One during Period IV had a top layer of coarser sand not previously observed. It is suggested that the flows necessary to move these coarser sediments were sufficiently strong to wash out the mounds of fine sediments modified by Ampelisca milleri at this station.

Hence, not only were this amphipod's numbers reduced by elimination, but also populations of species normally found within the community at Station One were reduced. These resident species were apparently utilizing the amphipods modified fine sediments for high density habitat. In fact six of the ten most dominant species (four annelids and two arthropods) other than A. milleri displayed significant decreases in populations at Station One between Periods III and IV.

INTRODUCTION

This report presents the results of a macrofaunal survey of the San Pablo Bay Dredge Disposal Site. The primary study objective was to define and quantify the benthic infauna of the disposal site and adjacent areas. A further objective was the determination, wherever possible, of specific and population dynamics prerequisite to a general ecological baseline summary of the study area. This information was to be provided to the Corps of Engineers, San Francisco District, as one element of a more comprehensive effort to evaluate the impact of dredge disposal using a submerged pipeline discharge.

The specifications for the study were initially prepared by the United States Army Corps of Engineers on 20 June 1977 and later refined in discussions between the Government (USACE) and Underwater Biological Research on 5 July 1977. The final Scope of Services was included in contract DACW07-77-C-0022 dated 7 July 1977. The schedule for submission of the first draft report and the final report, and the termination of the contract was modified and extended in June 1978 due to a delay in the third and fourth sampling periods.

SCOPE OF THE INVESTIGATION

1. The benthic macrofauna of the study area were surveyed over a ten month period. The survey consisted of one (1) sampling before dredging, one (1) during dredging, one (1) immediately after dredging, and one (1) six months after dredging. Quantitative samples of benthic infauna were taken by District personnel (SCUBA divers) from three (3) stations located in the study area. Three (3) replicate samples (a total of approximately nine liters of bottom material) were taken at each station. Samples were immediately sieved by Contractor personnel (0.5mm mesh) and all entrapped organisms preserved for identification and enumeration by the Contractor.

2. The government performed particle size analyses on sediment samples collected at each station during the first sampling

period and approximately one month following sampling period three. Pollution test data on samples taken from the dredge source seven (7) months prior to the present study were supplied to the Contractor. The Government also furnished the Contractor with a navigation chart of the area detailing station locations.

3. The Contractor provided two personnel to perform the infaunal sample sieving and the narcotization and preservation of retained organisms. All processing materials were provided by the Contractor.

4. The Contractor identified all organisms collected to species or other lowest taxonomic category. Based on specific identifications and organism counts the seral community existing at the individual stations was established. Population densities, diversities and differences were determined where applicable and species interaction patterns defined wherever possible. The resultant data were interpreted with particular emphasis upon the ecological and environmental importance of the benthic organisms encountered.

DESCRIPTION OF THE STUDY AREA

General. San Francisco Bay can be divided into four sub-bay systems - South Bay, Central Bay, San Pablo Bay and Suisun Bay (USACE Main Report, 1977). This investigation is centered in the southern portion of San Pablo Bay which is defined at its upper perimeter by the Benicia-Martinez Bridge and at its southwestern extremity by San Pablo Strait (Figure 1). This sub-bay system is the first area of extensive mixing of freshwater and saltwater within the San Francisco Bay system and serves as a reservoir for sediments, nutrients and pollutants drained and eroded from California's Central Basin and transported to San Francisco Bay by the Sacramento and San Joaquin Rivers. Reduced current velocities and flocculation during mixing of freshwater and saltwater deposit these materials throughout San Pablo Bay, fine materials accumulating in the shallows and coarse sediments settling from swifter channel currents. Subsequent periods of increased current velocity and turbulence generated by tidal flow, freshwater influx, salinity-density gradients, and wind patterns resuspend the majority of the sediment and transport it in suspension or as bedload through San Pablo Strait where it is redeposited in the Central Bay as the next stage in its journey to the ocean. While this cycle is well established, its magnitude and subsequent impact varies from year to year.

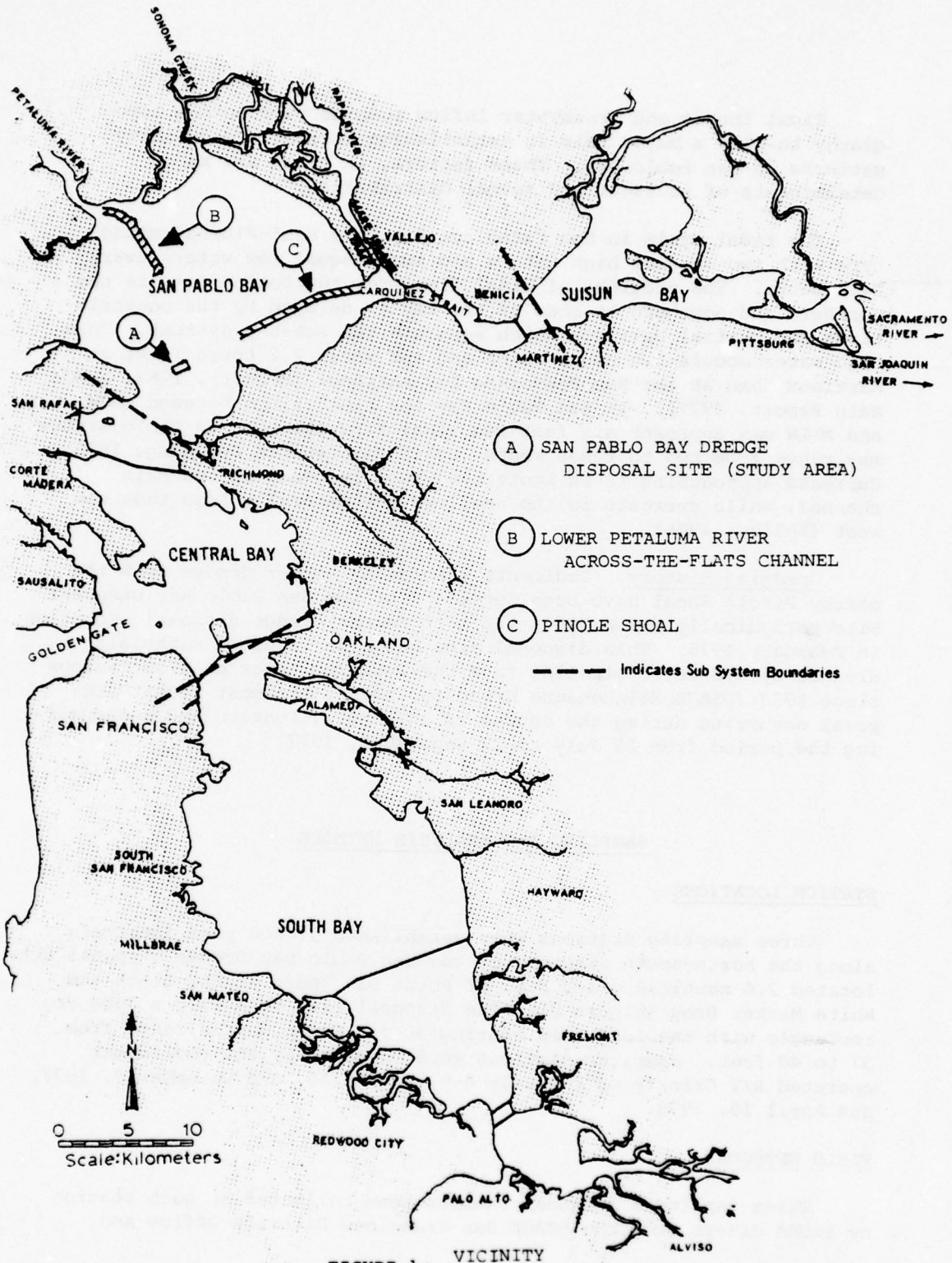


FIGURE 1: VICINITY MAP

Tidal forces and freshwater influx combine with bottom topography to play a major role in establishing current and salinity patterns in San Pablo Bay. These factors, in turn, are major determinants of sediment and faunal distribution.

The tidal cycle in San Francisco Bay is a semi-diurnal mixed type with two unequal high waters and two unequal low waters every 24.8 hours. The progress of tidal flow from the Golden Gate to the northern and southern reaches of the Bay is delayed by the constrictions and partial barriers which separate the sub-bay systems. Thus high water occurs 1.6 hours later and low water 2.2 hours later at Martinez than at the San Francisco Bay entrance (McCarty, 1962, USACE Main Report, 1977). In San Pablo Bay the tidal range between MHHW and MLLW may approach six feet and tidal flow through San Pablo Strait may range from two to three knots (USACE Maintenance Dredging, 1975). Currents approaching three knots have been recorded in the main channel, while currents in the shallows are generally less than one knot (Kelley, 1966).

Dredging History. Sediments removed by hopper dredge from the nearby Pinole Shoal have been deposited at the San Pablo Bay Disposal Site periodically since 1957, the most recent dredge disposal occurring in February 1976. This disposal area has also received materials dredged by hydraulic pipeline from the Petaluma River on 17 occasions since 1933 (USACE Maintenance Dredging, 1975), the most recent disposal occurring during the course of this investigation and encompassing the period from 25 July to 27 September, 1977.

SAMPLING AND ANALYSIS METHODS

STATION LOCATIONS

Three sampling stations were established at 500 yard intervals along the north-south diagonal of the San Pablo Bay Dredge Disposal site located 2.6 nautical miles N.E. of Point San Pedro at the Black and White Marker Buoy (Figure 2). The disposal site is a 1500 x 3000 ft. rectangle with the long axis bearing 50^{O}T. Chart depths range from 37 to 40 feet. Sampling stations were occupied by the government operated R/V Grizzly on the July 8-9, August 15, and November 2, 1977, and April 19, 1978.

FIELD METHODS

Three replicate infaunal samples were collected at each station by SCUBA divers from the USACE San Francisco District Office and

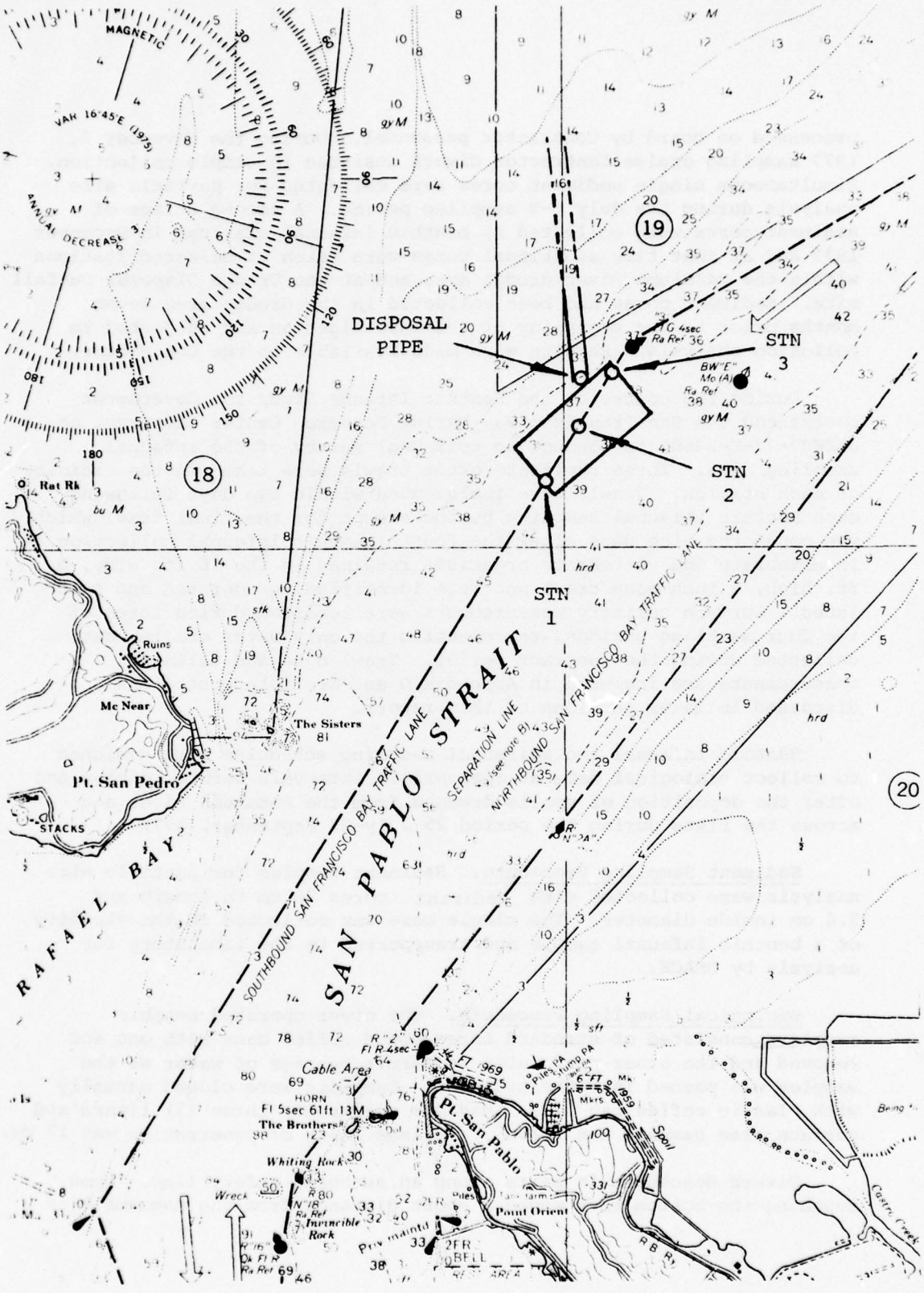


FIGURE 2: DISPOSAL OUTFALL AND STATION LOCATIONS

processed on board by Contractor personnel. During the November 2, 1977 sampling cruise Contractor divers assisted in sample collection. Simultaneous single sediment cores were collected for particle size analysis during the July 8-9 sampling period. A second series of sediment cores were collected at benthic infaunal stations in December 1977 and at that time additional cores were taken at selected stations within the Petaluma River dredge area and at the Dredge Disposal Outfall site. Sediment cores had been collected in the dredge area seven months prior to the beginning of the investigation and subjected to pollution analysis. Results were made available to the Contractor.

During the course of the Benthic Infauna Study the Government contracted the San Francisco Bay Marine Research Center (contract no. DACW07-77-E-2368) to conduct an epifaunal survey of the infaunal sampling area. Three replicate otter trawls were taken in the vicinity of each station. Trawls were implemented within two days following each benthic infaunal sampling period except for the final trawl which was conducted nine days after the fourth benthic infaunal collection. Invertebrate and vertebrate organisms retained in the 16 ft. wide, 5 ft. high, ¼ inch mesh trawl net were identified, enumerated and tabulated. Surface salinity measurements were recorded during three of the four sampling periods, representing the only water quality data collected during the contract period. Trawl data and salinity measurements are included in Appendix D and are interpreted and discussed in later sections of this report.

Benthic infaunal and epifaunal sampling schedules were designed to collect biological data at appropriate intervals before, during and after the deposition of spoils dredged from the Petaluma River and across the flats during the period 25 July-27 September, 1977.

Sediment Sampling Procedure. Sediment samples for particle size analysis were collected with sediment cores 76 cm in length and 5.4 cm inside diameter. The single core was collected in the vicinity of a benthic infaunal sample and transported to the laboratory for analysis by USACE.

Biological Sampling Procedure. The diver operated benthic samplers consisted of standard three pound coffee cans with one end removed and the other perforated to permit passage of water as the sampler was pushed into the sediment. Samplers were closed manually with plastic coffee can lids. Maximum volume was three (3) liters and surface area sampled was .018m^2. Maximum depth of penetration was 17 cm.

Divers descended in pairs along an anchored safety line. Upon reaching the bottom they moved a short distance from the descent line

to an undisturbed area and proceeded to collect one replicate. The divers pushed the entire length of the sampler into the sediment and sealed the top with a plastic lid. The sediment was partially removed from around the sampler and the bottom lid applied. Samples were transported to the surface immediately upon collection and examined for leakage and adequacy of sample volume. This sampler provided maximum sample volumes at all stations.

A discussion of the effectiveness of the sampling procedures utilized in this study is included in Appendix A.

Sample Processing Procedure. The sieve was constructed of 0.5mm mesh Nytex screening laminated between two sections of PVC pipe (inside diameter 15.0 cm). Each sample was transferred to a bucket, mixed thoroughly with filtered (0.25mm mesh) bay water and poured through the sieve. Wash water was applied to the screen only as required in an effort to reduce fragmentation of more fragile organisms.

All materials retained on the screen were washed into quart jars by reversing water flow through the sieve. Organisms were stained by adding Rose Bengal and narcotized by addition of a sufficient volume of concentrated $MgCl_2$ solution (300 gm/liter) to achieve a final concentration of 75 gm/liter. After approximately one hour the samples were fixed by adding buffered formaldehyde (hexamethylene-tetramine added at 454 gm/gal.) to achieve a final concentration of 10% formalin.

LABORATORY METHODS

Sediment Pollution and Particle Size Analysis. All analyses of sediment characteristics were performed by USACE. Analysis procedures and results are presented in Appendix C.

Biological Sample Processing. Following four to five days in formalin the samples were transferred to 70% isopropyl alcohol. This was accomplished by pouring the formalin off through a 0.5mm sieve and repeatedly washing the sample with fresh water until all formalin and any excess sediment was removed. Loss of specimens by retention in the sieve was negligible as confirmed by examination of the mesh with a magnifier.

Sorting of Biological Specimens. Each replicate was initially sorted to major and/or specific taxa and other convenient groupings. After larger items, such as worm tubes, were removed and examined individually for adhering stained organisms, small portions of the remaining material were transferred to a petri dish and sorted with a 10X stereomicroscope. Great care had to be taken to dissect all

Ampelisca tubes as this amphipod was frequently found within its flacid tube of cemented silt. Upon removal of the organisms, all sorted materials and debris were stored for future re-examination.

Upon completion of the initial sorting, organisms were further sorted to the lowest possible taxon. While the molluscs were often successfully separated visually, all other groups required initial preliminary identifications or at least determination of those diagnotic characters which facilitated tentative separation. When there was no doubt as to the identity or homogeneity of a group of organisms, they were counted prior to submission to taxonomists for verification or identification.

Taxonomic Processing. After determination of organisms to the lowest possible taxon or at least consolidation into homogeneous groups, vouchers were prepared for examination by taxonomic consultants. In the case of some particularly difficult groups, namely the Capitellids, Oligochaetes and Corophium spp., mixed samples were submitted for sorting as well as identification. The completed vouchers were used by contractor personnel to identify and enumerate the remaining organisms.

Acknowledgements. We wish to acknowledge the assistance of the following taxonomic authorities in identifications and/or identity confirmations of organisms during this study. This does not imply that they have checked all species or individuals of a species listed herein unless otherwise indicated.

Dr. Donald Abbott Hopkins Marine Station	Tunicata
Dr. James Blake Pacific Marine Station	Polychaeta and Oligochaeta
Mr. John Chapman University of California, Santa Barbara	Gammaridea, Tanaidacea, Misc. Arthropoda
Dr. Louis S. Kornicker U.S. National Museum	Ostracoda
Dr. Welton Lee California Academy of Sciences	Isopoda (all specimens)
Mr. John Rees Lawrence Berkeley Laboratory	Hydrozoa, Misc. Taxa

Dr. Barry Roth
California Academy of Sciences

Mollusca (all specimens)

ANALYTICAL METHODS

Several methods were employed to analyze raw data in terms of spacial and temporal variations and similarities of: 1) faunal abundance and composition; 2) species diversity and evenness; 3) species similarity; 4) principle taxa composition; and 5) major species constituents.

Species Composition and Abundance. Identified species were enumerated by Replicate and Station, and were tabulated as station, period and study totals. The number of species and of individuals were illustrated graphically.

Species Diversity and Evenness. Species diversity (H') and species evenness (J') were used to define species assemblages at each station within a sampling period, for each sampling period, and at each station over the entire period of study.

The Shannon-Wiener diversity index (Shannon and Weaver, 1949; Pielou, 1975) is defined by the equation,

$$H' = -\sum_{i}^{S} n_i/N \ln n_i/N,$$

where N is the total number of individuals, n_i is the number of individuals of species i, and S is the total number of species. This parameter measures the variability of the organisms' species identity. It depends on two things: the number of species and the evenness with which the individuals are apportioned among them.

Species evenness (Pielou, 1975) may then be defined by the equation,

$$J' = H'/\ln S.$$

Again, this parameter is a measure of the relative equality of distribution of individuals among the species present.

Species diversity (H') and evenness (J') are only estimates (as opposed to determinations) when sampling from a large uncensused community that is suspected of containing an unknown number of species that might be represented by very low numbers of individuals (Pielou, 1975). However, such indices can still be of value in enhancing the interpretation of major community structure and dynamics.

Faunal Similarity. The Sorensen (1948) quotient of similarity (QS) was employed to describe similarity of species composition between stations within a sampling period and stations of different periods, between stations for the entire duration of study, and between periods during the study. This parameter is defined by the equation,

$$QS = 2C/(A+B),$$

where A is the number of species at Station A, B is the number of species at Station B, and C is the number of species common to both stations. This coefficient can serve as an indicator of the homogeneity of infaunal species composition between sampling stations and sampling periods in the study area.

Principle Infaunal Taxa Composition. Numbers of individuals and species of the major phyla were tabulated for each station with totals for periods, stations, and the entire study. Diagrams were prepared from these data to illustrate percent total abundance and percent total species composition.

Major Species Composition. The ten most abundant species may each be analyzed in diagrams of the distribution of abundance per station over the course of the study period, the summation of abundances of each station and each period for the entire study period, percent abundance composition of the major species for stations and periods, and frequency of occurrence for stations and periods.

Major Species in Numbers per Liter. A number of benthic infaunal studies, in recent years, have presented abundance data for the major specific constituents as number of individuals per liter. The primary purpose has been the need to compare data from sample volumes with high and varied coefficients of variation. In the present study, however, all replicate sets had CV values of 0.0% with the exception of one set which had the low coefficient of variation of 3.9% (3.0, 3.0, and 2.8 liters) where,

$$CV\% = \hat{S}/\bar{X} \times 100.$$

Nevertheless, the ten most abundant species were tabulated in numbers per liter to facilitate comparison with results of similar studies.

Epifaunal Survey. No detailed analyses were conducted on the results of the benthic otter trawls taken in the study area since this was not included in the study objectives and design. However, a brief summary of the raw data is presented in a latter section of this report.

Underwater Biological Research recognizes that an accurate description of epifaunal assemblages is an important part in the development of a more complete understanding of the benthic seral community. It is important that epifaunal sampling be integrated into project designs of efforts that need to establish and monitor benthic faunal communities which may be of significant ecological and commercial importance. There is a need to develop epifaunal sampling and analysis techniques which can facilitate comparisons with benthic infaunal data and at the same time be consistent with the conservation of benthic faunal resources.

PHYSICAL-CHEMICAL ENVIRONMENTAL CHARACTERISTICS

SALINITY

The importance of salinity as a primary determinant of species distribution in San Pablo Bay is well documented (Filice, 1958; Kelley, 1966), as is the seasonal surface salinity pattern in this sub-bay system. In general, minimum levels occur in December and January, during periods of elevated rainfall and river runoff, and increase to peak levels in September and October (USACE Maint. Dredge Vol. 1, 1975). Water quality investigations during the period 1970-1975 (USACE Main Report, 1977) recorded a salinity range of 1.5‰ to 23.5‰ with a mean of 11.5‰. Other surveys have recorded maximum values up to 28‰ while the July 1977 reading during this investigation was 33.4‰. Such broad annual variations can probably be attributed to freshwater influx and variations in chlorinity ($S = 1.8\ Cl + 0.03$) with the tidal phase of as much as 6‰ having been recorded in the shallows of San Pablo Bay (Kelley, 1966). The Distance to which saline waters penetrate San Pablo and Suisun Bays also vary seasonally and annually with the magnitude of freshwater inflow from the Sacramento and San Joaquin Rivers.

San Francisco Bay is a well-mixed estuary, i.e., there is little vertical salinity variation, and this pattern prevails in San Pablo Bay during all periods except those of high freshwater inflow. Under such conditions stratification occurs as a layer of freshwater spreads across the surface of San Pablo Bay, and portions of the Central Bay in extreme circumstances, while a saline wedge extends upstream along the bottom into the Carquinez Strait (Kelley, 1966).

Surface salinity measurements during the course of the present investigation were restricted to the July 10, August 17 and November 3 otter trawls and were recorded as 33.2-33.4‰, 30.4-30.5‰, and 29.9-32.1‰,

respectively (Appendix D). Major storms occurred during the winter of 1977-78 causing flood flows from the California delta waterways. This would be expected to increase sediment transport and cause significant reductions in salinity within the study area. Salinity tolerances and preferences among the dominant infauna are presented and discussed individually wherever possible.

SEDIMENTS

Results of sediment analyses are present as Field Sediment Descriptions (Tables 2 - 5), Gradation Curves (particle size analysis) for samples from the Dredge Disposal and Dredge Source sites (Appendix C), Gradation Curves for samples taken in 1975 from Pinole Shoal (Appendix C), and Pollution Test Data for samples taken in December 1976 from the Dredge Disposal and Dredge Source sites (Appendix C). The particle size analysis data are summarized as percent sand ($> 74\mu$), silt and clay ($< 2\mu$) in Tables 6 and 7.

Field descriptions of the benthic environment at the sampling stations and at the dredge disposal outfall site, compiled from divers' observations *in situ*, are presented in Appendix B.

An additional method to characterize sediment types at the benthic infaunal sampling stations was developed by the Contractor in order to augment the interpretation of biological results. Detailed descriptions of sediment constituents retained in each of the benthic infaunal replicate samples were recorded in the laboratory during the initial phase of separation and sorting of biological speciments (10 X magnification). Data were compiled and classified into four major sediment types (Table 1). These sediment type classifications and sediment sample volumes retained from each replicate sample after sieving are included with the Benthic Sampling Data (Tables 2 - 5) to facilitate comparison. This additional method for sediment classification is admittedly subjective, but was developed primarily for the following reasons:

1) Sediment samples were taken at benthic infaunal stations during only one of the benthic infaunal sampling cruises. A second set of sediment samples was taken nine weeks following the third benthic infaunal sampling period.

2) Results are based only on single cores at each station (i.e., no replicate samples).

3) Cores sample sediments to a much greater depth (>50 cm) than the benthic infaunal samplers (17 cm).

Description of Station One. Field notes describe Station One sediments as clayey-silt with varying proportions of fine sand (6 replicates), coarse sand (3 replicates), and gravel/shell fragments (2 replicates). One replicate was characterized by a loose surface film with large numbers of Ampelisca tubes.

Retained sample descriptions classify the majority of Station One sediments as TYPE A in which plant debris predominates while silt-clay aggregates are common and sand, gravel and shell fragments are sparsely represented. One replicate was classified as TYPE C (filamentous masses and Ampelisca tubes dominant) and another as TYPE D (coarse sand dominant). The volume of retained material ranged from 0.128 to 0.416 liters with a mean volume of 0.217 liters.

Gradation curves for Station One prior to dredging indicate that silt (62%) was the major component of the sediment core sample with the silt-clay fraction predominating (90%). The sand constituent comprised only 10% of the sample by weight. The median grain size was 18 microns (silt) and the plasticity level was moderately high.

Gradation curves for a Station One sample following dredging (December, 1977) indicated that sand (38%) and silt (46%) were nearly equally predominant as single components and that the sand-silt fraction composed the major make-up. Clay (16%) was the least prevalent constituent. The median grain size for the sample was 35 microns (coarse silt) with a moderate plasticity level.

Station One then exhibited the greatest variation in sediment composition. This is supported by a diver's observation (Contractor personnel) of alternating patches of fine sand and elevated muddy mounds of Ampelisca tubes.

Description of Station Two. Field notes describe Station Two sediments as clayey-silt with fine sand and some shell fragments (3 replicates), with coarse sand (5 replicates), and with combinations of coarse sand, gravel and shell fragments (4 replicates).

Retained sample descriptions classify all but one station 2 replicate as TYPE B in which fine to medium sand dominates with shell fragments sparse to common and gravel common to abundant. A single

TABLE 1: CLASSIFICATION OF RETAINED PORTION OF BENTHIC SAMPLES ACCORDING TO MAJOR CONSTITUENTS

TYPE A	Composed primarily of plant debris; silt-clay aggregates common; shell fragments, sand and gravel sparse.
TYPE B	Composed primarily of fine to medium sand; plant debris present; silt-clay aggregates sparse; shell fragments sparse to common; gravel sparse to abundant.
TYPE C	Composed primarily of filamentous masses; plant debris present; large worm tubes present; shell fragments present; Ampelisca tubes common to abundant.
TYPE D	Composed almost entirely of coarse sand; Ampelisca tubes present; shell fragments,gravel and silt-clay aggregates sparse.

TABLE 2 : FIELD SAMPLING AND SEDIMENT DESCRIPTION DATA - PERIOD I

STN-REPL	FATHOMETER DEPTH/TIME (ft./hrs.)	CORRECTED DEPTH (ft.)	TOTAL SAMPLE VOLUME (liters)	RETAINED SAMPLE VOLUME (liters)	SEDIMENT DESCRIPTION-FIELD	SEDIMENT DESCRIPTION-LAB
1-1	43/1000	40	3.0	0.256	compact fine sand with clayey-silt, grey and grey-black, H_2S detectable	TYPE A.
1-2	43/1000	40	3.0	0.192	compact fine sand with clayey-silt, grey and grey-black, H_2S detectable	TYPE A.
1-3	43/1000	40	3.0	0.320	compact fine sand with clayey-silt, grey and grey-black, H_2S detectable	TYPE A.
2-1	42/1100	39	3.0	0.128	compact fine sand with clayey-silt, dark grey with brown-green surface fim.	TYPE B.
2-2	42/1100	39	3.0	0.544	medium course sand with clayey-silt, brown, shell fragments in upper 2 cm	TYPE B.
2-3	42/1100	39	2.8	0.256	compact fine sand with clayey-silt, dark grey	TYPE B.
3-1	35/1030	32	3.0	0.256	plastic silty-clay grey mud H_2S slightly detectable	TYPE C.
3-2	35/1035	32	3.0	0.128	plastic silty-clay grey mud H_2S slightly detectable	TYPE C.
3-3	35/1045	32	3.0	0.288	plastic silty-clay grey mud H_2S slightly detectable	TYPE C.

TABLE 3 : FIELD SAMPLING AND SEDIMENT DESCRIPTION DATA - PERIOD II

STN-REPL	FATHOMETER DEPTH/TIME (ft./hrs.)	CORRECTED DEPTH (ft.)	TOTAL SAMPLE VOLUME (liters)	RETAINED SAMPLE VOLUME (liters)	SEDIMENT DESCRIPTION FIELD	SEDIMENT DESCRIPTION-LAB
1-1	44/1530	39	3.0	0.128	compact clayey-silt, dark grey, with top .5 cm layer of fine sand	TYPE A.
1-2	44/1535	39	3.0	0.160	compact clayey-silt, dark grey, with top .5 cm layer of fine sand	TYPE A. few large worm tubes
1-3	44/1535	39	3.0	0.256	compact brown fine sand	TYPE D.
2-1	44/1100	38	3.0	0.736	compact clayey-silt, grey, with some fine sand, top 5 cm layer of brown coarse sand	TYPE B.
2-2	43/1505	38	3.0	0.384	compact clayey-silt, grey with some fine sand,top 2 cm layer of brown coarse sand	TYPE B.
2-3	43/1505	38	3.0	0.800	compact clayey-silt, grey, with some fine sand, top 5cm layer of brown coarse sand	TYPE B. large gravel
3-1	34/1000	32	3.0	0.160	plastic silty-clay grey mud H_2S slightly detectable	TYPE C.
3-2	34/1000	32	3.0	0.320	plastic silty-clay grey mud, moderate no. of large worm tubes. H_2S detectable	TYPE C.
3-3	34/1005	32	3.0	0.179	plastic silty-clay grey mud, moderate no. of large worm tubes. H_2S detectable	TYPE C.

TABLE 4 : FIELD SAMPLING AND SEDIMENT DESCRIPTION DATA - PERIOD III

STN-REPL	FATHOMETER DEPTH/TIME (ft./hrs.)	CORRECTED DEPTH (ft.)	TOTAL SAMPLE VOLUME (liters)	RETAINED SAMPLE VOLUME (liters)	SEDIMENT DESCRIPTION FIELD	SEDIMENT DESCRIPTION-LAB
1-1	43/1200	40	3.0	0.416	fine brown sand with some light grey silt with grey/brown surface film penetrated by many Ampelisca tubes	TYPE C.
1-2	43/1200	40	3.0	0.192	clayey-silt, dark grey, with top 2 cm layer of coarse brown sand - moderate H_2S	TYPE A Sand Common
1-3	43/1200	40	3.0	0.224	clayey-silt, grey, with top 1 cm layer of coarse brown sand - H_2S detectable	TYPE A. Ampelisca tubes
2-1	41/1110	38	3.0	0.384	plastic clayey-silt, grey, with top 4 cm layer coarse brown sand with shell fragments and gravel - slight H_2S	TYPE B.
2-2	41/1110	38	3.0	0.576	clayey silt, grey, with top 2 cm layer coarse brown sand with shell fragments	TYPE B.
2-3	41/1110	38	3.0	1.824	coarse brown sand with shell fragments - bottom 4 cm clayey silt	TYPE D.
3-1	33/1030	30	3.0	0.160	clayey-silt, grey, very loose	TYPE C.
3-2	33/1030	30	3.0	0.320	clayey-silt, grey, very loose	TYPE C.
3-3	33/1030	30	3.0	0.173	clayey-silt, grey, very loose	TYPE C.

TABLE 5 : FIELD SAMPLING AND SEDIMENT DESCRIPTION DATA - PERIOD IV

STN-REPL	FATHOMETER DEPTH/TIME (ft./hrs.)	CORRECTED DEPTH (ft.)	TOTAL SAMPLE VOLUME (liters)	RETAINED SAMPLE VOLUME (liters)	SEDIMENT DESCRIPTION FIELD	SEDIMENT DESCRIPTION-LAB
1-1	43/1230	40	3.0	0.147	clayey-silt with sparse sand. brown surface layer	TYPE A.
1-2	43/1230	40	3.0	0.154	clayey-silt, compact, dark grey. top 1cm of brown sand, with shell and gravel	TYPE A.
1-3	43/1230	40	3.0	0.160	clayey-silt, compact, dark grey. Top ½cm of brown sand with shell and gravel	TYPE A.
2-1	40/1130	37	3.0	0.211	clayey-silt, compact, dry, with some sand, shell and gravel	TYPE B.
2-2	40/1130	37	3.0	0.173	clayey-silt, compact, dry, with brown surface layer with some sand, shell and gravel deeper in sample	TYPE B.
2-3	40/1130	37	3.0	0.256	clayey-silt, compact, dry, with bottom ¼ of sand, shell and gravel	TYPE B. Large gravel
3-1	35/1045	30	3.0	0.160	silty-clay, plastic, grey with thin brown surface layer (sparse shell). Worm tubes	TYPE C.
3-2	35/1045	30	3.0	0.288	silty-clay, plastic, grey with thin brown surface layer (sparse shell). Worm tubes	TYPE C. Gravel Common, Sparse filaments
3-3	35/1045	30	3.0	0.320	silty-clay, plastic, grey with thin brown surface layer (sparse shell). Worm tubes	TYPE C. Sparse filaments

replicate was classified as TYPE D (coarse sand dominant). The volume of retained material ranged from 0.128 - 1.824 liters with a mean volume of 0.523 liters.

Gradation curves for Station Two samples taken prior to dredge disposal indicate that silt (52%) and clay (28%) had the greatest fractions by weight with sand comprising 20% of the sample. The median grain size was 15 microns (silt) and the plasticity level was determined to be moderate to moderately-high.

Gradation curves for Station Two samples taken following dredge disposal indicated that sand (66%) was by far the principal component with silt (23%) and clay (11%) comprising minor components. The median size was 0.35 millimeters with a moderate to moderately-high plasticity level.

Station Two then was characterized by the most coarse sediments in the study area and was the only station to contain a common gravel component.

Description of Station Three. Field notes describe Station Three sediments as loose clayey-silt (3 replicates) or plastic silt-clay (4 replicates) in which large worm tubes (Asychis sp.) were commonly embedded (5 replicates).

Retained sample descriptions classify all Station Three samples as TYPE C in which filamentous masses dominate. Ampelisca tubes are common to abundant, and shell fragments, plant debris and large Asychis worm tubes are present. In two replicates the filamentous masses were reduced and in one of these gravel was present. The volume of retained material ranged from 0.128 - 0.320 liters with a mean volume of 0.229 liters. The actual volumes of some samples were biased by an abundance of large worm tubes.

Gradation curves for Station Three samples taken prior to dredge disposal indicate that silt (54%) and clay (36%) had the greatest fractions by weight with sand (10%) being the least predominant. The median grain size was six microns (silt-clay) with the plasticity moderately high (fat clay).

Gradation curves for Station Three samples taken after dredge disposal indicate silt (64%) to be the primary component with clay (25%) comprising the next lower fraction. Sand (11%) was the least predominant. The median grain size was 17 microns (silt) and the plasticity level was determined to be moderately high (fat clay).

Station Three was characterized by the finest sediments and the highest degree of sediment homogeneity in the study area.

Description of the Dredge Disposal Outfall Site. Government personnel (USACE divers) made an inspection of the dredge disposal diffuser pipe two days after the disposal had begun. Only 10% - 20% of the spoils material was exhausting out of the diffuser openings of the pipe which had been suspended at 18' water depth (Appendix, B1). The bulk of the material (80% - 90%) was being emitted out of the end of the pipe and settling quickly to the bottom (personal communication, July 1978).

Field observations during a disposal site inspection 72 hours after completion of dredging disposal describe newly deposited loose material spread over an area of at least 200' in diameter and at least 6' height at center (Appendix, B2).

A gradation curve from a sample taken from the dredge spoils mound in December 1978 (Station number Pt-104) indicates a major component of silt (69%) with minor fractions of clay (17%) and sand (14%). The median grain size was 33 microns (medium silt) with a moderately low plasticity level.

Description of Dredge Source Sediments. Gradation curves for samples taken at two stations just adjacent to the dredged channel across the flats near the mouth of the Petaluma River indicate very fine sediments. Even though dredging had already occurred, an attempt was made to obtain "pre-dredge type" material (data lost from pre-study sampling) by sampling just outside the edge of the dredged channel.

The sediment sample taken from the "outer flats" station (Pt-105; four to six feet water depth) was composed primarily of silt (70%) with clay (27%) a secondary constituent. Sand (3%) composed a minor fraction. The median grain size was 13 microns (silt) and the plasticity level was high.

The sediment sample taken from the "inner flats" station (Pt-106; two to four feet water depth) was composed of approximately a two-to one ratio of silt (64%) over clay (35%) with just a trace of sand (1%). The median grain size was 6 microns.

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Pinole Shoal Sediments. Gradation curves of five sediment samples taken in the Pinole Shoal channel (water depths 25' - 40') in May 1975, indicate that sand was the predominant single constituent with a percent composition mean of 48% (range 34% - 50%). Silt composed a mean of 29% (range 21% - 36%) while clay composed a mean of 22% (range 16% - 30%).

Pollution Tests. Pollutant level tests were run by the Government on six samples taken in December 1976 from the channel within the mouth of the Petaluma River (three samples) and across the flats (three samples). The results of Bulk Sediment Analysis and Standard Elutriate tests for levels of mercury, cadmium, lead, zinc, and oil and grease are presented in Appendix C. As stated in the Government laboratory report, all samples were within maximum limits set by the Environmental Protection Agency, Region IX, for Marine (shallow) and Estuarine water disposal and 40 CFR, Part 230, Section 230.4.3.

Summary of Sediments at the Disposal Site and Adjacent Areas. During the course of the study sediments in the disposal area ranged from loose clayey-silt and plastic silty-clay at the shallow (30-32') northern-most station on the edge of the bay channel (Station Three) to a heterogeneous composition of clayey-silt and fine to medium sand at the deeper (37' - 39') center station (Station Two). The southern-most and deepest (39' - 40') station (Station One) contained clayey and sandy-silts. Organic filamentous masses (faunal filaments) were common in the northern-most station and a high degree of plant debris was commonly found at the southern-most station.

Sediments in the dredge source area across the flats near the Petaluma River mouth were described as predominately fine clayey-silt with high amounts of clay.

Sediments in the Pinole Shoal channel area were described as containing primarily sand with a moderate fraction of clayey-silt.

Sediments in the dredge spoils material at the disposal outfall site were described as mainly silt with minor components of clay and sand.

Although the deposition of dredge spoils undoubtedly had significant impact on the sediments in the immediate outfall disposal area there is no clear indication how sediment composition at the infaunal sampling stations was affected by dredge disposal.
Station Three, approximately 300 yards from the outfall, had slightly higher silt and lower clay composition after the dredging. Stations Two and One, at approximately 400 and 800 yards from the outfall, had

TABLE 6: SUMMARY OF PARTICLE SIZE GRADATIONS FOR THE SAN PABLO BAY DREDGE DISPOSAL SITE AND THE PETALUMA RIVER ACROSS THE FLATS CHANNEL

COMPONENT	BENTHIC INFAUNAL STATIONS SAN PABLO BAY DREDGE DISPOSAL SITE						DISPOSAL OUTFALL SITE	DREDGE SOURCE PETALUMA RIVER ACROSS THE FLATS	
	8-9 JULY 1977 PRE-DREDGE			7 DECEMBER, 1977 POST DREDGE					
	STN ONE	STN TWO	STN THREE	STN ONE	STN TWO	STN THREE	PT-104	PT-105	PT-106
% SAND	10	20	10	38	66	11	14	3	1
% SILT	62	52	54	46	23	64	69	70	64
% CLAY	28	28	36	16	11	25	17	27	35
MEDIAN GRAIN SIZE	18μ	15μ	6μ	35μ	.35mm	17μ	33μ	13μ	6μ

TABLE 7: SUMMARY OF PARTICLE SIZE GRADATIONS FOR THE PINOLE SHOALS CHANNEL, MAY 1975

COMPONENT	STATION 2D-164	STATION 2D-165	STATION 2D-166	STATION 2D-167	STATION 2D-168	MEAN
% SAND	50	53	63	42	34	48.4
% SILT	30	25	21	35	36	29.4
% CLAY	20	22	16	23	30	22.2
MEDIAN GRAIN SIZE	75μ	.11mm	.19mm	50μ	16μ	88μ

significant increases in sand content after dredging but considering the low sand content in dredge source material it is suggested that this freshly deposited surface layer (see sediment descriptions, Tables 3-5) had been transported from the Pinole Shoals channel area. The absence of control stations and valid background data preclude any complete assessment of dredge disposal impact on the sediment composition in the study area.

Previous investigations in San Pablo Bay tend to support the sediment descriptions developed in the present study. McCarty (1962) sampled nine stations between San Pablo Strait and Carquinez Strait during six cruises (October 1960 - May 1961). The stations encompassed both shallow flats and deep channels, and sediment composition ranged from clay to fine sand. Fine sand, silty-sand, and clayey-sand characterized the deeper stations. Painter (1966) collected sediment samples at eight stations ranging from deep channel to intertidal. The two channel stations were described as clay and silt by a simple qualitative examination. During a Comprehensive Study of San Francisco Bay (Storrs, 1966) sediments were separated into four categories on the basis of sand content. The San Pablo Bay stations were the same ones occupied by McCarty a few years prior. Of the three deeper stations in the vicinity of the San Pablo Bay Dredge Disposal Site, two contained 30% - 54% sand while one contained 54% - 75% sand.

BIOLOGICAL STUDIES

Biological data and analyses are presented with reference to temporal and spacial variations so that a general ecological baseline description of the benthic infauna at the San Pablo Bay Dredge Disposal Site may be established. It should be noted that only non-colonial organisms which have specific identity determinations have been included in the data analysis. These organisms constitute 96.8% of the total number of individuals collected during the course of the study. Refer to Table F-1 in Appendix for those organisms which have not been included.

NUMBER OF SPECIES AND INDIVIDUALS, SPECIES DIVERSITY AND EVENNESS

The raw data from the infaunal analysis are presented as benthic species and abundance by station and period in Table F-1 of Appendix F, and benthic species and abundance by replicate for each station in Table F-2 of Appendix F. Additionally, the results of the epifaunal survey conducted by the San Francisco Bay Marine Research Center is presented in Appendix D. These data are discussed at the end of the Biological Studies section. A master phylogenetic species list is

presented in Appendix E. A summary of major infaunal parameters is presented as Table 8 and distributions of these parameters are presented in Figure 3.

Numbers of Species and Individuals. Fifty-two species representing 7370 individuals were identified and enumerated from all four sampling periods from 8 July, 1977 to 19 April, 1978.

The total number of species observed at each station and period ranged from seven at Station Two, Period I to 30 at Station One, Period III. The total number of species observed at each station over the entire period of study ranged from 18 at Station Two to 36 at Station Three. The total number of species observed during each sampling period ranged from 21 during Period II to 36 during Period III. The mean number of species observed at each station over the entire study period ranged from 9.3 at Station Two to 17.0 at Station One. The mean number of species observed during each sampling ranged from 11.3 during Period II to 16.0 during Period III.

The total number of individuals observed at each station and period ranged from 23 at Station Three, Period II to 3159 at Station One,Period III. The total number of individuals observed at each station over the entire study period ranged from 368 at Station Two to 4694 at Station One. The total number of individuals observed during each sampling period ranged from 639 during Period IV to 3482 during Period III. The mean number of individuals observed at each station over the entire study period ranged from 92.0 at Station Two to 1173.5 at Station One. The mean number of individuals observed during each sampling period ranged from 213 during Period IV to 1161 during Period III.

Species Diversity and Evenness. Shannon-Wiener species diversity (H') and Pielou species evenness (J') values were calculated for the total fauna found at each station for each period using the abundances of those organisms identified to the species level (Table 8 and Appendix F, Table F-1).

Species diversity values at each station and period ranged from .68 at Station Two, Period I to 1.82 at Station Three, Period II. Species diversity values at each station over the entire study period ranged from .88 at Station One to 1.80 at Station Two. Species diversity values during each sampling period ranged from .68 during Period II to 1.99 during Period IV. The Diversity Index for the entire study was 1.32. Mean species diversity values at each station for the entire study range from 1.10 at Station One to 1.39 at Stations Two and Three. Mean species diversity values for each sampling period

TABLE 8: MAJOR INFAUNAL PARAMETERS

	PERIOD	STATION 1	STATION 2	STATION 3	TOTAL	MEAN
TOTAL ABUNDANCE (N)	I	103	110	1587	1800	600
	II	1392	34	23	1449	483
	III	3159	105	218	3482	1161
	IV	40	119	480	639	213
	TOTAL	4694	368	2308	7370	
	MEAN	1174.5	92	577		
# OF SPECIES(S)	I	14	7	22	27	14.3
	II	15	11	8	21	11.3
	III	30	8	10	36	16.0
	IV	9	11	18	22	12.6
	TOTAL	36	18	32	52	
	MEAN	17	9.3	14.5		
SPECIES DIVERSITY (H')	I	1.44	.68	.83	1.22	.98
	II	.53	1.59	1.82	.68	1.31
	III	.87	1.57	1.21	1.17	1.22
	IV	1.57	1.71	1.70	1.99	1.66
	TOTAL	.88	1.80	1.59	1.32	
	MEAN	1.10	1.39	1.39		
SPECIES EVENNESS (J')	I	.55	.35	.27	.37	.39
	II	.19	.66	.88	.22	.58
	III	.26	.76	.53	.33	.52
	IV	.71	.71	.59	.64	.67
	TOTAL	.24	.62	.46	.33	
	MEAN	.43	.62	.57		

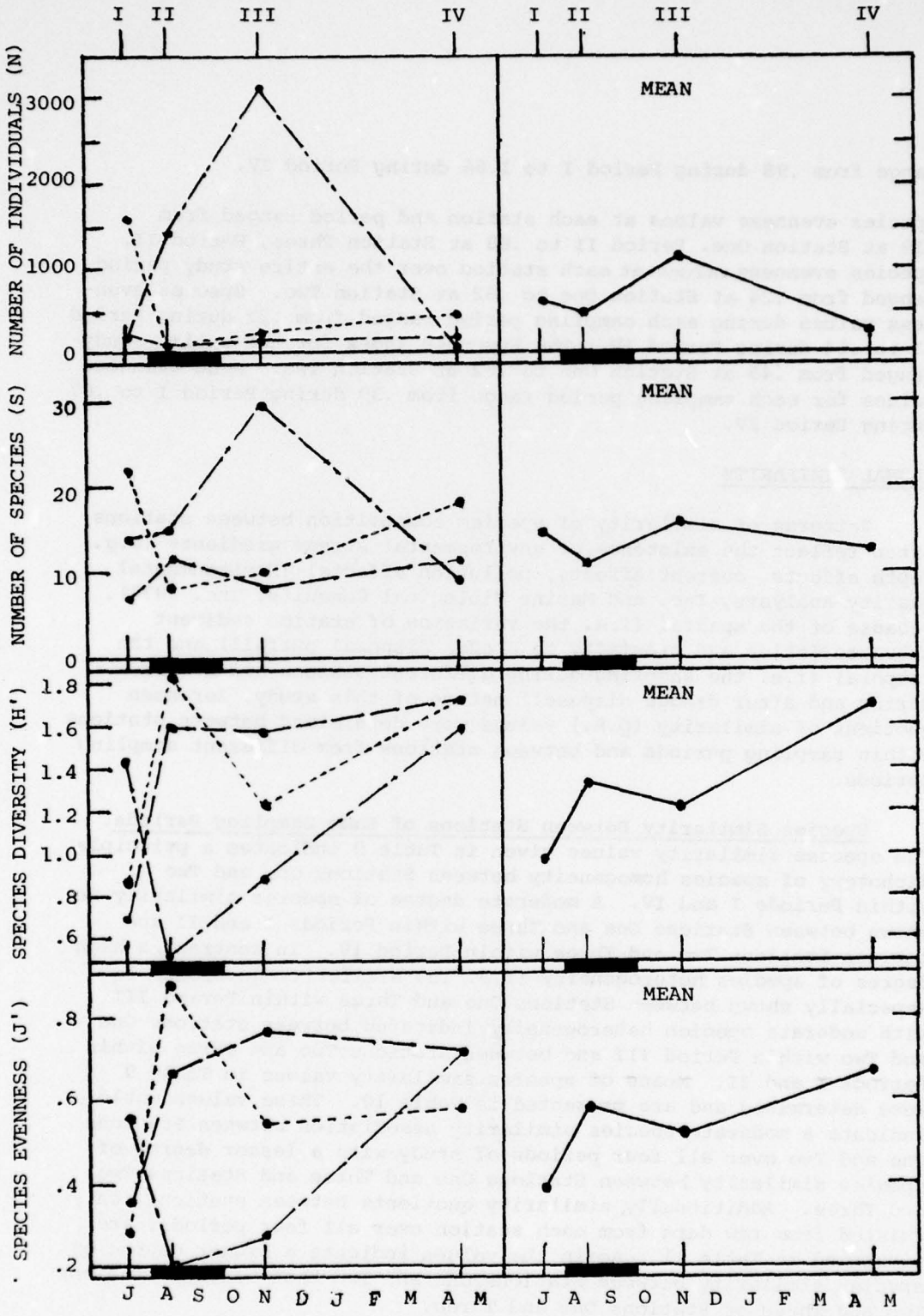


FIGURE 3: DISTRIBUTION OF MAJOR INFAUNAL PARAMETERS

range from .98 during Period I to 1.66 during Period IV.

Species evenness values at each station and period ranged from .19 at Station One, Period II to .88 at Station Three, Period II. Species evenness values at each station over the entire study period ranged from .24 at Station One to .62 at Station Two. Species evenness values during each sampling period ranged from .22 during Period II to .64 during Period IV. The Evenness Index for the entire study ranged from .43 at Station One to .62 at Station Two. Mean evenness values for each sampling period range from .39 during Period I to .67 during Period IV.

FAUNAL SIMILARITY

Patterns of similarity of species composition between stations often reflect the existence of environmental stress gradients (e.g. depth effects, current effects, pollution effects) (Environmental Quality Analysts, Inc. and Marine Biological Consults, Inc. 1973). Because of the spacial (i.e. the variation of station sediment characteristics and proximity to dredge disposal outfall) and the temporal (i.e. the sampling during different seasons and before, during and after dredge disposal) nature of this study, Sorensen quotient of similarity (Q.S.) values were determined between stations within sampling periods and between stations from different sampling periods.

Species Similarity Between Stations of Same Sampling Periods. The species similarity values given in Table 9 indicates a principle dichotomy of species homogeneity between Stations One and Two within Periods I and IV. A moderate degree of species similarity is shown between Stations One and Three within Periods I and II and between Stations Two and Three within Period IV. In contrast, a high degree of species heterogeneity (i.e. low similarity quotient) is especially shown between Stations One and Three within Period III with moderate species heterogeneity indicated between Stations One and Two within Period III and between Stations Two and Three within Periods I and II. Means of species similarity values in Table 9 were determined and are presented in Table 10. These values would indicate a moderate species similarity association between Stations One and Two over all four periods of study with a lesser degree of species similarity between Stations One and Three and Stations Two and Three. Additionally, similarity quotients between stations, calculated from raw data from each station over all four periods, are presented in Table 11. Again the values indicate a higher degree of species similarity between Stations One and Two than between Stations Two and Three or Stations One and Three.

TABLE 9: SPECIES SIMILARITY (QS) BETWEEN STATIONS OF SAME SAMPLING PERIOD

	STATION ONE				STATION TWO			
	PERIOD I	PERIOD II	PERIOD III	PERIOD IV	PERIOD I	PERIOD II	PERIOD III	PERIOD IV
STATION TWO	.67	.46	.32	.70				
STATION THREE	.56	.52	.25	.37	.34	.32	.44	.55

TABLE 10: SPECIES SIMILARITY (QS) BETWEEN STATIONS (MEAN)

	STATION ONE	STATION TWO
STATION TWO	.54	
STATION THREE	.43	.43

TABLE 11: SPECIES SIMILARITY (QS) BETWEEN STATIONS (TOTALING METHOD)

	STATION ONE	STATION TWO
STATION TWO	.46	
STATION THREE	.37	.41

Species Similarity Between Stations of Different Sampling Periods. Similarity Quotient values are given in Table 12 for all possible combinations of Station comparisons between different sampling periods. A very high degree of species homogeneity is indicated between Station One, Period I and Station One, Period II. A moderately high degree of species similarity is shown with Station One, Period IV as compared to Station Two, Period I and also Station Two, Period III. In contrast a high degree of species heterogeneity (i.e. low similarity quotient) is indicated between Station Two, Period III and Station Three, Period I and between Station Two, Period II and Station Three, Period III.

Species Similarity Between Sampling Periods. Similarity quotients for all possible combinations of comparisons between sampling periods, calculated from raw benthic infaunal data, are given in Table 13. Moderate to moderately high similarity coefficients are indicated between all period comparison combinations with the exception of the comparison of Period I with Period IV where a moderately low species similarity is indicated.

COMPOSITION OF PRINCIPLE TAXA

The number of individuals and species of the three principle phyla (Annelida, Arthropoda, and Mollusca) are presented in Table 14. Composition by percent abundance for each station is presented in Figure 4 with summaries for each station and period given in Figures 5 and 6. Distribution by percent species composition for each station is presented in Figure 7 with summaries for each station and period given in Figures 8 and 9.

Number of Individuals and Species. The highest number of individuals identified and enumerated for the entire study belonged to the phylum Arthropoda (5658) with the phylum Annelida being second most abundant (1595) and the phylum Mollusca having relatively low numbers (110). The greatest number of species for the period of study was represented by the phylum Annelida (26). Phylum Arthropoda (15) and Phylum Mollusca (9) followed in the number of specific determinations.

The arthropods predominate numerically primarily due to the high population of the amphipod Ampelisca milleri collected during the first three sampling periods. Arthropods were found in both their least and greatest abundance during Period III: zero at Station Three to 2750 at Station One. Period III contained the greatest arthropod population and Period IV the least. Over the period of study, Station One composed the highest number of arthropod individuals and Station Two the least.

TABLE 12: SPECIES SIMILARITY (QS) BETWEEN STATIONS OF DIFFERENT SAMPLING PERIODS

		PERIOD I			PERIOD II			PERIOD III		
		STATION ONE	STATION TWO	STATION THREE	STATION ONE	STATION TWO	STATION THREE	STATION ONE	STATION TWO	STATION THREE
PERIOD II	STATION ONE	.83	.55	.49						
	STATION TWO	.48	.56	.36						
	STATION THREE	.55	.53	.40						
PERIOD III	STATION ONE	.45	.27	.50	.44	.24	.26			
	STATION TWO	.36	.40	.20	.35	.42	.25			
	STATION THREE	.50	.35	.44	.48	.19	.44			
PERIOD IV	STATION ONE	.43	.63	.26	.35	.53	.35	.46	.59	.32
	STATION TWO	.48	.56	.30	.46	.45	.42	.34	.53	.38
	STATION THREE	.50	.40	.45	.48	.28	.38	.38	.31	.43

TABLE 13: SPECIES SIMILARITY BETWEEN PERIODS

	PERIOD I	PERIOD II	PERIOD III
PERIOD II	.58		
PERIOD III	.57	.56	
PERIOD IV	.45	.56	.59

The annelid worms were greatest in numerical abundance at Station One, Period III and least in abundance at Station Three, Period II and Station Two, Period I. Period III comprised the highest number and Period II the lowest, and over the study period Station Three exhibited the greatest number of individuals and Station Two the least.

The molluscs were present in relatively low numbers as a group. They were seen most prevalently at Station Three and in greatest number in Period III. Only two individuals were recorded from Station Two over the entire period of study. Period II comprised only five individuals. During the first three periods there were no molluscs recorded at five sampling stations.

The annelids exhibited the most species with the greatest number recorded at Station One, Period III and the least number recorded at Station Two, Period I. Period III comprised its greatest number of species and Period IV the least. Over the entire study period Station One had the greatest number of annelid species and Station Two the least.

Arthropod species were most prevalent at Station Three, Period I and Station One, Period Three. No arthropod species were recorded at Station Three, Period III. Period I contained the most number of arthropod species with Periods II and IV the least. Over the entire study period all three stations composed an approximately equal number of arthropod species.

Molluscs had the least number of species but more than might be expected considering the very low total number of individuals recorded. Most species were recorded from the third and fourth sampling periods. Only one species was recorded at Station Two during the entire period of the study.

Distribution of Principle Taxa by Percent Abundance. The three principle taxa constituted more than 99% of the total number of individuals identified and enumerated in the study.

While the arthropods comprised 77% of the total number of individuals collected throughout the study, they were numerically dominant in only three of the series of 12 samples collected and averaged 36% numerical composition per sample. Annelids constituted 22% of the total study abundance and due to their numerical dominance in nine of the samples, averaged 61% numerical composition per sample. Molluscs exceeded five percent composition in only one sample (22%) and averaged less than one percent numerical composition per sample. They comprised only one percent of all individuals collected.

TABLE 14: NUMBER OF INDIVIDUALS AND SPECIES OF PRINCIPAL TAXA

		PERIOD I				PERIOD II				PERIOD III				PERIOD IV				STATION TOTALS			TOTAL
		1	2	3	T	1	2	3	T	1	2	3	T	1	2	3	T	1	2	3	T
ANNELIDA	(N)	94	13	207	313	110	28	13	152	387	104	174	665	36	72	357	465	627	217	751	1595
	(S)	8	4	12	14	11	6	4	13	16	7	9	21	6	6	7	11	19	10	16	26
ARTHROPODA	(N)	9	97	1364	1470	1281	5	5	1291	2750	1	0	2751	3	45	98	146	4043	58	1554	5658
	(S)	6	3	7	10	4	4	2	5	7	1	0	8	2	4	5	5	10	8	8	15
MOLLUSCA	(N)	0	0	14	14	0	0	5	5	20	0	44	64	1	2	24	27	21	2	87	110
	(S)	0	0	2	2	0	0	2	2	6	0	1	7	1	1	5	5	7	1	7	9
MISC	(N)	0	0	3	3	0	1	0	1	2	0	0	2	0	0	1	1	2	1	4	7
	(S)	0	0	1	1	0	1	0	1	1	0	0	1	0	0	1	1	1	1	2	2

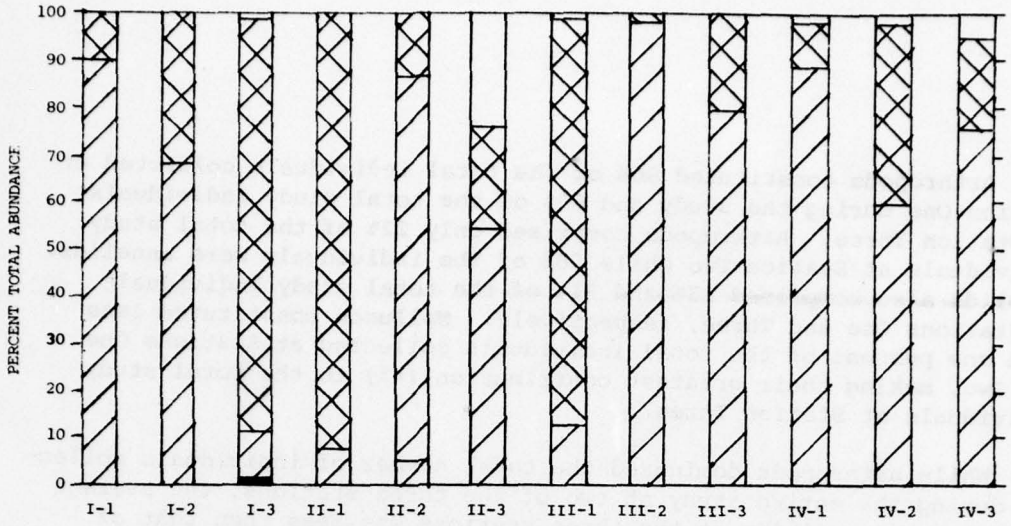


FIGURE 4: DISTRIBUTION OF PRINCIPLE TAXA AT STATIONS BY PERCENT ABUNDANCE

ANNELIDS ARTHROPODS MOLLUSCS MISC. TAXA

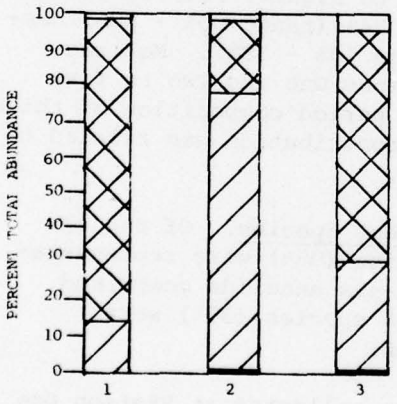


FIGURE 5: PERCENT ABUNDANCE OF PRINCIPLE TAXA AT EACH STATION FOR THE ENTIRE DURATION OF STUDY

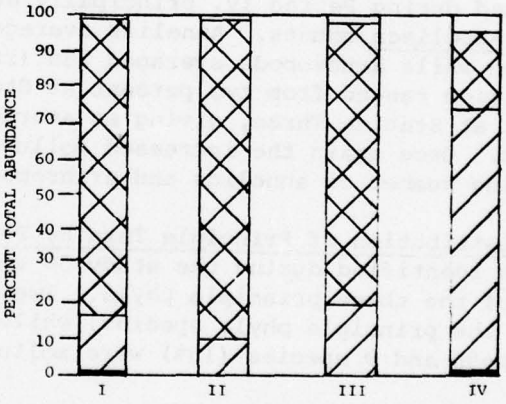


FIGURE 6: PERCENT ABUNDANCE OF PRINCIPLE TAXA DURING EACH PERIOD

ANNELIDS ARTHROPODS MOLLUSCS MISC. TAX

Arthropods constituted 86% of the total individuals collected at Station One during the study and 65% of the total study individuals at Station Three. Arthropods comprised only 22% of the total study individuals at Station Two while 78% of the individuals were annelids. Annelids also comprised 13% and 31% of the total study individuals at Stations One and Three, respectively. Molluscs constituted less than one percent of the total individuals collected at Stations One and Two, making their greatest contribution (4%) to the total study individuals at Station Three.

While arthropods dominated the total number of individuals collected during the entire study at two of the three stations, the average percentage composition at the three stations was less than that of annelids during all four sampling periods. During Period I the average percent composition of annelids at all sampling stations was 57% (range 12% - 90%), while that of arthropods was 43% (range 10% - 87%). Molluscs made an insignificant contribution, average less than one percent composition over all three stations. During Period II annelids averaged 49% (range 8% - 82%) composition at the three stations and arthropods continued to average 43% (range 15% - 92%) composition. Reduced annelid and arthropod counts and slightly increased mollusc abundance at Station Three resulted in a more significant average mollusc contribution (7%) during Period II. Annelids averaged 64% (range 12% - 99%) at the sampling stations during Period III and average arthropod composition declined to 36% (range 1% - 87%). Once again molluscs were insignificant ($<$ 1%). The dominance of annelids increased during Period IV, principally due to significant reductions in the Ampelisca counts. Annelids averaged 74% (range 60% - 88%) composition while arthropods averaged 23% (range 10% - 38%). Mollusc composition ranged from two percent at Stations One and Two to five percent at Station Three, giving an average period composition of three percent. Once again the increased mollusc contribution was related to declining number of annelids and arthropods.

Distribution of Principle Taxa by Percent Species. Of the 52 species identified during the study 50 species (96%) were representatives of the three principle phyla. Twenty-six annelids comprised 52% of the principle phyla species, while 15 species (30%) were arthropods and 9 species (18%) were molluscs.

Thirty-six principle phyla species were collected at Station One throughout the study. Annelids (19 species) comprised 53% of the total and ten arthropods comprised 28% of the total. Nineteen percent of the species at Station One were molluscs (7 species). The number of principle phyla species collected at Station Two (18) was

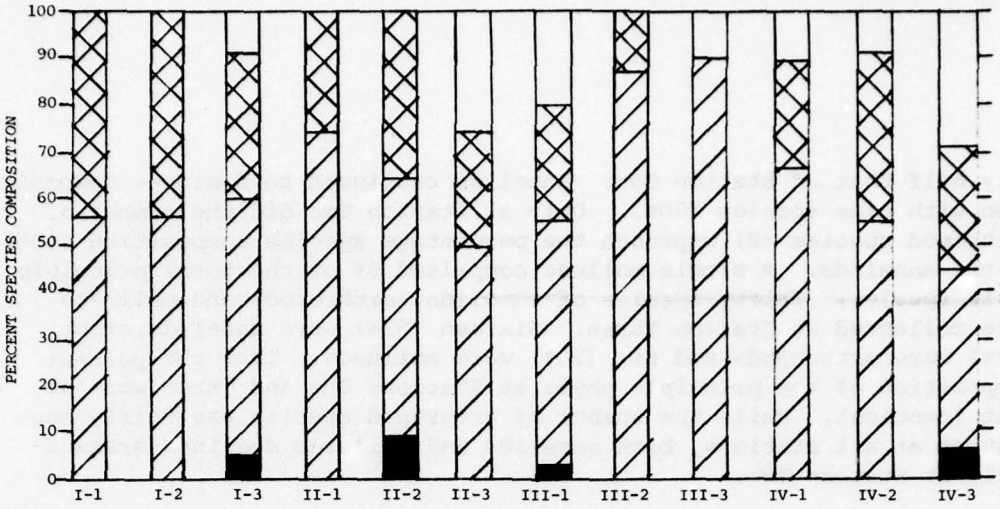
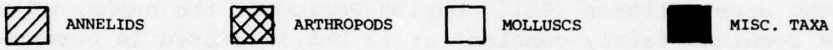


FIGURE 7: DISTRIBUTION OF PRINCIPLE TAXA AT STATIONS BY PERCENT SPECIES COMPOSITION



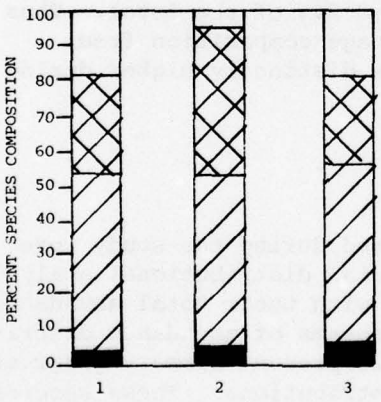


FIGURE 8: PERCENT SPECIES COMPOSITION OF PRINCIPLE TAXA AT EACH STATION FOR THE ENTIRE DURATION OF STUDY

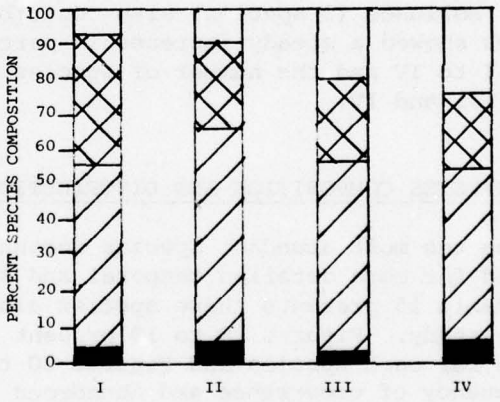


FIGURE 9: PERCENT SPECIES COMPOSITION OF PRINCIPLE TAXA DURING EACH PERIOD



only half that of Station One. Annelids continued to dominate composition with nine species (50%). Only at Station Two did the number of arthropod species (8) approach the percentage species composition (44%) of the annelids. A single mollusc comprised 6% of the total principle phyla species. Thirty species of annelids, arthropods and molluscs were collected at Station Three. Sixteen (53%) were annelids,eight (27%) were arthropods and six (20%) were molluscs. Thus the percent composition of the principle phyla at Stations One and Three were almost identical. While the number of arthropod species was fairly consistent at all stations, both annelids and molluscs declined dramatically at Station Two.

Twenty-six principle phyla species were collected at all stations during Period I. Fourteen were annelids (54%), 10 were arthropods (38%) and two were molluscs (8%). During Period II the number of annelid species remained fairly constant at 13 but increased in percentage composition to 65%, primarily at the cost of arthropod species which were reduced to five (25%). Two species of molluscs constituted 10% of the total. By Period III the number of principle phyla species increased dramatically to 36. Annelids increased and continued to dominate with 21 species (58%), while the number of arthropod species increased less dramatically to eight and constituted 22% of the total. The number of species of molluscs more than tripled to seven (20%). During Period IV annelid species had declined to 11 but continued to comprise over half (52%) of the total. The number of arthropod species equaled the Period II low of five and comprised 24% of the total. Molluscs (5 species) also contributed 24% of the total. Thus molluscs showed a steady increase in percentage composition from Period I to IV and the number of species was distinctly higher during Period III and IV.

MAJOR SPECIES COMPOSITION AND DISTRIBUTIONS

The ten most abundant species encountered during the study were selected for more detailed temporal and spacial distributional analyses. Table 15 presents these species along with their total abundance for the study. Figures 10 to 19 present diagrams of abundance distributions for each species and Figures 20 to 29 present summary diagrams of frequency of occurrence and abundance distributions. These species comprised 95.3% (7028) of the 7370 Individuals collected during the study.

The vast majority (70.7%) of the most abundant species were Ampelisca milleri. Number of individuals were similar for Periods I (1301) and II (1255), nearly doubled during Period III (2569) and

TABLE 15: TEN MOST ABUNDANT SPECIES

SPECIES	TOTAL ABUNDANCE
Ampelisca milleri Barnard, 1954	5208
Exogone lourei Berkeley and Berkeley, 1938	568
Peloscolex gabriellae Marcus, 1950	505
Sarsiella zostericola Cushman, 1906	271
Polydora brachycephala Hartman, 1936	155
Leptochelia dubia (Kroyer, 1842)	102
Tharyx parvus Berkeley, 1929	65
Gemma gemma (Totten, 1834)	56
Hesionura sp. A	51
Polydora ligni Webster, 1879	47

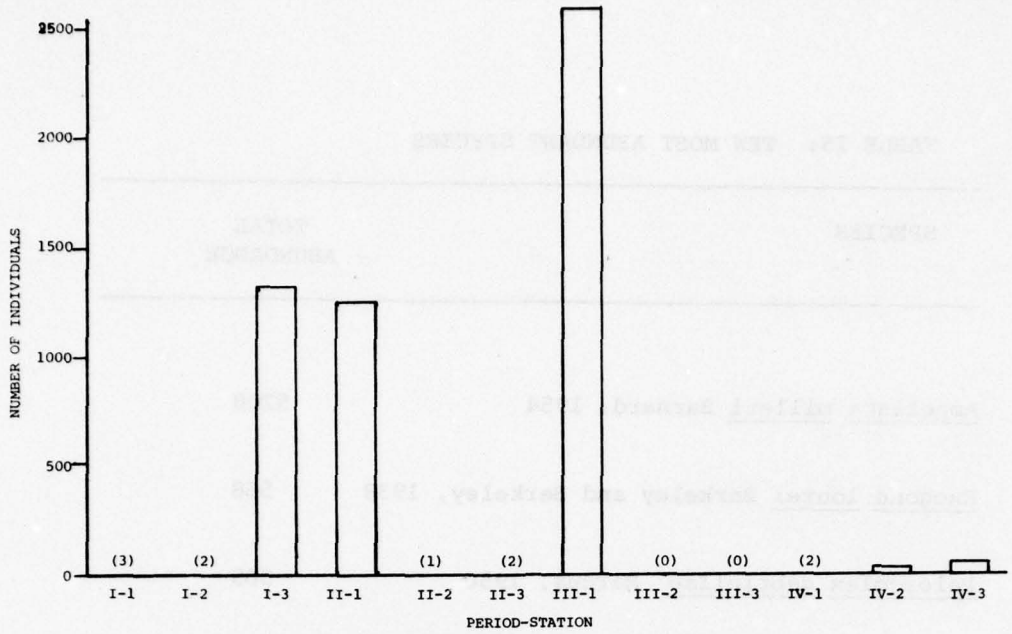


FIGURE 10: DISTRIBUTION OF Ampelisca milleri IN NUMBER OF INDIVIDUALS PER PERIOD AND STATION.

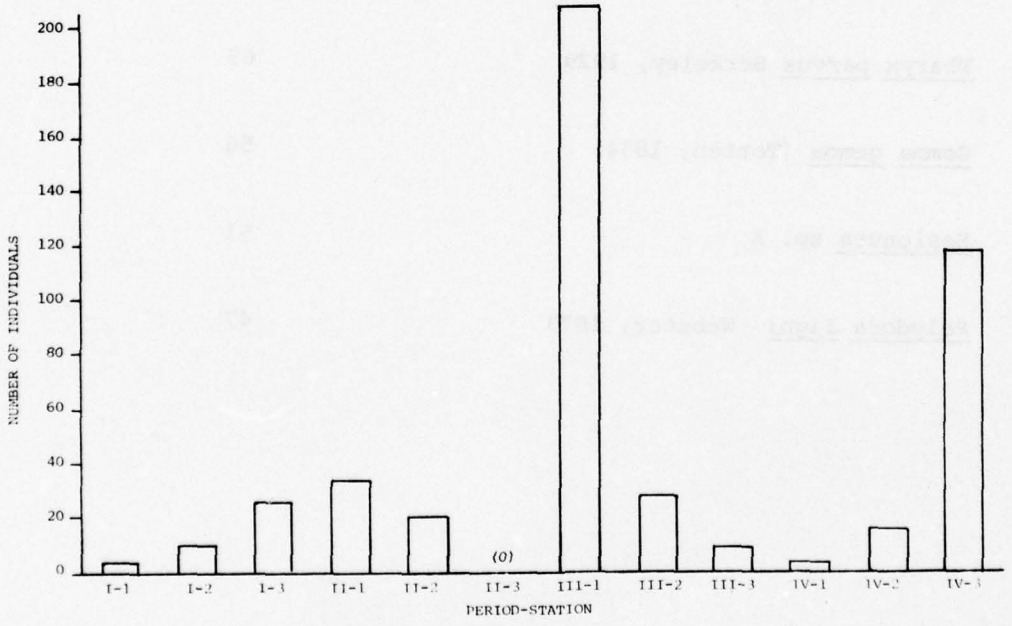


FIGURE 11: DISTRIBUTION OF Exogone lourei IN NUMBER OF INDIVIDUALS PER PERIOD AND STATION.

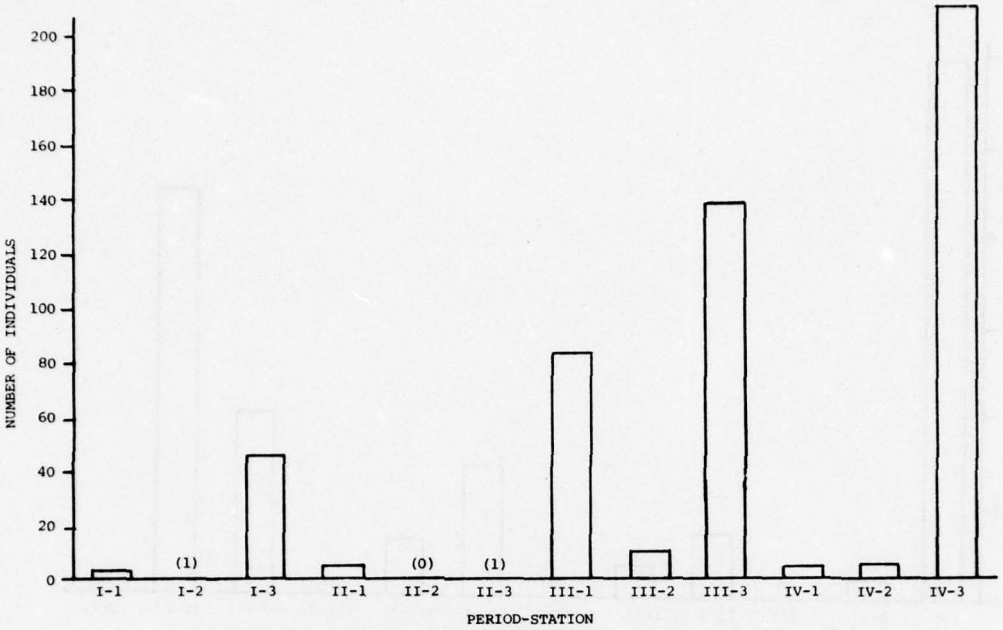


FIGURE 12: DISTRIBUTION OF Peloscolex gabriellae IN NUMBER OF INDIVIDUALS PER PERIOD AND STATION.

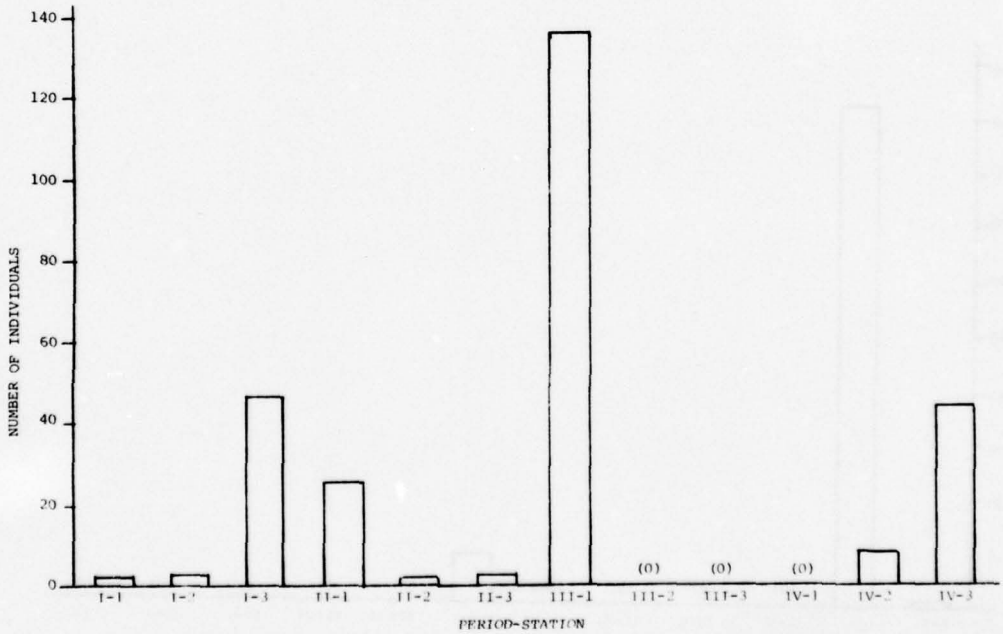


FIGURE 13: DISTRIBUTION OF Sarsiella zostericola IN NUMBER OF INDIVIDUALS PER PERIOD AND STATION.

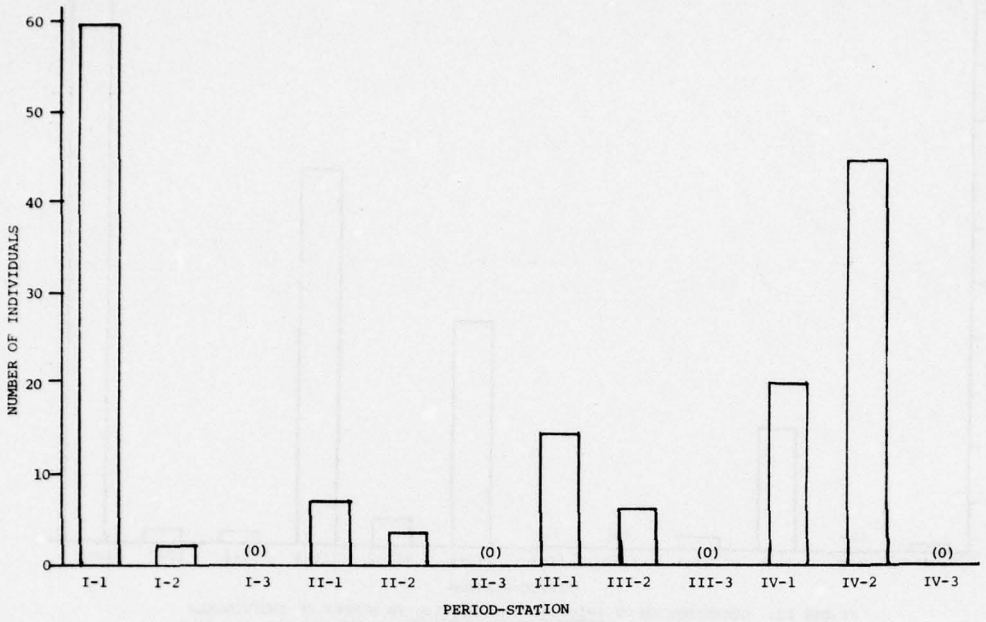


FIGURE 14: DISTRIBUTION OF Polydora brachycephala IN NUMBER OF INDIVIDUALS PER PERIOD AND STATION.

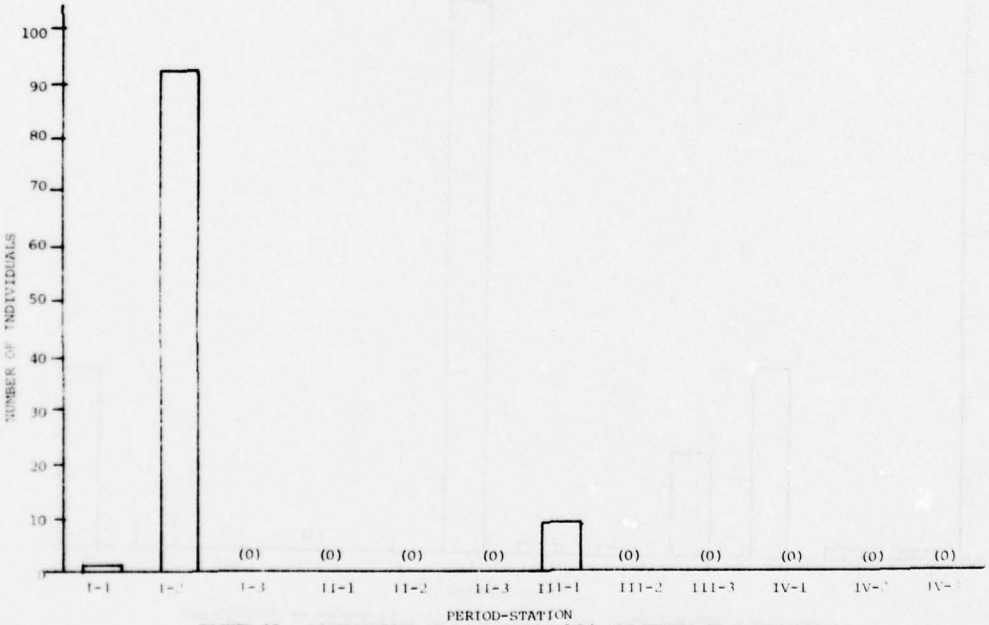


FIGURE 15: DISTRIBUTION OF Leptochelia dubia IN NUMBER OF INDIVIDUALS PER PERIOD AND STATION.

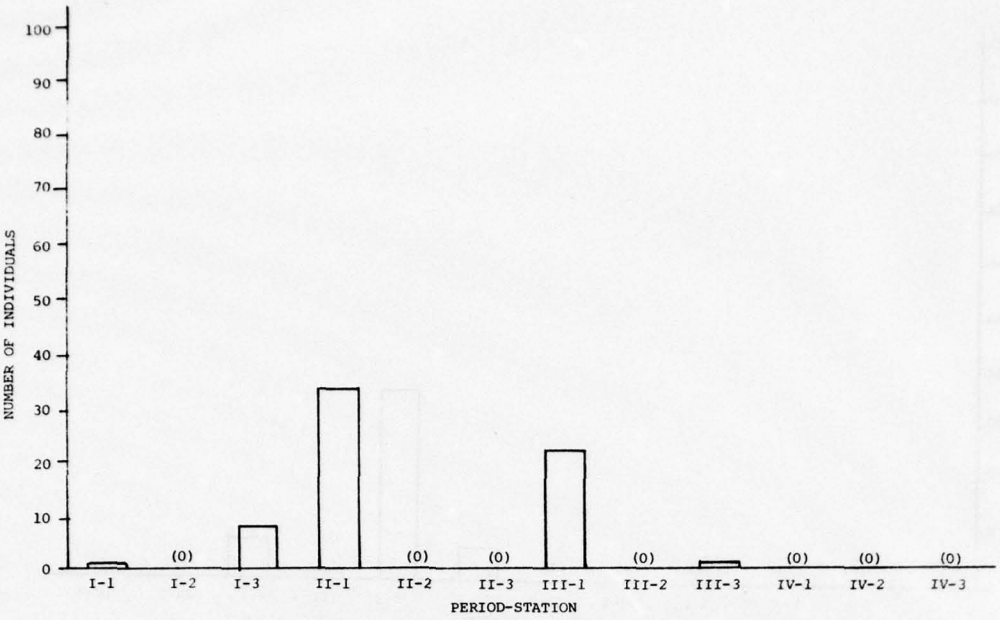


FIGURE 16: DISTRIBUTION OF Tharyx parvus IN NUMBER OF INDIVIDUALS PER PERIOD AND STATION.

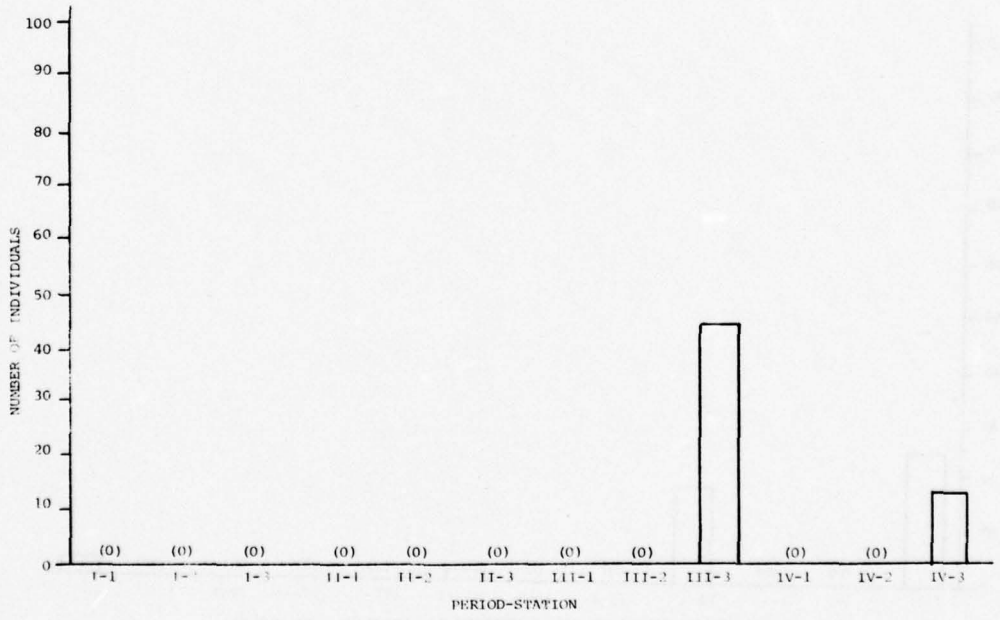


FIGURE 17: DISTRIBUTION OF Gemma gemma IN NUMBER OF INDIVIDUALS PER PERIOD AND STATION.

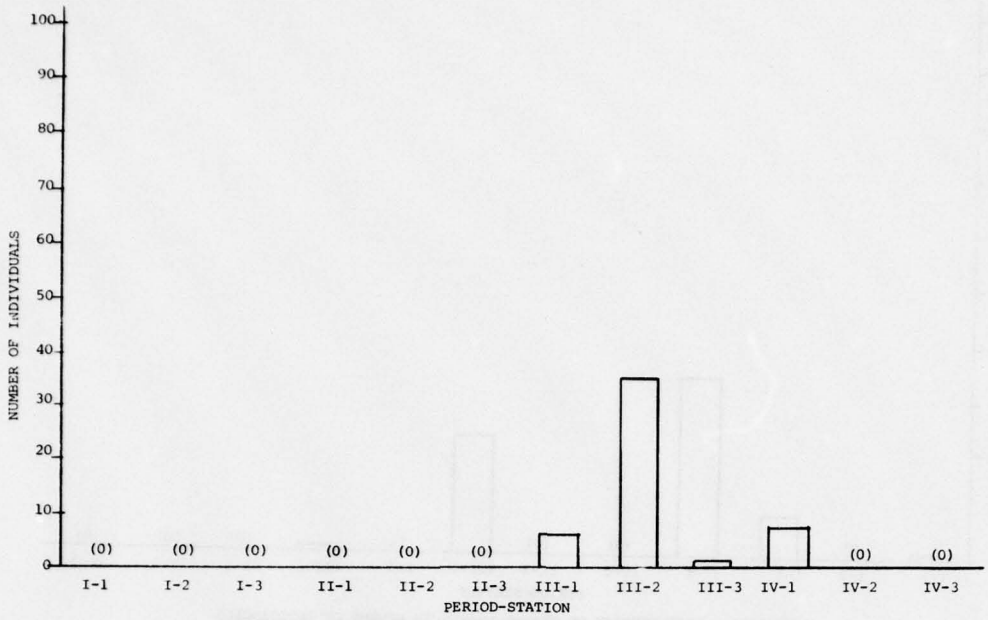


FIGURE 18: DISTRIBUTION OF Hesionura IN NUMBER OF INDIVIDUALS PER PERIOD AND STATION.

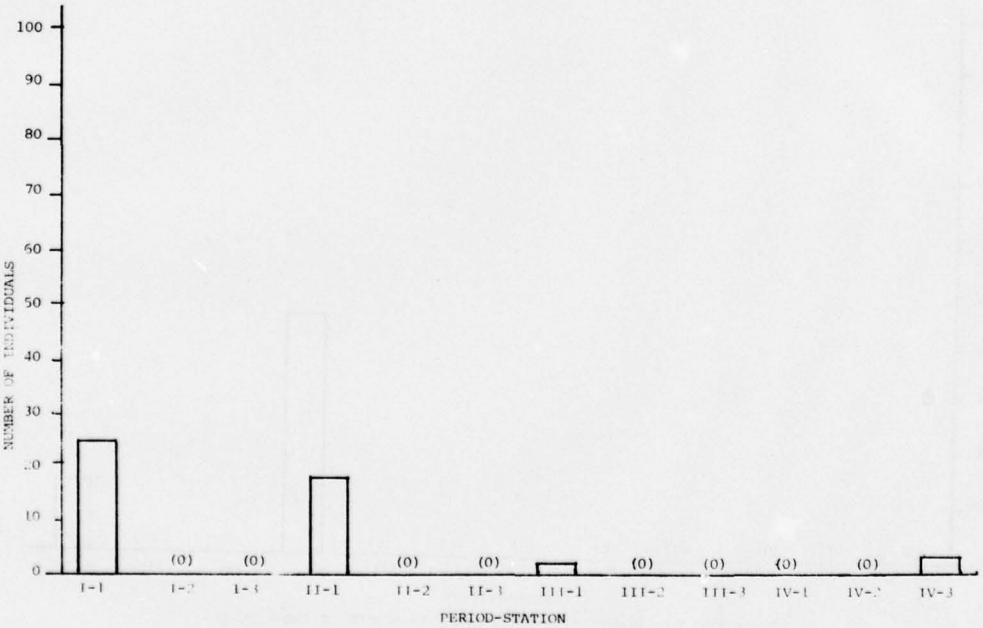


FIGURE 19: DISTRIBUTION OF Polydora ligni IN NUMBER OF INDIVIDUALS PER PERIOD AND STATION

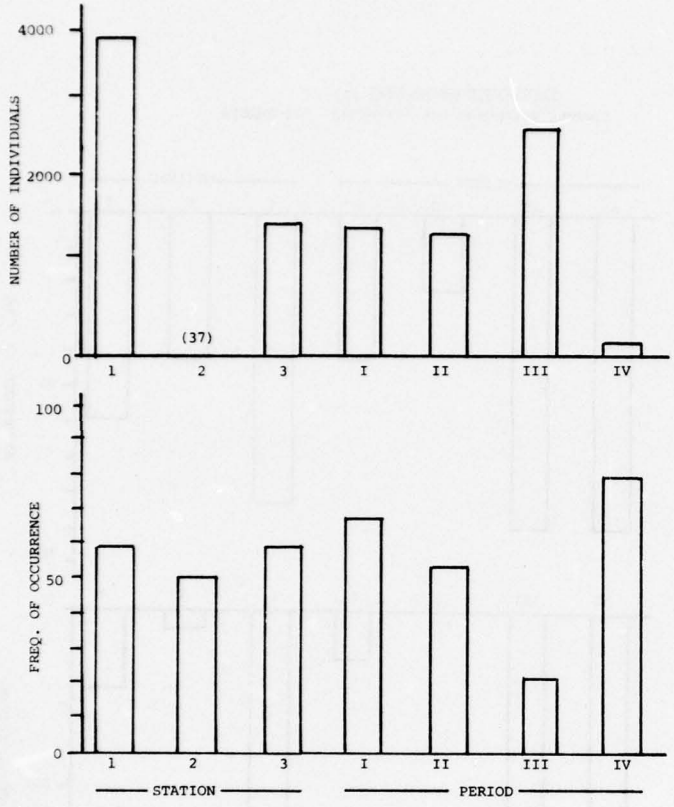


FIGURE 20: Frequency and Abundance Summary for Ampelisca milleri.

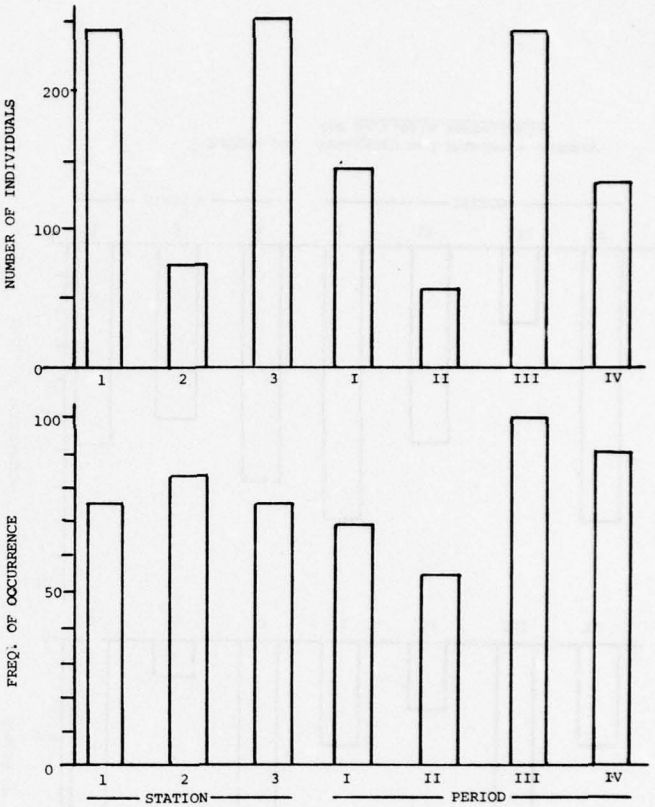


FIGURE 21: Frequency and Abundance Summary For Exogone lourei.

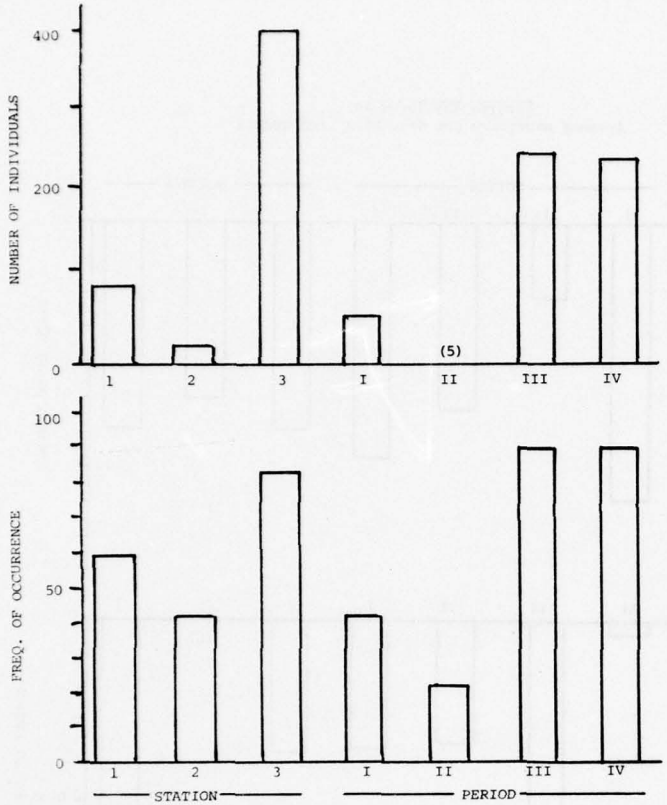


FIGURE 22: Frequency and Abundance Summary for Peloscolex gabriellae.

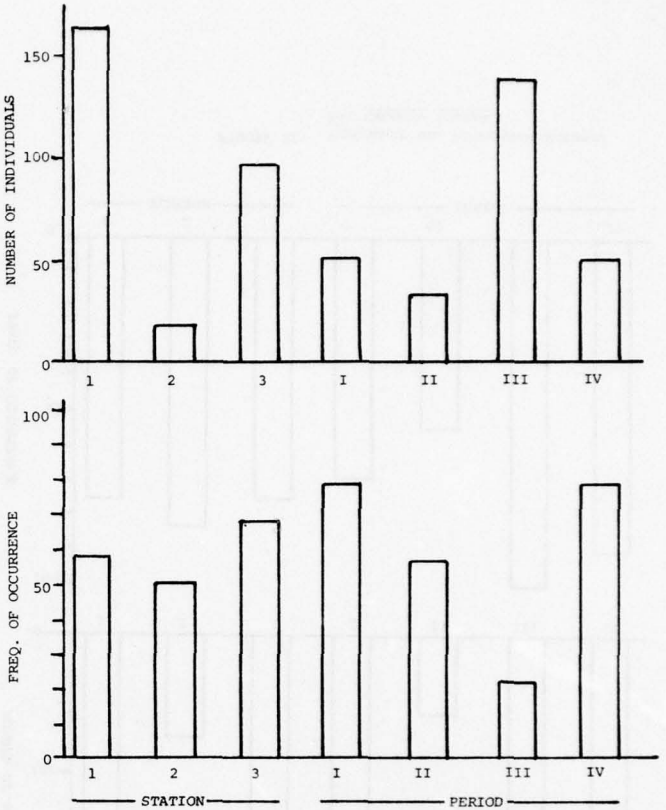


FIGURE 23: Frequency and Abundance Summary for Sarsiella zostericola.

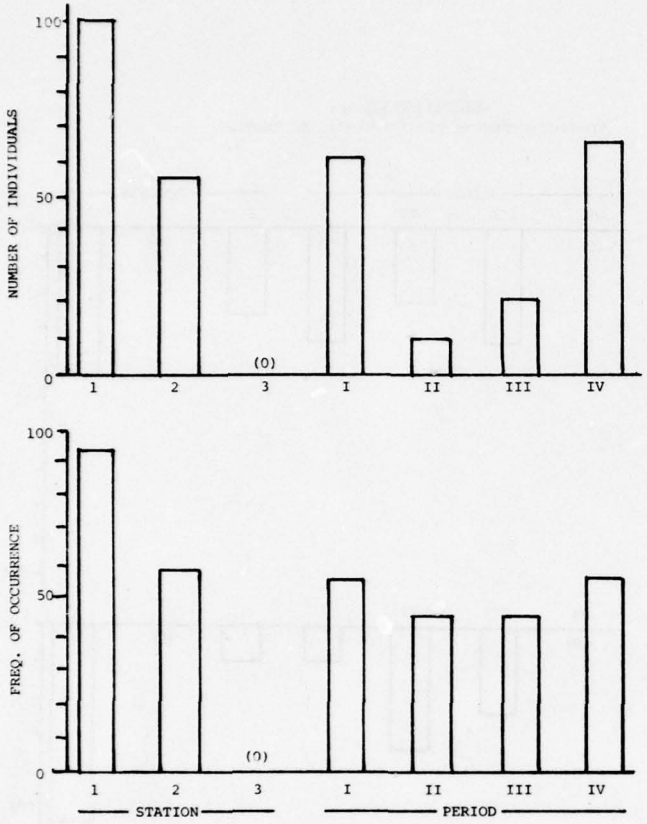


FIGURE 24: Frequency and Abundance Summary for Polydora brachycephala.

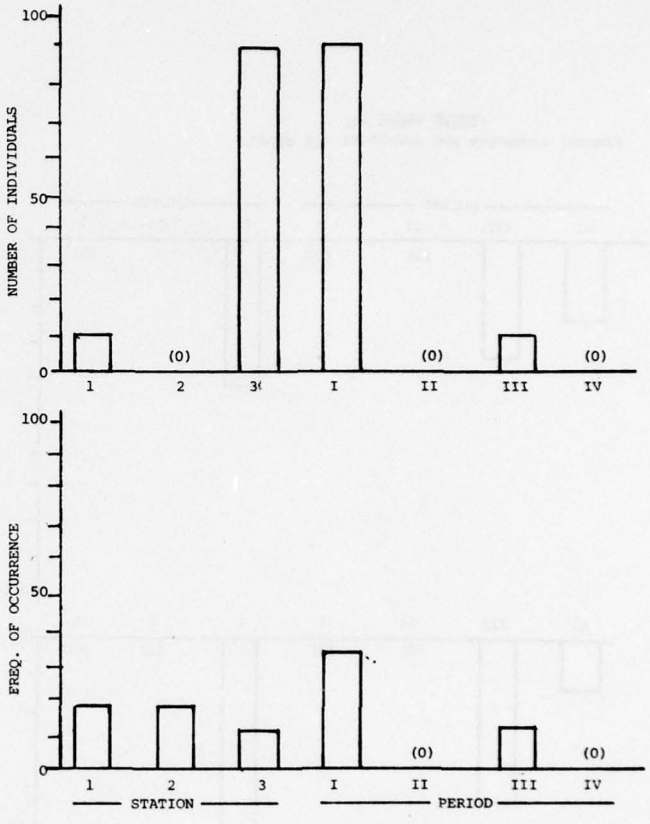


FIGURE 25: Frequency and Abundance Summary for Leptochelia dubia.

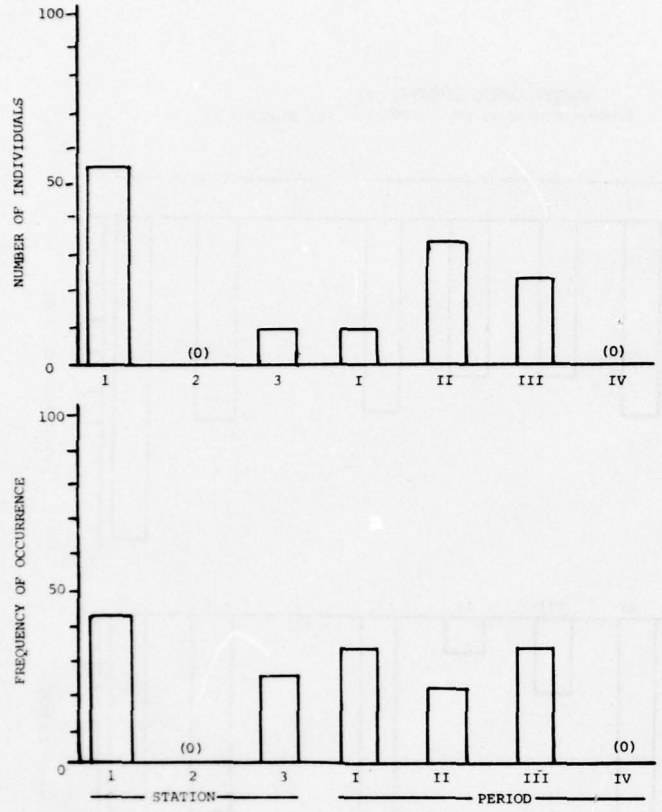


FIGURE 26: Frequency and Abundance Summary for Tharyx parvus.

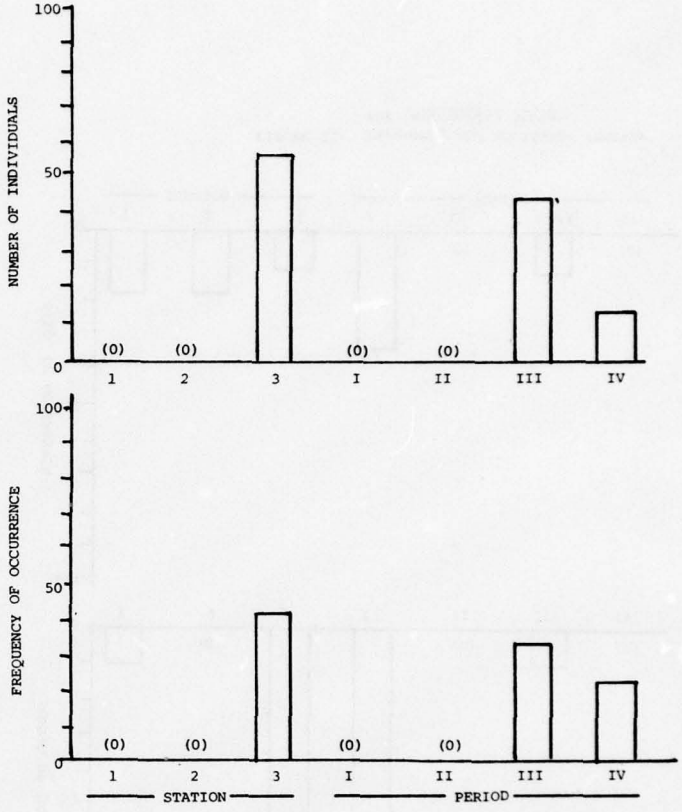


FIGURE 27: Frequency and Abundance Summary for Gemma gemma.

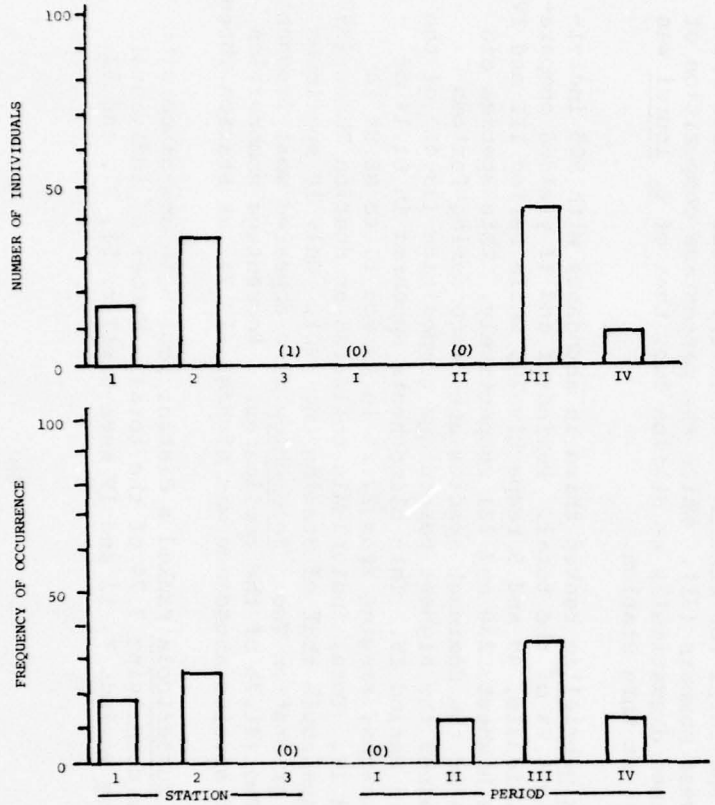


FIGURE 28: Frequency and Abundance Summary for Hesionura sp. A.

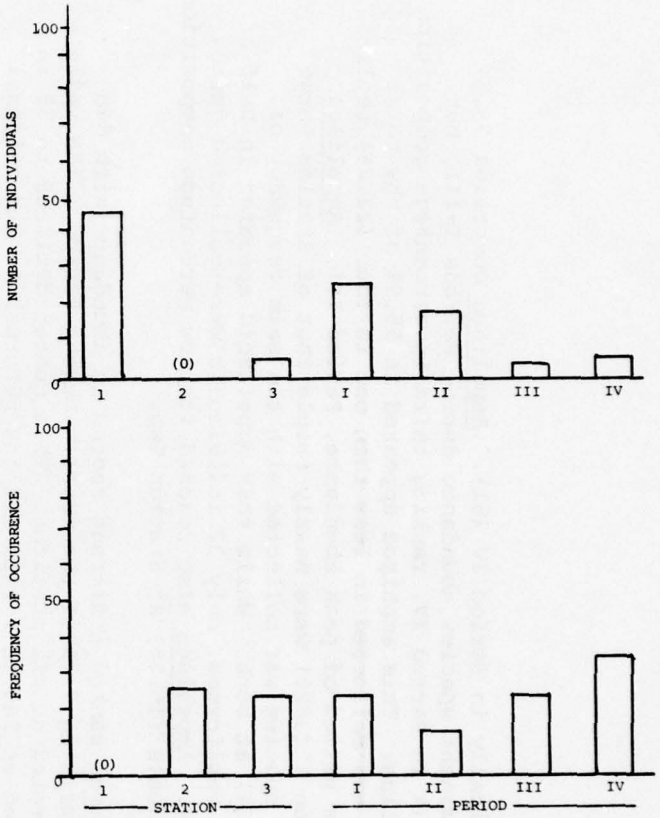


FIGURE 29: Frequency and Abundance Summary for Polydora ligni.

declined dramatically in Period IV (81). Ampelisca comprised 75.5-89.2% of the dominant species abundance during Periods I-III, but declined to 14.1% in Period IV, ranking third in percentage composition behind two annelids. This amphipod appeared in 55.5% of the total replicates, but was collected in less than one in four (22.2%) replicates during its period of peak abundance, Period III. Ampelisca counts at Station 1 (3826) were nearly triple that of Station Three (1345) and this species was collected with the same frequency of occurrence (58.3%) at both. While this ampeliscid appeared in half of the Station Two replicates, only 37 individuals were collected during the entire study. Ampelisca also reached its low percentage composition of total individuals (16.3%) at Station Two.

Exogone lourei ranked a distant second in abundance with 568 individuals comprising 7.7% of the total. During Period I 136 individuals were collected at all stations. This number declined to 55 in Period II, peaked at 242 in Period III and returned to its original abundance (135) in Period IV. E. lourei did not comprise more than 7.9% of the dominant species abundance during Periods I-III, but increased to 23.4% composition in Period IV. This polychaete appeared in 77.8% of the total replicates, ranging from 55.6% in Period II to 100% in Period III. Total individuals collected at Station One (246) was similar to the total for Station Three (251), while Station Two yielded the lowest numbers (71). While the percentage composition of Ampelisca declined dramatically at Station Two, that of E. lourei was greatest (31.3%) at this station.

Peloscolex gabriellae ranked third in abundance with 505 individuals comprising 6.9% of the total. Periods I and II yielded comparatively few individuals, 49 and 5 respectively, while Period III and IV counts were the highest, 230 and 221 respectively. This species did not exceed 6.9% of the dominant species abundance during Periods I-III, but attained the highest percentage composition (38.4%) of the ten dominants in Period IV. This oligochaete appeared in 61.1% of the total replicates, ranging from 22.2% in Period II to 88.9% in Periods III and IV. Total individuals collected at Station Three (397) was more than quadruple that of Station One (92). Only 16 specimens were collected at Station Two. Peloscolex also appeared most frequently at Station Two (41.7% of the replicates). Percentage composition of the dominant species abundance was highest (17.7%) at Station Three.

Sarsiella zostericola ranked a distant fourth in abundance with 271 individuals comprising 3.7% of the total. Number of individuals collected during Periods I, II and IV were similar, 51, 31, and 52

respectively, while peak abundance (137) was achieved in Period III. This ostracod constituted 9% of the dominant species abundance during Period IV, never achieving half that percentage during the first three Periods. Sarsiella appeared in 58.3% of the total replicates. Like Ampelisca, the lowest frequency of occurrence (22.2%) was during peak abundance, Period III. Station Two yielded few (13) individuals, while Station I counts (166) were nearly double those of Station Three (92). Sarsiella appeared in 50% of the Station Two replicates, and in 58.3% and 66.7% of the Station One and Station Three replicates respectively.

Polydora brachycephala ranked fifth in abundance with 155 individuals comprising 2.1% of the total. Total individuals were nearly equal for Period I (61) and Period IV (64), with fewer specimens present during Period II (10) and Period III (20). Maximum percent abundance composition (11.1%) occurred in Period IV. This polychaete appeared in 50% of the total replicates, ranging between 44.4% and 55.6% for each period. Total individuals at Station One (100) was nearly twice that at Station Two (55). No Polydora were collected at Station Three. Frequency of occurrence (91.7) was also highest at Station One. Maximum percent abundance composition (24.2%) occurred at Station Two.

Leptochelia dubia ranked sixth in abundance with 102 individuals comprising 1.4% of the total. Highest number of individuals appeared in Period I (93), only nine specimens were counted in Period III and no Leptochelia were found in Periods II and IV. This tanaid appeared in one-third of the Period I replicates. Ninety-two of the 102 specimens were collected at Station Three, 10 at Station One and none at Station Two. Frequency of occurrence and percent abundance composition were very low at all stations.

Tharyx parvus ranked seventh in abundance with 65 individuals comprising 0.9% of the total. Maximum abundance occurred during Period II (33) and Period III (23). Only nine specimens were collected in Period I and none in Period IV. Frequency of occurrence averaged 22.2% for all periods. Percent abundance composition was never significant. All but nine specimens were collected at Station One where this species appeared in 41.7% of the replicates.

Gemma gemma ranked eighth in abundance with 56 individuals comprising 0.8% of the total. This mollusc appeared exclusively in Period III and Period IV. Forty-four of the 56 specimens were collected in Period III when Gemma appeared in one-third of the replicates. All gem clam specimens were collected at Station Three where they

constituted 2.5% of the abundance composition.

Hesionura sp. A ranked ninth in abundance with 51 individuals comprising 0.7% of the total. No specimens were collected in Periods I and II, 43 were collected in Period III and eight were counted in Period IV. This species did not appear with any significant frequency in any period. Thirty-five individuals were collected at Station Two where Hesionura constituted 15.4% of the abundance composition.

Polydora ligni ranked tenth in abundance with 47 individuals comprising 0.6% of the total. All but five specimens were collected in Periods I and II. Frequency of occurrence was low for all periods, averaging 22.2%. All but three specimens occurred at Station One where this polychaete constituted 1% of the abundance composition.

RESULTS OF THE EPIFAUNAL SURVEY

Epifaunal survey results are tabulated in Appendix D. This survey was designed to augment infaunal data by collecting those organisms that connot be effectively sampled with the infaunal samplers. These included fish and the larger, motile and more widely dispersed invertebrates which are sampled quantitatively by otter trawl or become incidentally enmeshed in the trawl net.

Fish. During the July trawls 177 specimens were collected representing 16 taxa. Specimens of the genus Sebastes were most common (37) appearing in largest numbers in the vicinity of Stations Two (25) and Three (12). Thirty-three specimens of Citharichthys stigmaeus were fairly well distributed among the three stations. Nine of 13 Leptocottus armatus were collected at Station Two. Station Two yielded 104 individuals, Station Three 57 individuals, Station One 16 individuals.

During the August trawls 126 specimens were collected representing 12 taxa. Porichthys notatus was most abundant with 44 specimens, Lepidogobius lepidus specimens numbered 20 and Citharichtys stigmaeus specimens numbered 18. Station Three yielded 70 individuals, Station One 30 individuals and Station Two 26 individuals.

During the November trawls 55 specimens were collected representing 10 taxa. Abundances were much lower than previous trawls. Citharichthys stigmaeus specimens numbered 28, Cymatogaster aggregata 9 and Leptocottus armatus 7. Station One yielded 29 individuals, Station Two 17 individuals and Station Three 9 individuals.

During the April trawls 54 specimens were collected representing 13 taxa in addition to assorted larval fishes and fish eggs. No species appeared in any abundance. Acanthogobius flavimanus specimens numbered 12 and Cymatogaster aggregata specimens numbered 10. Station Two yielded 26 individuals, Station One 17 individuals, Station Three 11 individuals

These data are presented without comment due to the limited abundances recorded and the undetermined relationship between infauna/ invertebrate epifauna and fish species collected.

Invertebrates. July trawls yielded 2989 specimens representing 16 taxa. Only one of these taxa (Macoma sp.) was recorded in infaunal samples. The distribution of individuals is as follows: Crangon nigricauda (2581), Cancer magister (145), Crangon franciscorum (75) and Palaemon macrodactylus (66). Station Two yielded 2224 individuals, Station Three 682 individuals and Station One 83 individuals.

August trawls yielded 1135 specimens representing 13 taxa. None of these taxawere recorded in infaunal samples. The distribution of individuals is as follows: Crangon nigricauda (797), Crangon franciscorum (104), Cancer magister (95). Station Three yielded 571 individuals, Station One yielded 291 individuals, Station Two yielded 273 individuals.

November trawls yielded 602 specimens representing 13 taxa (excluding Polyorchis sp.). One taxa, Synidotea laticauda, was recorded in infaunal samples (4 specimens). Two specimens were collected by trawl. The distribution of individuals is as follows: Crangon nigricauda (243), Nassarius obsoletus (110), Palaemon macrodactylus (115). Station Two yielded 290 individuals, Station One yielded 180 individuals, and Station Three yielded 132 individuals.

April trawls yielded 1030 specimens representing nine taxa (excluding large numbers of specimens identified as Mysidacea). Two of these taxa were recorded in infaunal samples. One Nassarius obsoletus specimen was collected in a benthic infaunal sample at Station Three. The otter trawl collected 82 specimens, 10 in the vicinity of Station Three. Three Synidotea laticauda specimens were also collected at infaunal sample Stations Two and Three. The otter trawl collected eight specimens, five in the vicinity of Station Three. The distribution of invertebrate epifauna is as follows: Crangon nigricauda (396), Crangon franciscorum (285). Station Two yielded 410 individuals, Station One yielded 347 individuals and Station Three yielded 273 individuals.

These trawl data are valuable in expanding our knowledge of the invertebrate communities inhabiting the vicinity of San Pablo Bay Dredge Disposal Site. The invertebrate inventory initiated by the benthic infaunal sampling program has been expanded by 13 epifaunal species. Crangon nigricauda is a major component of the invertebrate epifaunal community during all sampling periods. Crangon franciscorum, Cancer magister and Palaemon macrodactylus also represent significant components.

There appears to be little correlation between total epifaunal abundance and trawl station, but there does appear to be a seasonal trend with maximum abundance (dominated by Crangon nigricauda) in July, reduced abundance in August and a further decline in November. By April, epifaunal abundance was on the increase.

DISCUSSION

The San Pablo Bay disposal site is composed of a moderately diverse assemblage of arthropods, annelids and molluscs found at stations which exhibit a relatively high degree of variation of sediment types. The total population is primarily influenced by a relatively few species with the majority of species containing low numbers of individuals (i.e. <30) over the entire ten month study period. The amphipod Ampelisca milleri was the most abundant species. The polychaete Exogone lourei and the oligochaete Peloscolex gabriellae comprised moderately high populations.

Of the many factors which influence benthic infaunal abundance, distribution and species composition, salinity, sediment characteristics, and species interaction have been established as primary determinants (Brinkhurst et.al., 1968). Seasonal salinity variations have a major effect on species abundance and distribution (Painter, 1966; Filice, 1958), particularly in an area of extensive mixing of fresh and saline water such as San Pablo Bay. Salinity is acknowledged as a major component of that complex of environmental variables which establishes seasonal variation in benthic populations. However, it is deemed unlikely that a significant salinity gradient would exist over the 1000 yds. that separate the extreme stations. Hence, it is assumed that salinity exerts its influence uniformly within the study area, and the following discussion will emphasize sediment and infaunal characteristics where applicable.

Study design and difficulty with physical-chemical sampling

precluded an ideal in-depth study of the complexities of community structure. However, analysis of benthic infaunal data made possible a general description of specific and population dynamics, both spacially and temporarily, to give a general account of the major constituents of the seral community.

SPACIAL CHARACTERISTICS OF THE INFAUNA

Sampling Station One. This station was characterized by the most heterogeneous sediment type ranging from clayey-silt to fine sand with patches of coarser sand. A major physical and biological feature was characterized by the isolated beds of Ampelisca milleri. Communities dominated by Ampelisca have been described as exhibiting dynamic instability resulting from the modification of sediment by the amphipod and the need to move from areas of physical instability (Mills, 1969). Ampelisca is largely a selective deposit feeder which puts fine organic material and sand grains into suspension by the rotary beating action of the second antennae (Enequist, 1960; Mills, 1967). The effect of feeding is to increase the proportion of fine particles about the tubes. The decrease in median grain size associated with aggregations of Ampelisca has been shown to cause instability, that is, susceptability to washing out (Mills, 1969). Masses of Ampelisca tubes create microhabitats for many other small organisms and a positively correlated faunal association has been established between A. milleri and the ostracod Sarsiella zostericola in the present study. While the amphipod was numerically dominant at Station One, nine other arthropod species were present as were seven species of molluscs and 19 species of annelids. Assorted ectoprocts were present during Period I and two Molgula manhattensis specimens were collected in Period III. This station also comprised the most species for the study period. Species diversity was lowest, due primarily to the high Ampelisca numbers. Species similarity compared to Station Two more closely than to Station Three.

Sampling Station Two. The station was characterized by fine to medium sand with some clayey-silt. Exogone lourei constituted the greatest abundance and frequency of occurrence of all species over the study period with Polydora brachycephala and Hesionura sp. A comprising other major components. Hesionura sp. A has been found commonly in sand in San Francisco Bay and its increase in abundance during the November sampling period correlates with relative abundance fluctuations of the species at the Alcatraz dredge disposal site. At that location in September 1973 the "population explosion" was almost entirely the result of Hesionura (USACE, Maint. Dredging 1975). This station exhibited the lowest numbers of individuals and species for the entire study period. It compared with Station Three

in relative species diversity but contrasted to that station in species similarity.

Sampling Station Three. This station was characterized by loose to plastic muds of clayey-silts and silty-clays. Organic filamentous masses, apparently from the fauna (biological staining observations), were commonly found in the retained sediments. It is suggested that such filament masses could provide habitat in the form of shelter and anchor sites for benthic infauna and epifauna. This station was dominated numerically by Ampelisca milleri (60%) with Peloscolex gabriellae (18%) and Exogone lourei (11.2%) comprising secondary abundance compositions. However, Peloscolex exhibited a higher frequency of occurrence (83%) than Ampelisca (58%). Nichols (1970) has concluded that the finer sediments are conducive to organism growth due to the presence of greater nutrient supplies. In the present study it is noted that the total abundance is greatest in Period IV at Station Three where the effect of Ampelisca milleri associated sediment from other stations would not affect numbers of individuals of other species. Hence, an apparent association of abundance with median grain size is indicated. Also, it is noted that the highest percentage species composition occurred during this time. Station Three had a relatively high species diversity that compared with Station Two, but only moderately low species similarity comparisons with Station One and Two.

TEMPORAL CHARACTERISTICS OF INFAUNA

Station One

Between July and August 1977 species diversity decreased significantly, abundance increased greatly, and number of species increased slightly. The increase in relative abundance of a few species is reflected in a sharp reduction in species evenness. Species similarily (0.83) is quite high indicating a shift in abundance of a few species but little change in species composition. Ampelisca milleri was the primary cause of the shift, increasing from 3 individuals in July to 1252 individuals in August. Sarsiella zostericola and Exogone lourei also increased markedly. The Ampelisca increase probably reflects sampling variations in view of the discontinuous distribution of amphipod beds. The correlation between Ampelisca and Sarsiella has already been cited.

Between August and November species diversity began an upward trend which coincided with a dramatic increase in both number of

species and number of individuals. The moderate rise in species evenness indicates that the increased number of individuals was tending to be distributed uniformly among the increased number of species. The similarity quotient (0.44) indicates a shift in species composition. Exogone lourei abundance increased from 35 to 207, Ampelisca milleri abundance increased from 1252 to 2569, and Sarsiella zostericola increased from 26 to 137. Once again an examination of field and retained sample notes indicates considerable variation in sediment composition. The December core particle size analysis indicates a dramatic increase in % sand (from 10% to 38%). Considering the heterogeneity of Station One sediments this shift may well be due to sampling variation. However, some thought must be given to the increased sand content at Station Two.

Between November and April species diversity continued to increase to a peak value in response to a marked decline in both numbers of species and numbers of individuals. Species evenness increased as well indicating that a few of the missing species had comprised a disproportionate share of the total abundance. (i.e. Exogone declined from 207 to two, Tharyx parvus declined from 22 to zero, Peloscolex declined from 82 to four, Ampelisca milleri declined from 2569 to two, and Sarsiella declined from 137 to two). The level of species similarity (QS) was the same.

Station Two

Between July and August 1977 species diversity increased dramatically in conjunction with a moderate increase in species and a small decline in individuals. That individuals had become more uniformly distributed among the species present is indicated by a jump in evenness. Station Two lost one oligochaete species but gained three species of polychaetes and two species of arthropods - all in very low numbers. Species composition was moderately similar (QS = 0.56).

Between August and November 1977 species diversity remained constant while total number of species declined. Individuals increased slightly and were uniformly distributed among species as indicated by a second increase in species evenness. This station lost one species of polychaete and 4 arthropod species. Species similarity (0.42) between these periods indicated a moderate shift in species composition.

Between November 1977 and April 1978 species diversity increased slightly to a peak while number of species increased and abundance remained constant. Evenness declined slightly. Three polychaete species were replaced by four arthropods and one mollusc. Species similarity (0.53) was greater than between November and August sampling periods.

Station Three

Between July and August species diversity increased dramatically as both number of individuals and number of species declined dramatically. The elimination of some species with high numbers is illustrated by a significant increase in evenness. Additional species of low abundance did not reappear including seven annelid species, six arthropod species and two mollusc species. Ampelisca declined from 1298 to two individuals.

Between August and November species diversity declined significantly as both number of species and of individuals increased moderately. Two species appear in sufficient numbers to upset evenness. Gemma gemma was first introduced (44 specimens), and Peloscolex abundance increased from 49 to 138. Two additional annelid species were added (Streblospio benedicti, 3 specimens; Tharyx parvus, 1 specimen).

During the period between August and December the silt component increased (based on single cores) and median grain size tripled from 6μ to 17μ. A change in sediment characteristics is further demonstrated by a shift in field description of samples from a plastic silty-clay grey mud to a very loose clayey silt.

The sudden appearance of Gemma gemma is a possible sign of deposition of sediments from shallow waters. Nichols (1977) cites high population levels in shallow mudflats of the South Bay. Painter (1966) found the gem clam to be most numerous in shallow water for which it showed a preference. Specimens were abundant on clay and silt-clay bottom. The preponderance of literature documents the shallow water preference, but presence in deeper water has also been recorded. While McCarty (1962) found G. gemma to constitute at least 10% of the population during 12 of 24 shallow station cruises, this species was recorded during two of thirty deep station cruises and in October represented 10% of the population at channel Station 5 which most closely approximates the study area. In addition, this mollusc was found only at Station Three, where sediments were finest.

Between November 1977 and April 1978 species diversity increased markedly as both number of species and number of individuals increased. Much of the increase in individuals can be attributed to increases in abundance of four species (Peloscolex gabriellae, Exogoni lourei, Sarsiella zostericola and Ampelisca milleri). Three other arthropods

were added in small numbers as was one annelid and four molluscs.

By Period IV the sediments had regained their plastic consistency although a layer of gravel appeared in one replicate.

TEMPORAL COMPARISONS WITH OTHER STUDIES

Numerical Abundance. Figure 30 presents a comparison of temporal fluctuations in abundance during the present investigation, with those during a 1962 to 1963 study of San Francisco Bay (Storrs, 1964), and during the 1960-61 investigation of San Pablo Bay by McCarty (1962). The 1962-63 figures are derived from a single sampling site (Station Five) which is situated northeast of the current study area in the main channel. Data extracted from McCarty represents a composite of all nine sampling stations, both deep and shallow.

There is a distinct similarity in "seasonal" trends, i.e. a decline in abundance during late Spring and early Summer, an upswing in late Summer or early Fall to peak abundance in November and a repetition of the Spring decline. Fluctuation characteristics will vary with the year, the sampling technique, and the sampling location. The composite data display a highly modified, but still recognizable, correlation in abundance between the current study period and two other infaunal surveys in the vicinity of the San Pablo Bay dredge disposal site over a period of 17 years.

Number of Species. Figure 31 illustrates a comparison of fluctuations in total number of species during the three investigations cited in the preceding section. Once again the fluctuation characteristics vary with the year, the sampling technique, the sampling location and the influence of other variables. Variations in the number of species determined in the current investigation do not correlate with those of the cited previous studies. Examination of the current data reveals that no less than six species of annelids, four species of arthropods, and five species of molluscs are added to the Period III (November) faunal inventory. With the exception of one mollusc none of the additions are represented in any abundance. In contrast to the present study McCarty cites a very low number of annelid species and a predominance of molluscs. Hence it remains a possibility that during the present study species were being introduced from other benthic communities.

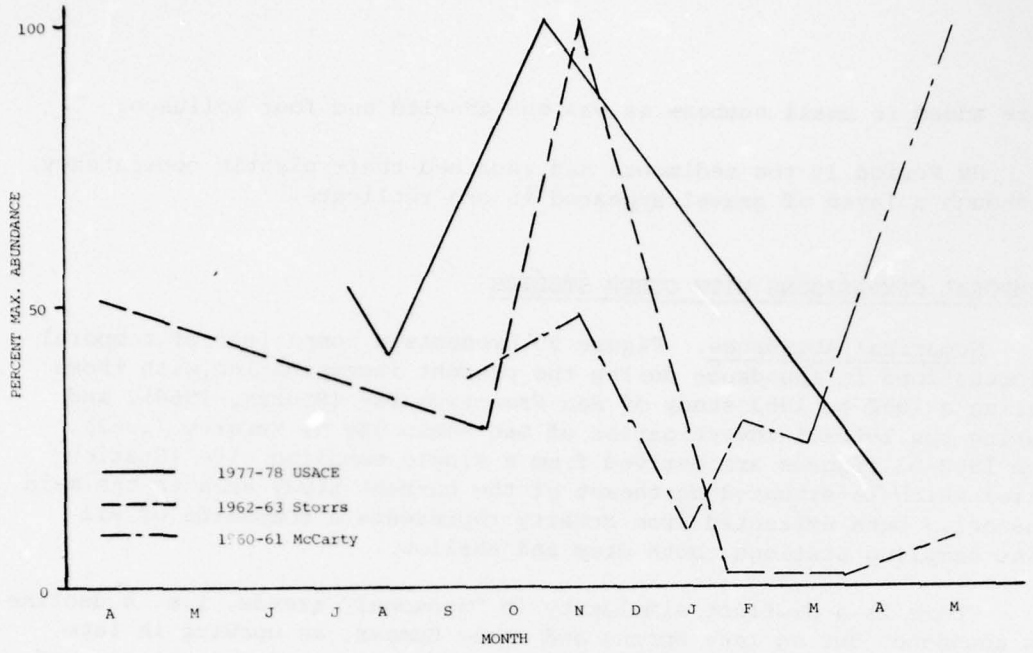


FIGURE 30: ABUNDANCE COMPARISONS WITH OTHER STUDIES

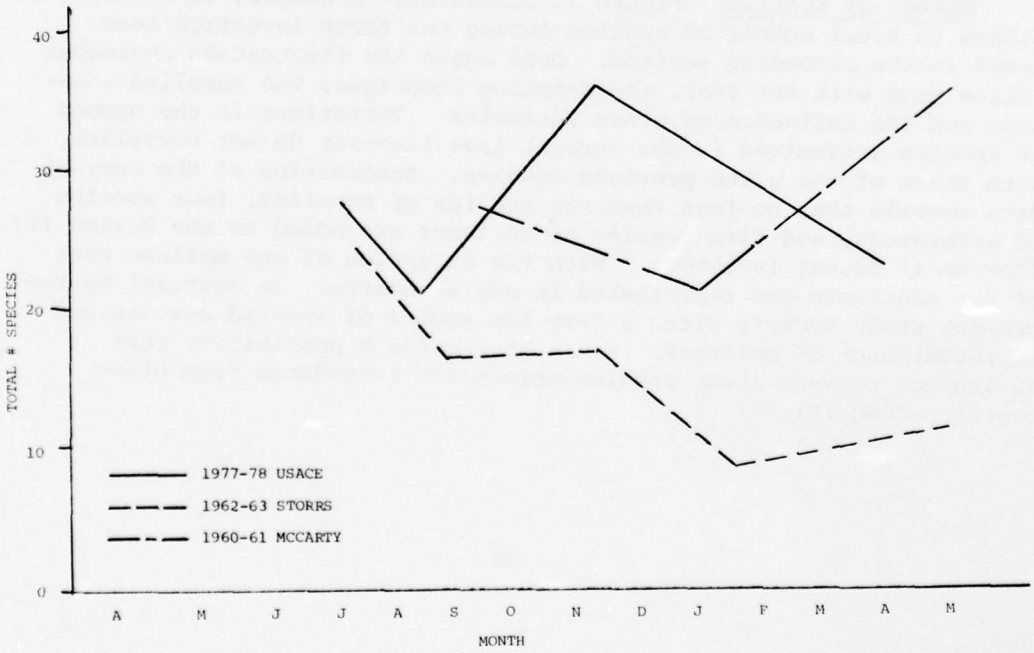


FIGURE 31: SPECIES COMPARISONS WITH OTHER STUDIES

FAUNAL ASSOCIATIONS/SPECIES NOTES

Intermittently, throughout the first three sampling periods the hydroid Operculariella sp. was observed perforating abandoned tubes of the amphipod Ampelisca milleri. In a few instances the hydroid utilized annelid tubes. At no time was the hydroid found in a tube still occupied by the amphipod.

Cursory examination of the tabulated data revealed a significant positive correlation between the temporal fluctuations in abundance of the ostracod Sarsiella zostericola and the amphipod Ampelisca milleri. Kornicker (1977) describes Sarsiella zostericola as a predator. It is suggested that this correlation is due to the relative available "food supply" that is offered by the sediment modification of Ampelisca. Mills (1969) describes the increased abundance of small infaunal polychaetes in the food rich recesses between the flattened, parchment-like tubes of Ampelisca abdita.

Three Molgula manhattensis specimens were collected at Station Three during Period I. Two small commensal copepods of the Family Notodelphyidae were found in one M. manhattensis specimen. A single larger commensal copepod was dissected from the pharynx of a single M. manhattensis collected at Station Two during Period II. Illg (1958) describes such a commensal relationship between tunicates and both copepods and amphipods as common. The tunicate host has been introduced from the Atlantic coast where it occupies brackish waters.

The hesionid ?Heteropodarke heteromorpha Hartman-Schroeder, 1962 collected in this study is described as a new introduction to Northern California waters (UBR, 1978). A positive correlation in abundance was demonstrated with the phyllodocid Hesionura sp.A. Since Hesionura has been reported to be quite numerous in other sandy locations in San Francisco Bay'(USACE Maint. Dredge, 1975) it is suggested that ?H. heteromorpha will soon be a common occurrence here.

The presence of the oligochaete Peloscolex gabriellae has been shown to correlate with high organic pollution levels in shallow sediments (Brinkhurst et.al., 1968).

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APPENDIX A

EVALUATION

OF THE

BIOLOGICAL SAMPLING PROCEDURE

EVALUATION OF THE BIOLOGICAL SAMPLING PROCEDURE

THE SAMPLER

The coffee can sampler (= corer) is comprised of two interacting elements, the sampling container and the diver. While these two elements function as a single mechanism, they are treated separately due to their very different impact upon the sampling process.

The sampler is a standard 1.4 kilogram (3 pound) coffee can with one end removed and the other perforated to allow passage of water as it is pushed into the sediment. The maximum core length is 17 cm and maximum sample volume is 3.0 liters. Sample surface area is 0.018 m^2.

Oliver and Slattery (1976) used the same sampler to assess the effects of dredging and dredge disposal on some marine benthos in the fine sand sediments of Monterey Bay. They cite a comparative study of the performance of the coffee can corer, a diver-operated suction dredge, and a Smith-McIntyre grab at Moss Landing. Results indicated that all three techniques produced similar estimates of numbers of species and numbers of individuals per unit area and one index of species diversity. The report acknowledges the significant effect of small sampler surface area on estimates of the total number of species in the community and the larger, less common organisms.

During the preliminary phase of the San Francisco Bay Benthic Community Study (Liu, et.al./USACE Appendix D, 1975) of the Army Corps of Engineers Dredge Disposal Study, the performance of a 0.12m^2 modified Petersen grab was compared with that of a diver operated core sampler. Sampler length was nearly twice that of the coffee can sampler, while surface area sampled was less than half as great (75 cm^2). Results indicated that the greater area and sampling capacity of the Petersen sampler yields more specimens and taxa of benthic animals per sample. Both samplers collected approximately the same number of specimens per liter with less variation using the Petersen sampler. Data also indicated that the two samplers were about equal in sampling. Investigators concluded that the core sampler did offer the possibility of obtaining more uniform sample size and more quantitative biological data.

A benthic survey of Oakland Outer Harbor (Leighton and Associates, 1976) utilized PVC pipe corers of dimensions nearly identical to the corer evaluated in the Benthic Community Study. The contents of two corers were combined to constitute one replicate with a maximum volume of 4.4 liters and surface area of 0.015 m^2. In evaluating sampling procedure, the sampler length of 29.5 cm was judged excessive in view of other investigations (Hodgson and Nybakken, 1973, Environmental Quality Analysts and Marine Biological Consultants, 1975, Oliver and Slattery, 1976) which concluded that collecting sediments to a depth of 10 cm will adequately sample the bulk of the infauna.

Anderlini (1975) collected benthic samples in and around Mare Island Strait as one phase of a more comprehensive effort to define and quantify infaunal uptake of pollutants released during dredging. He used two diver-operated PVC corers to collect samples, a large corer (10.2 cm dia. x 30 cm length) to sample Macoma balthica (Mollusca) and Neanthes succinea (Polychaeta), and a small corer (7.6 cm dia. x 12 cm length) to sample Ampelisca milleri. He selected the PVC corer over the 0.05 m^2 Van Veen grab used to collect pre-survey samples because the corer permitted (1) uniform substrate penetration, (2) increased numbers of random samples of uniform volume and surface area, and (3) reduction of sediment volumes to be processed.

THE DIVER

The coffee can sampler was transported to the bottom by a diver who then moved from his point of impact to an undisturbed area and collected the sample as described in the body of the report.

In comparing samplers prior to the Benthic Community Study, the corer was ultimately rejected primarily due to problems related to the diver, i.e., concern for diver safety, extended time (and expense) required to collect core samples, and disturbance of sediments by diver movements.

Leighton and Associates acknowledged limitations of depth and expense, further discussing the effect of unstable water conditions and emphasizing the training and experience of the diver both in black water and with the sampling device as critical to sampling effectiveness. This investigation considered diver disturbance of sediments as minimal (under stable water conditions) as opposed to the flushing action of the pressure wave which precedes the remote sampler as it approaches the bottom. Further advantages of the diver operated corer were more consistent application of the sampler

to the sediment and additional visual information about the habitat being sampled. While diver sampling in San Francisco Bay is usually affected during zero visibility, diver observations during the Oakland Outer Harbor survey provided a more realistic estimate of sea pen (Phylum Cnidaria, Order Pennatulacea) abundance. In the course of the current investigation, a UBR diver accompanied Corps of Engineers divers during a sampling dive at Station No. 1. Visibility ranged from 2 - 3 feet and permitted divers to observe the heterogeneous sediment pattern reflected in station faunal counts and onboard sample observation (i.e., patches of sand interspersed among beds of Ampelisca tubes).

Oliver and Slattery considered careful placement of the corer by the diver as minimizing bottom disturbance (in fine sand) and cited the ability to adjust depth of core penetration, to place samplers for optimum replication, and precise control of the area sampled as further advantages of the diver operated coffee can corer. However, most of the advantages would doubtless be mitigated by typical San Francisco Bay diving conditions, i.e., frequent unstable water conditions, zero visibility and fine, soft sediments.

NUMBER OF REPLICATES

Study design (USACE) specified the number of replicate samples (3) to be taken at each station at the San Pablo Bay Dredge Disposal Site and that only a general description of the benthic infaunal seral community be presented. As always, however, the number of replicates collected at each sampling station is a compromise between ideal project objectives and the limitations of time and expense.

Oliver and Slattery investigated the relationship between the number of replicates and selected benthic infaunal parameters using the coffee can corer in fine sand sediments. They found that: (1) 4 cores collected 57% of the species in 28 cores and that 8 and 16 replicates collected 76% and 92% of the species respectively; (2) the average number of species per core varied little with increased number of cores; (3) 95% confidence limits for the mean number of individuals decreased sharply from 4 to 8 cores for most of the common species; and (4) species diversity (Shannon and Weaver) and species evenness (Pielou) appeared to stabilize between 4 and 8 cores. They concluded that 8 replicates were sufficient to estimate most of the benthic infaunal parameters.

Hodgson and Nybakken (1973) concluded that six replicates were adequate to sample dominant species in coastal marine sediments of Monterey Bay using the Smith-McIntyre grab (0.1 m^2).

Environmental Quality Analysts and Marine Biological Consultants (1975) collected 36 Ponar grab samples at 12 stations near Oakland Outer Harbor. Uniformly soft sediments and selected statistical analyses prompted the conclusion that three replicates per station (average volume 5.9 liters, sampling area 0.05 m^2) were adequate to sample major components of the infauna.

During the preliminary phase of the Benthic Community Study, five replicates were collected at each of two sampling stations in order to compare the performance of the modified Petersen grab and the diver operated corer. Each core was found to contain an average of 34.2 and 31.8% of the total taxa collected at each station, while each grab sampler contained an average of 50.4 and 38% respectively. During the definitive phase the modified Petersen grab was used to collect three replicates at each station.

Leighton and Associates collected three core samples (sampling area 0.015 m^2) at each of six stations in the vicinity of Oakland Outer Harbor, concluding that unstable or heterogeneous sediments at most stations required additional replicates to accurately characterize the infauna.

SUMMARY AND CONCLUSIONS

(1) The small sampling surface area (0.018 m^2) and volume (3.0 liters) of the coffee can corer: (a) precludes accurate estimates of larger, less common organisms, and (b) underestimates the total number of species in the benthic community when too few replicates are collected at each sampling station. The number of replicates required to adequately describe selected parameters of the infauna varies with sediment type and areal homogeneity. In view of sampler dimensions, instances of sediment heterogeneity (diver observations and sample descriptions), and evaluation of this and similar samples in previous studies, the three replicates collected at each San Pablo Bay station are deemed adequate to estimate abundance of numerically dominant taxa only.

(2) The coffee can corer offers the possibility of collecting more uniform samples (all data from the current investigation are based upon maximum sampler volumes) and more quantitative biological data.

(3) The coffee can corer consistently penetrates to depths adequate to sample the bulk of the infauna without collecting excessive deeper sediments and incurring unnecessary analysis expense.

(4) Use of the diver operated coffee can corer introduces the elements of diver safety, extended collecting time (and expense), and the possibility of diver disturbance of the sediments. The first two factors must be evaluated in terms of sampling area and objectives. The probability of disturbance will vary with sediment type and water conditions. Under proper conditions this factor may have less impact than the flushing action of the pressure wave that precedes the remote sampler. Unstable water conditions such as surge and tidal currents may quite possibly result in diver disturbance (in fact, they may preclude any sampling by divers), although such conditions are likely to affect remote sampler efficiency and consistency as well.

(5) Diver training and experience with the sampling device under a wide range of diving conditions is perhaps the most critical factor in determining sampling efficiency.

(6) During those rare occasions when the lower depths of the San Francisco Bay water column offers some degree of visibility, the presence of the diver during the sampling operation adds a visual dimension which is valuable in evaluating the sampling technique and qualifying sampling results.

APPENDIX B

DIVER OBSERVATIONS DURING INSPECTION

OF

DIFFUSER PIPE AND DISPOSAL SITE

SAN PABLO BAY DREDGE DIFFUSER PIPE

JULY 1977

DIVERS' OBSERVATIONS

(George Perry)
USACE

On 27 July 1977, divers Ard, Perry and Bruch made an inspection of the Petaluma Creek across-the-flats channel dredge disposal diffuser pipe.

The diffuser outlet pipe consists of a 16" diameter, 10' long pipe with 4" diameter openings. These openings are spaced on 18" centers on the longitudal axis, with five openings spaced equally about the circumference.

The diffuser pipe is held off the bottom by two slings that are attached to a well-anchored stationary barge. The 18' x 25' barge carries a deck-mounted, double-drum winch, which is used for setting and pulling anchors. The downstream end of the diffuser pipe extends 8' beyond the holding sling, at 18' below the surface. The other end of the barge holds the pipe at 25' below the surface. (See accompanying sketch.)

The diffuser seems to be working as planned, with disposal material exhausting out of each 4" opening. The diffuser would probably work much better if it was 30' long instead of its present 10' as only 10% - 20% of the material is exhausting out of the openings. If the diffuser was longer, more material would subsequently be diffused by the increased number of openings.

SAN PABLO BAY DISPOSAL SITE

October 1977

DIVERS' OBSERVATIONS
(George Perry)

While diving for infauna samples at stations 1, 2, and 3 it was noticed that the visibility to one meter ± above the bottom was zero during flood and ebb tides. This was very noticeable to a diver while he was descending on the anchor line to the bottom.

The visibility would gradually decrease to about one foot and then at ± one-meter from the bottom the visibility would abruptly become zero. At slack tide visibility would increase from zero to about 1-0' on the bottom. As soon as the tidal movement started the divers could see the material starting to be transported thru the lower water column until visibility again decreased to zero.

At the dredge disposal diffuser pipe the visibility was zero from about 3. meters below the surface to the bottom. This situation existed while dredging or not and existed when last observed 72 hrs. after the dredging was completed. This was true during tidal movement and even during periods of slack tide

BOTTOM CHARACTERISTICS

The bottom at the three infauna sampling stations is different than that found in other areas of the bay. Instead of being all sand or all clay or silt it has alternating patches of clays, silts and sand. These patches vary in size from 2-meter square to 5-meter square. The changes in material are abrupt with very little overlapping of materials. The silts and clays are soft; the sand is fine grained and loose.

Seventy-two hours after completion of dredging a dive was made at the disposal site directly under the outfall end of the dredge disposal pipe. The bottom here was covered with dredged material consisting of silts, clays, sands and many broken shells. This material was in excess of six feet deep and very loose as was found by probing with a six-foot length of plastic pipe. The area covered is in excess of 200 feet in diameter. This was found by the divers making a circle on the end of a 100-foot long length of rope with the center of the circle directly under the end of the outfall pipe.

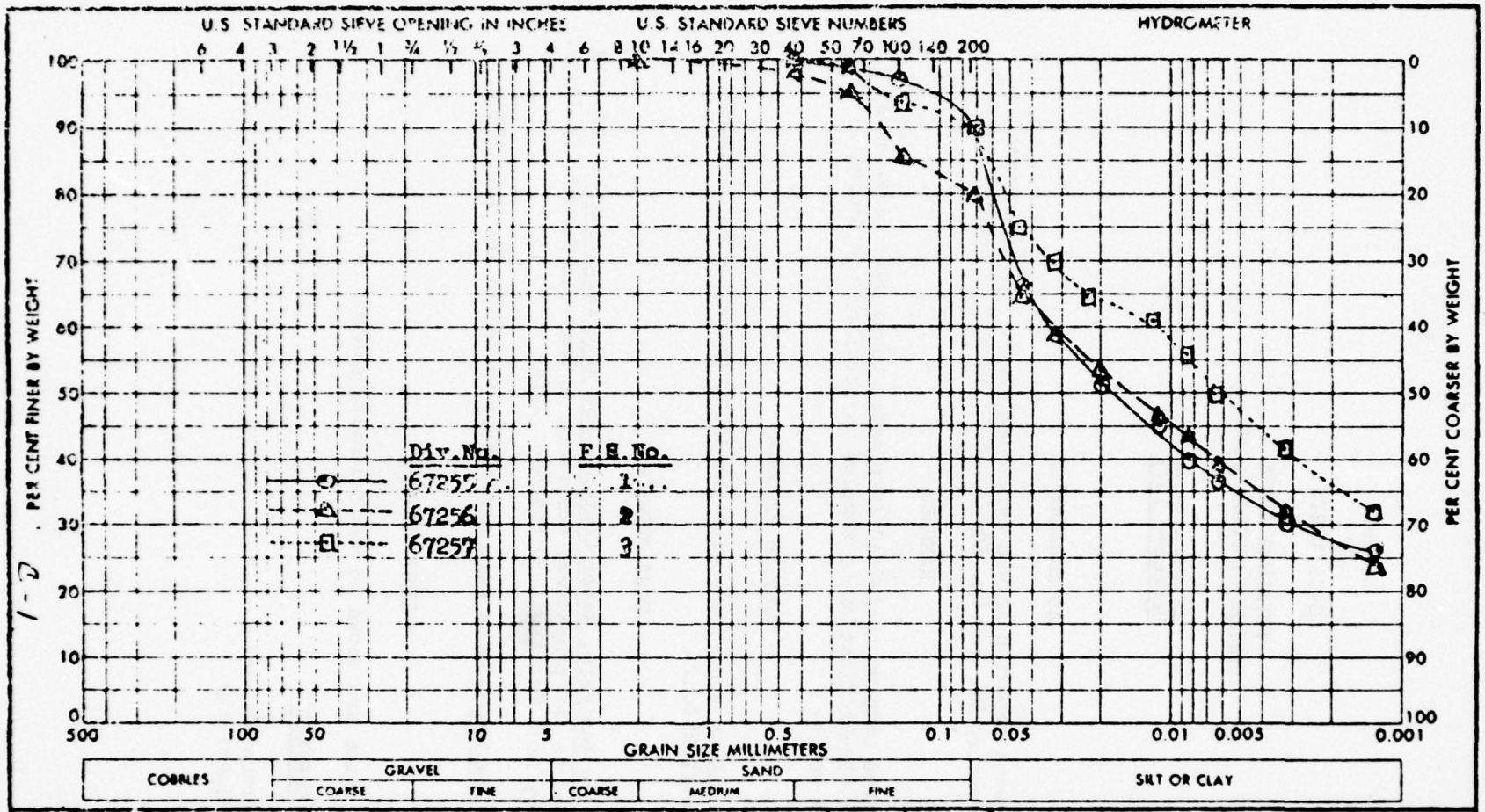
The only animal life found on this newly deposited material by visual inspection were small crabs from 1/2-inch to 1-1/2 inches in diameter. As there is zero visibility on the bottom here a strong underwater diver's light was used for inspection. The light would only penetrate approximately 6 inches but when the light was turned on the crabs that could see the light were attracted and would come to the light source.

APPENDIX C

ANALYSIS OF SEDIMENTS

AND

DISPOSAL SITE WATER



SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
67255		Clay(CH)	88.0	74	27	47
67256		Sandy Clay(CH)	89.2	66	25	41
67257		Clay(CH)	129.3	79	29	50

GRADATION CURVES

PROJECT PETALUMA CREEK
Dredge Disposal Site
AREA
BORING NO
DATE July 1977

1-2

ENG FORM 2087
1 MAY 63

REPLACES WES FORM NO 1241, SEP 1962, WHICH IS OBSOLETE.

REPORT
OF
SOIL TESTS

PETALUMA CREEK
DREDGE DISPOSAL SITE

December 1977

AUTHORIZATION

1. Results of tests reported herein were requested by the San Francisco District in Laboratory Request No. E86-78-3016, dated 2 December 1977.

SAMPLES

2. Six undisturbed samples contained in plastic tubes were received on 7 December 1977. Identification of samples is shown on the Gradation Curves, Plates 1 and 2.

TESTING PROGRAM

3. The program was in accordance with the test request which included laboratory classification.

TEST METHODS

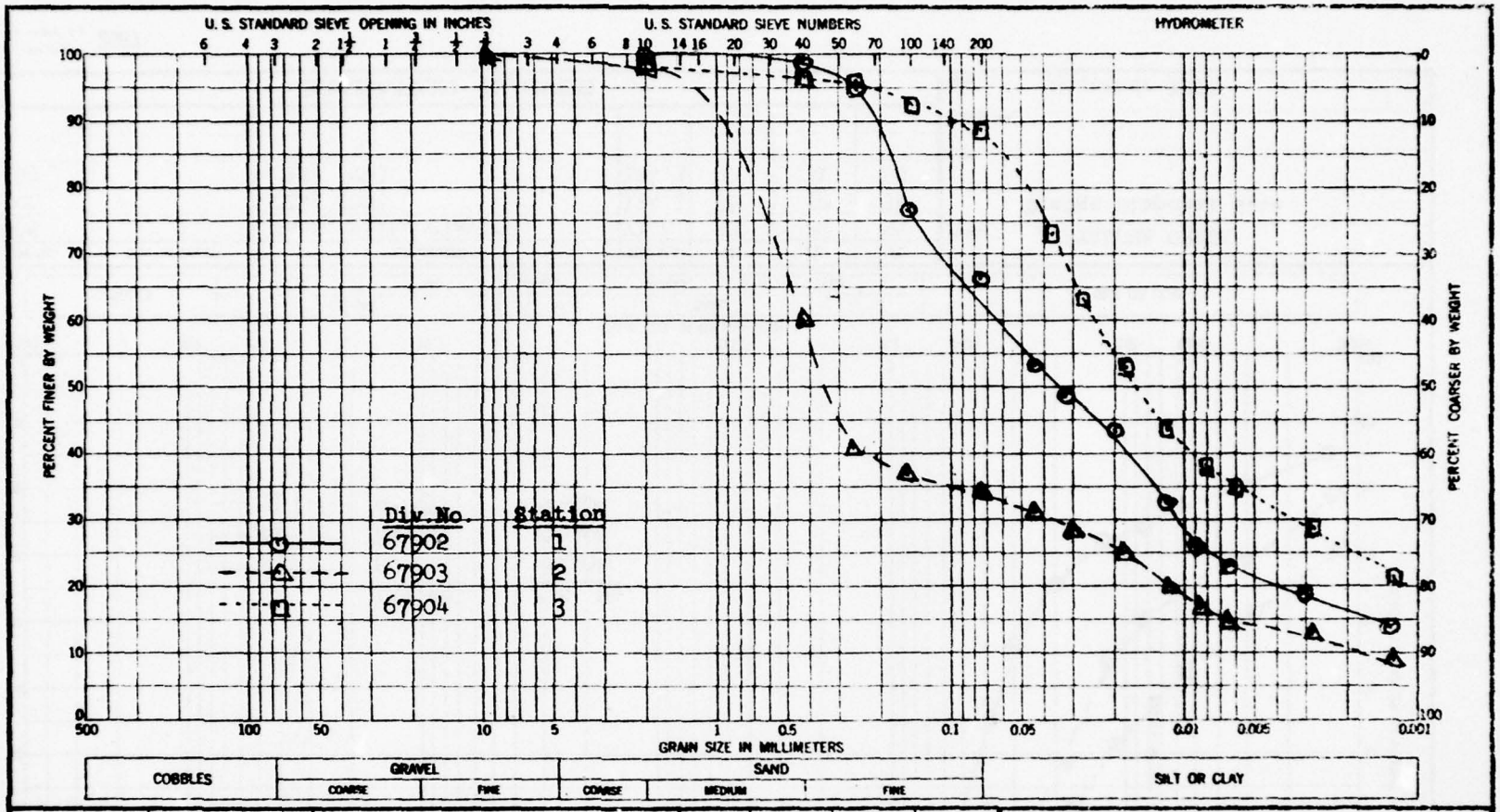
4. a. Grain-size Analysis, Water Content, and Atterberg Limits. Testing methods conformed to the procedures described in Engineer Manual, EM-1110-2-1906, "Laboratory Soil Testing", 30 November 1970.

b. Classification. Soils were classified in accordance with MIL-STD-619B.

TEST RESULTS

5. Results of tests are shown on the following plates:

SUBJECT	PLATE NO.
Gradation	1-2
Plasticity	3



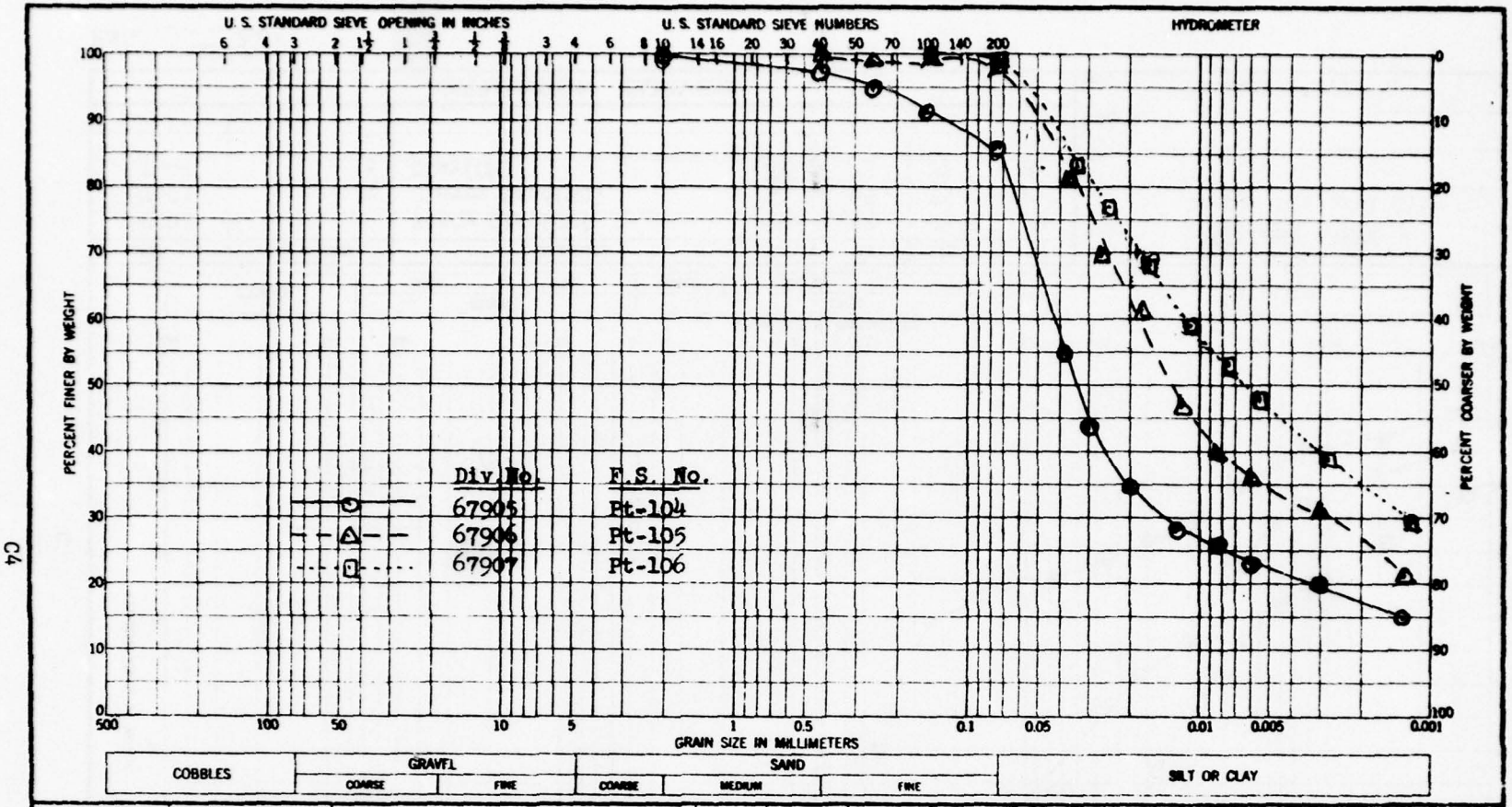
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
67902		Sandy Clay(CH)	83.6	52	22	35
67903		Clayey Sand(SC)	52.0	65	25	40
67904		Clay(CH)	105.8	73	27	46

GRADATION CURVES

Project: PETALUMA CREEK
Dredge Disposal Site
Area:
Boring No.:
Date: December 1977

C3

ENG FORM 1 MAY 65 2087



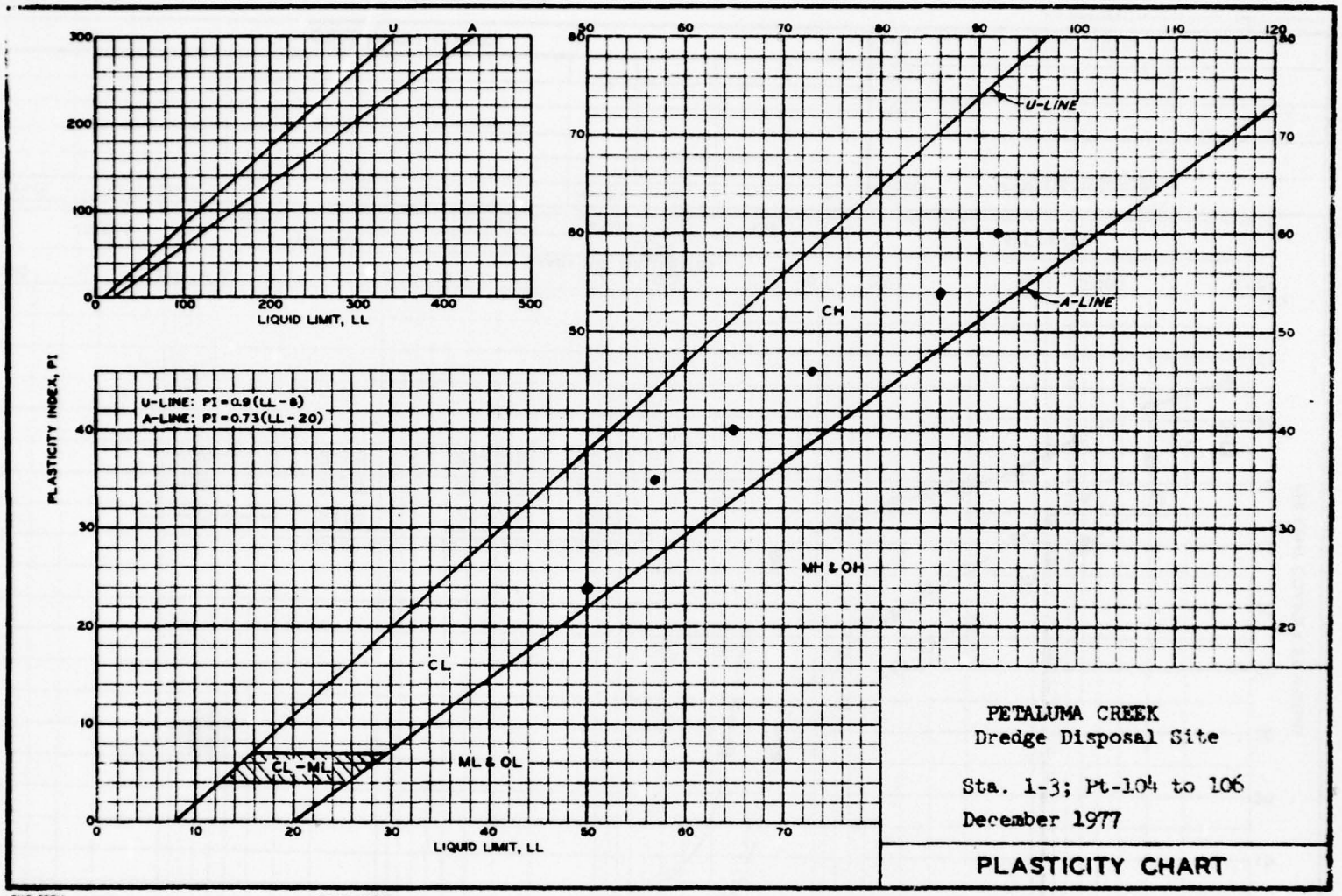
C4

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
67905		Sandy Silty Clay(CH)	71.8	50	26	24
67906		Clay (CH)	134.1	86	32	54
67907		Clay (CH)	124.3	92	31	60

GRADATION CURVES

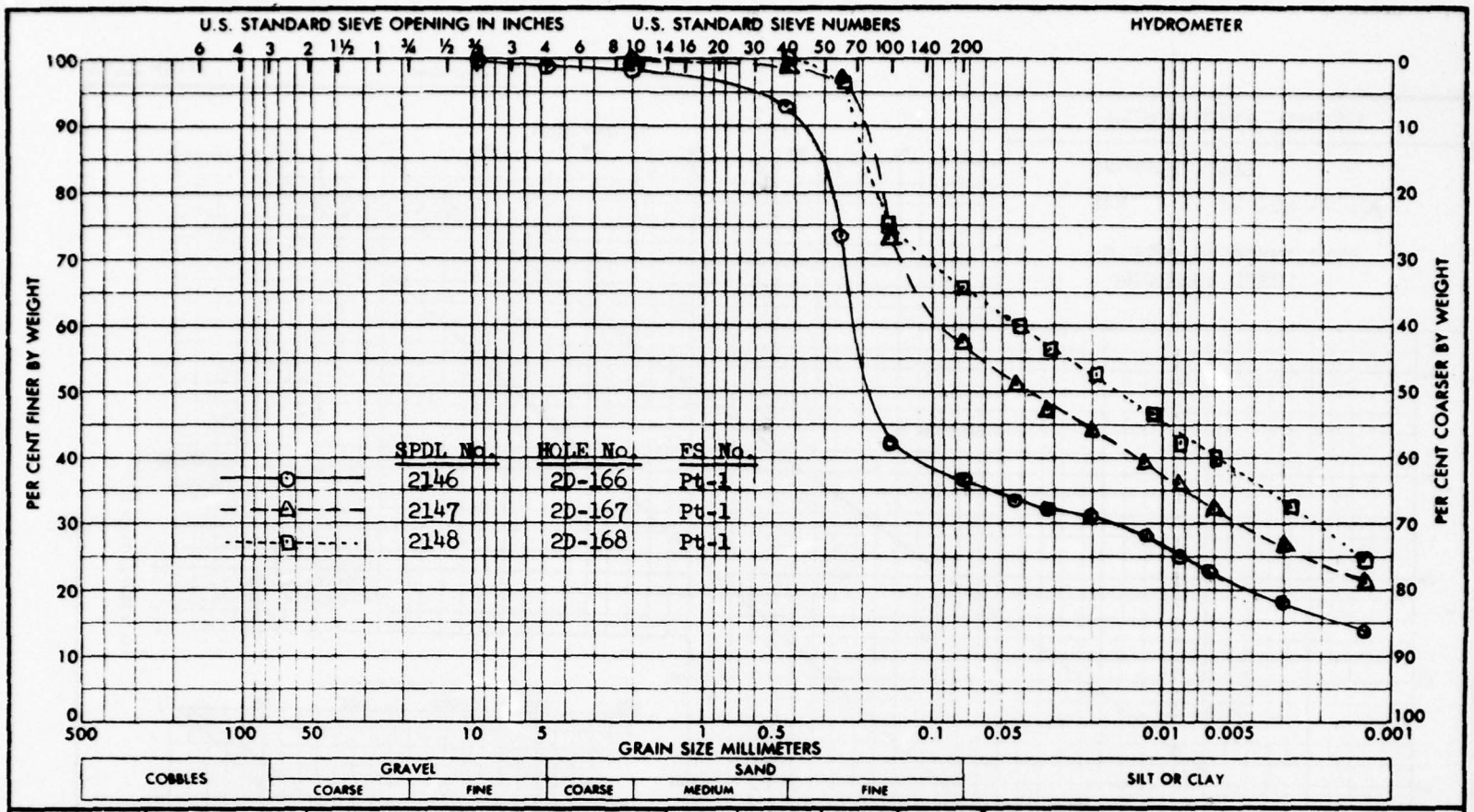
Project: PETALUMA CREEK
Dredge Disposal Site
Area:
Boring No.:
Date: December 1977

ENG FORM 1 MAY 63 2087



ENG FORM 4334
JUNE 1970

TRANSLUCENT



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

PROJECT: PINCLE SHOALS

AREA:

BORING NO.:

DATE: May 1975

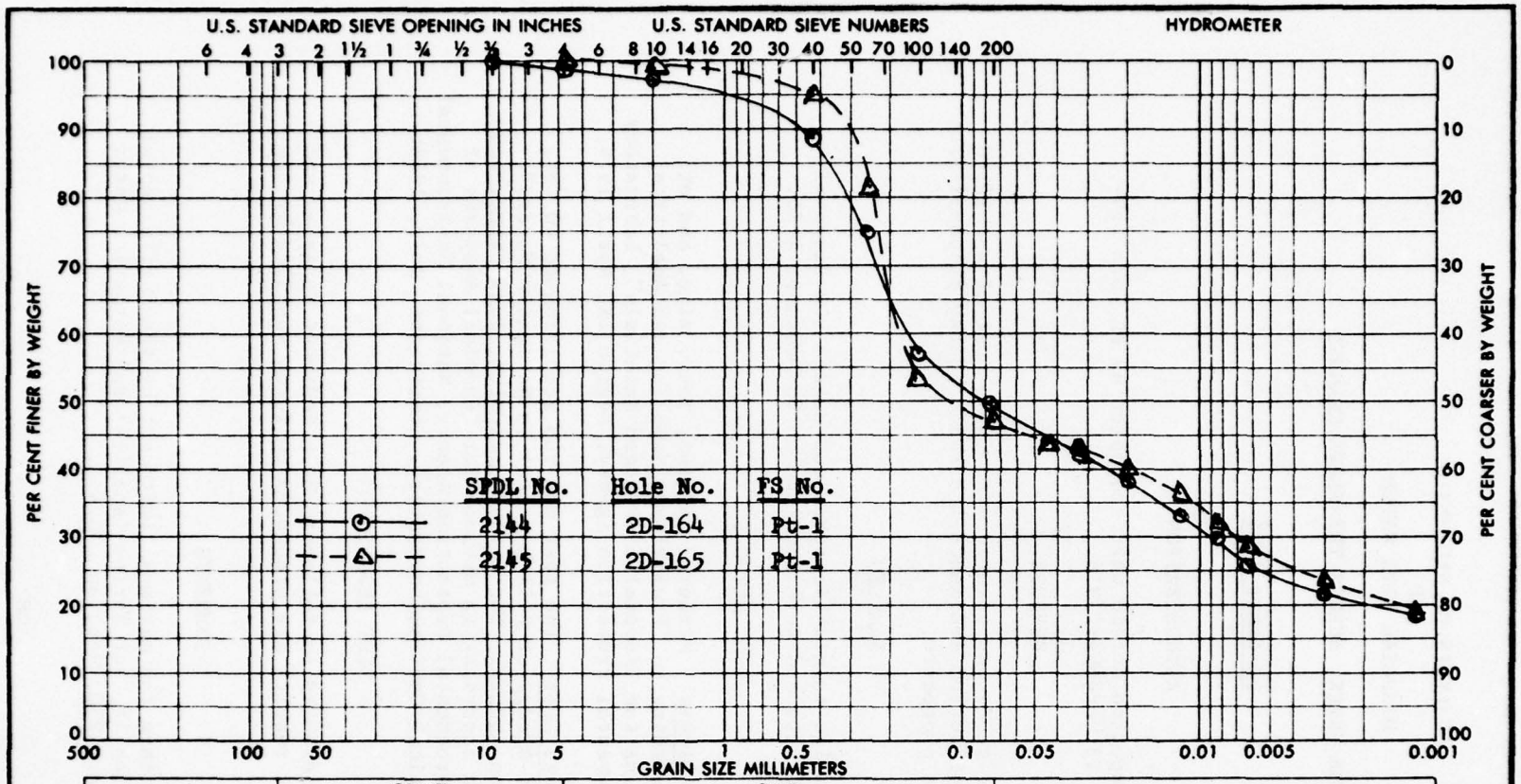
GRADATION CURVES

ENG FORM 2087
1 MAY 63

REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE.

U.S. GOVERNMENT PRINTING OFFICE 1963 OF—709-128

C6



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

GRADATION CURVES

PROJECT PINOLE SHOALS

AREA

BORING NO.

DATE May 1975

C7

ENG FORM 2087
1 MAY 63

REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE. *(TRANSLUCENT)*

U.S. GOVERNMENT PRINTING OFFICE : 1963 OF—709-126

ANALYSIS OF SEDIMENTS
AND
DISPOSAL SITE WATER

PETALUMA CREEK, ACROSS THE FLATS CHANNEL

December 1976

AUTHORIZATION

1. Results of tests reported herein were requested by DA Form 2544, No. E86-77-3013, dated 13 December 1976.

PURPOSE

2. The purpose of this study was to determine the amount of specified pollutants in samples of bottom sediments and added to the disposal site water in elutriate test procedure.

SAMPLES

3. Twelve sediment samples in plastic tubes and dredge and disposal site waters in gallon cubitaners were received on 20 December 1976.

TEST METHODS

4. a. Bulk Sediment Analysis. Mercury, cadmium, lead, zinc, and oil and grease were run according to "Preliminary Sampling and Analytical Procedures for Evaluating the Disposal of Dredged Materials", Laboratory Support Branch, Environmental Protection Agency, Region IX, April 1974.

b. Standard Elutriate Test. The test was run according to 40 CFR, Part 230, "Discharge of Dredge or Fill Material in Navigable Waters", Environmental Protection Agency. The mercury, cadmium, lead, zinc, and oil and grease were run according to methods for "Chemical Analysis of Water and Wastes", Environmental Protection Agency, National Environmental Research Center, Analytical Control Laboratory, Cincinnati, Ohio, 1974.

TEST RESULTS

5. Test results are presented as follows: Bulk Sediment Analyses and Standard Elutriate Test results are presented on forms supplied by the San Francisco District.

COMMENTS

6. All samples were within the maximum limits set by the Environmental Protection Agency, Region IX, for Marine (shallow) and Estuarine water disposal [illegible] 40 CFR, Part 230, Section 230.4.3.

NAME & ADDRESS OF LABORATORY: SPD Laboratory
P.O. Box 37, Sausalito, CA 94965
UNIT OF MEASUREMENT: Parts per Million of Dry Weight

PROJECT TITLE: Petaluma, CA
DATE OF SAMPLE: 8 Dec 76
TYPE OF TEST (Bulk Sediment Analysis or Standard Elutriate): Bulk Sediment

SAMPLE NO.	SAMPLE DEPTH	MERCURY	CADMIUM	LEAD	ZINC	OIL & GREASE
2D-179	0.0' - 3.0'	0.4	0.1	26	67	590
	3.0' - 6.0'	0.4	0.1	30	70	570
2D-180	0.0' - 3.0'	0.3	0.1	28	74	630
	3.0' - 6.0'	0.6	0.1	28	76	520
2D-181	0.0' - 3.0'	1.7	0.1	27	72	670
	3.0' - 6.0'	0.4	0.1	29	74	670
2D-182	0.0' - 3.0'	0.3	0.2	28	78	760
	3.0' - 6.0'	0.3	0.1	30	72	410
2D-183	0.0' - 3.0'	0.6	0.1	23	60	550
	3.0' - 6.0'	0.3	0.1	24	64	730
2D-184	0.0' - 3.0'	0.4	0.1	26	67	700
	3.0' - 6.0'	0.4	0.1	26	67	570

NAME & ADDRESS
OF LABORATORY: SPD Laboratory
P.O. Box 37, Sausalito, CA 94965
UNIT OF MEASUREMENT: mg/l

PROJECT TITLE: Petaluma, CA
DATE OF SAMPLE: 8 Dec 76
TYPE OF TEST (Bulk Sediment Analysis or Standard Elutriate): Standard Elutriate

SAMPLE NO.	SAMPLE DEPTH	MERCURY	CADMIUM	LEAD	ZINC	OIL & GREASE
2D-179	0.0' - 3.0'	0.0007	0.01	0.01	0.04	0.5
	3.0' - 6.0'	0.0008	0.01	0.01	0.04	0.5
2D-180	0.0' - 3.0'	0.0007	0.01	0.01	0.04	0.4
	3.0' - 6.0'	0.0007	0.01	0.01	0.04	0.4
2D-181	0.0' - 3.0'	0.0007	0.01	0.01	0.04	0.4
	3.0' - 6.0'	0.0007	0.01	0.01	0.04	0.4
2D-182	0.0' - 3.0'	0.0008	0.01	0.01	0.04	0.5
	3.0' - 6.0'	0.0009	0.01	0.01	0.04	0.4
2D-183	0.0' - 3.0'	0.0007	0.01	0.01	0.04	0.4
	3.0' - 6.0'	0.0009	0.01	0.01	0.04	0.5
2D-184	0.0' - 3.0'	0.0008	0.01	0.01	0.04	0.4
	3.0' - 6.0'	0.0008	0.01	0.01	0.04	0.4
Dredge Site Water		0.0009	0.01	0.01	0.04	0.2
Disposal Site Water		0.0007	0.01	0.01	0.04	0.4

APPENDIX D

RESULTS OF EPIFAUNAL SURVEY

(OTTER TRAWLS)

BY

SAN FRANCISCO BAY MARINE RESEARCH CENTER

SAN FRANCISCO BAY MARINE RESEARCH CENTER

REPORT ON U.S. ARMY CORPS OF ENGINEERS SISTER ISLANDS TRAWLING DONE 10 JULY 1977

Trawl type:	Otter	Ship speed:	2.5 kn.	Weather:	Sunny	Temperature:	1 - 66°F	Salinity:	1 - 33.2 ppt
Trawl size:	16' wide	Water current:	0.5 kn.	Swells:	0.5'		2 - 67°F		2 - 33.4 ppt
	5' high	Actual trawl speed:	2.0 kn.	Depth:	30'-40'		3 - 66°F		3 - 33.4 ppt
Net mesh:	¼"	Trawling time:	10 min.						
		Trawling distance:	2,000 ft.						

INVERTEBRATE SPECIES COLLECTED

Scientific Name	Common Name	Station 1				Station 2				Station 3			
		1-1	1-2	1-3	$\bar{x}$	2-1	2-2	2-3	$\bar{x}$	3-1	3-2	3-3	$\bar{x}$
Cancer gracilis	Cancer crab		1*		0.3			16	5.3	1	1	3*	1.7
Cancer magister	Dungeness crab	12*	5*	1§	6.0	1*	34*	53*	29	26†	7*	6*	13
Cancer productis	Cancer crab	1*			0.3	2*§	6*	3*	3.7			1	0.3
Crangon franciscorum	Bay shrimp	4			1.3		11†	38†	16	10	11†	1	7.3
Crangon nigricauda	Bay shrimp	42	1		14	1	234†	1730†	655	209	273†	91†	191
Hemigraspus oregonensis	Mud crab				0		1	1	0.7				0
Hermissenda crassicornis	Sea slug				0			1	0.3				0
Lironeca vulgaris	Marine salbug, parasitic	1§			0.3		1	5	2.0	2		3	1.7
Macoma sp.	Bent-nosed clam							1§	0.3				0
Molgula manhattensis	Tunicate, salps	1			0.3				0		1	1	0.7
Nassarius obsoletus	Mud snail				0			17	5.7	4			1.3
Pagurus hirsutiusculus	Hermit crab				0		1	3	1.3		1	1	0.7
Palaemon macrodactylus	Shrimp	4			1.3	1	15†	28†	15	4	4	10	6.0
Petricola carditoides	Ribbed clam				0			2	0.7				0
Pryomaia tuburculata	Kelp crab	7†		1	2.7	1†	7†	9	5.7	2	3	4	3.0
Synidotea laticauda	Estuarine salbug	1		1	0.7				0			2	0.7

* All female
† Female with eggs (gravid)
§ Juvenile

SAN FRANCISCO BAY MARINE RESEARCH CENTER

REPORT ON U.S. ARMY CORPS OF ENGINEERS SISTER ISLANDS TRAWLING DONE 10 JULY 1977

Trawl type:	Otter	Ship speed:	2.5 kn.	Weather:	Sunny	Temperature:	1 - 66°F	Salinity:	1 - 33.2 ppt
Trawl size:	16' wide	Water current:	0.5 kn.	Swells:	0.5'		2 - 67°F		2 - 33.4 ppt
	5' high	Actual trawl speed:	2.0 kn.	Depth:	30'-40'		3 - 66°F		3 - 33.4 ppt
Net mesh:	¼"	Trawling time:	10 min.						
		Trawling distance:	2,000 ft.						

FISH SPECIES COLLECTED

Scientific Name	Common Name	Station 1				Station 2				Station 3			
		1-1	1-2	1-3	$\bar{x}$	2-1	2-2	2-3	$\bar{x}$	3-1	3-2	3-3	$\bar{x}$
Amphistichus sp.	Surfperch				0			1	0.3				0
Citharichthys stigmaeus	Speckled sanddab	10			3.3		10	4	4.7	2	1	6	3.0
Cymatogaster aggregata	Shiner surfperch				0		2	1	1.0	1	1		0.7
Damalichthys vacca	Pile surfperch				0			1	0.3				0
Engraulis mordax	Northern anchovy				0		1		0.3				0
Isopsetta isolepis	Buttersole				0			1	0.3	1		1	0.7
Lepidogobius lepidus	Bay goby				0		4	5	3.0		3	1	1.3
Leptocottus armatus	Staghorn sculpin	1			0.3		6	3	3.0	2		1	1.0
Ophiodon elongatus	Lingcod				0		3‡	1†	0.3			1†	0.3
Platichthys stellatus	Starry flounder	1			0.3		3		1.0				0
Porichthys notatus	Plainfin midshipman				0		2†	9§	0.7	6	2	3	3.7
Raja binoculata	Big skate				0			2	0.7	1			0.3
Sebastes sp.	Rockfish	1			0.3		11	12	7.7	2	5	4	3.7
Sebastes pinniger	Canary rockfish				0		2		0.7			1	0.3
Symphurus atricauda	California tonguefish	2	1		1.0		15	4	6.3	6		6	4.0
---*	Sandshark				0			1	0.3				0

* Released on site
† One juvenile
§ Two juveniles
‡ Three juveniles

SAN FRANCISCO BAY MARINE RESEARCH CENTER

REPORT ON U.S. ARMY CORPS OF ENGINEERS SISTER ISLANDS TRAWLING DONE 17 AUGUST, 1977

Trawl type:	Otter	Ship speed:	2.5+ kn.	Weather:	Sunny	Water temp.:	1 - 67°F 2 - 68°F 3 - 67°F
Trawl size:	16' wide 5' high	Water current:	0.5 kn.	Wind:	None	Salinity:	1 - 30.4 ppt 2 - 30.4 ppt 3 - 30.5 ppt
Net mesh:	¼"	Actual trawling speed:	≃2.0 kn.	Swells:	None		
		Trawling time:	10 min.	Depth:	30' - 40'		
		Trawling distance:	2000 ft.				

INVERTEBRATE SPECIES COLLECTED

Scientific Name	Common Name	Station 1				Station 2				Station 3			
		1-1	1-2	1-3	$\bar{x}$	2-1	2-2	2-3	$\bar{x}$	3-1	3-2	3-3	$\bar{x}$
Balanus crenatus	Barnacle	0	0	0	0	0	0	0	0	0	0	1	0.3
Cancer magister	Dungeness crab	0	6	3	3.0	21	20	2	14	12	19	12	14
Cancer productus	Cancer crab	0	0	1	0.3	0	0	0	0	0	0	0	0
Crangon franciscorum	Bay shrimp	1	39	4	15	11	6	3	6.7	10	23	7	13
Crangon nigricauda	Bay shrimp	1	59	142	67	58	90	9	52	154	238	46	146
Hemigraspus oregonensis	Mud crab	0	0	3	1.0	0	0	0	0	0	0	0	0
Lironeca vulgaris	Marine sowbug, parasitic	0	2	1	1.0	3	0	0	1.0	2	0	1	1.0
Nassarius obsoletus	Mud snail	0	3	0	1.0	24	0	0	8.0	5	32	0	12
Pagurus hirsutiusculus	Hermit crab	0	0	4	1.3	4	0	0	1.3	1	1	0	0.7
Palaeomon macrodactylus	Shrimp	0	4	0	1.3	1	0	0	0.3	0	0	0	0
Pryomaia tuburculata	Kelp crab	0	15	2	5.7	16	3	2	7.0	0	5	1	2.0
Polynoidae, un I.D.	Scale worms	0	0	1	0.3	0	0	0	0	0	0	0	0
Nemertea, un I.D. *	Ribbon worms	0	0	0	0	0	0	0	0	0	1	0	0.3

*Unable to confirm tentative shipboard I.D. due to preservation problems.

SAN FRANCISCO BAY MARINE RESEARCH CENTER

REPORT ON U.S. ARMY CORPS OF ENGINEERS SISTER ISLANDS TRAWLING DONE 17 AUGUST, 1977

Trawl type: Otter
Trawl size: 16' wide, 5' high
Net mesh: ¼"

Ship speed: 2.5+ kn.
Water current: 0.5 kn.
Actual trawling speed: ≃2.0 kn.
Trawling time: 10 min.
Trawling distance: 2000 ft.

Weather: Sunny
Wind: None
Swells: None
Depth: 30'-40'

Water Temp.: 1 - 67°F, 2 - 68°F, 3 - 67°F

Salinity: 1 - 30.4 ppt, 2 - 30.4 ppt, 3 - 30.5 ppt

FISH SPECIES COLLECTED

Scientific Name	Common name	Station 1				Station 2				Station 3			
		1-1	1-2	1-3	$\bar{x}$	2-1	2-2	2-3	$\bar{x}$	3-1	3-2	3-3	$\bar{x}$
Citharichthys stigmaeus	Speckled sanddab	0	3	1	1.3	2	2	0	1.3	2	6	2	3.3
Cymatogaster aggregata	Shiner surfperch	0	0	2	0.7	0	0	0	0	0	4	0	1.3
Engraulis mordax	Northern anchovy	0	0	0	0	0	1	0	0.3	0	0	0	0
Lepidogobius lepidus	Bay goby	0	2	2	1.3	5	0	0	1.6	1	6	4	3.6
Leptocottus armatus	Staghorn sculpin	4	0	0	1.3	3	0	0	1.0	1	3	1	1.6
Mustelus henlei	Brown smoothhound shark	0	0	0	0	0	0	0	0	0	1	0	0.3
Porichthys notatus ***	Plainfin midshipman	3	8	2	4.3	1	9	0	3.3	11	9	1	7.0
Raja binoculata	Big skate	0	0	0	0	1	1	0	0.7	1	1	1	1.0
Sebastes auriculatus	Brown rockfish	0	1	0	0.3	0	0	0	0	1	1	0	0.7
Spirinchus sp.**	Smelt	1	0	0	0.3	0	0	0	0	0	0	0	0
Symphurus atricauda	California tonguefish	0	0	0	0	0	1	0	0.3	0	13	0	4.3
Triakis semifasciata	Leopard shark	0	0	1*	0.3	0	0	0	0	0	0	0	0

* 2½' specimen; released.

** Juvenile specimen

*** Many = juveniles approx. 2 cm long

SAN FRANCISCO BAY MARINE RESEARCH CENTER

REPORT ON U.S. ARMY CORPS OF ENGINEERS SISTER ISLANDS TRAWLING DONE 3 NOVEMBER 1977

Trawl type: Otter
Trawl size: 16' wide
5' high
Net mesh: ¼"

Ship speed: 2.5 kn.
Water current: 0.5 kn.
Actual trawl speed: 2.0 kn.
Trawling time: 10 min.
Trawling distance: 2,000 ft.

Weather: Sunny
Swells: 1.0'
Depth: 30'-40'

Salinity: 1 - 32.1 ppt
2 - 29.9 ppt
3 - 29.9 ppt

INVERTEBRATE SPECIES COLLECTED

Scientific Name	Common Name	Station 1				Station 2				Station 3			
		1-1	1-2	1-3	$\bar{x}$	2-1	2-2	2-3	$\bar{x}$	3-1	3-2	3-3	$\bar{x}$
Cancer gracilis	Cancer crab	3	0	0	1.0	1	1	1	1.0	0	1	1	0.7
Cancer magister	Dungeness crab	1	0	0	0.3	1	4	0	1.7	2	13	2	5.7
Cancer productus	Cancer crab	0	0	1	0.3	0	0	0	N/S	0	0	1	0.3
Crangon franciscorum	Bay shrimp	0	0	0	N/A	3	1	0	1.3	0	1	3	1.3
Crangon nigricauda	Bay shrimp	38	0	22	20	50	31	38	40	0	36	28	21
Hemigraspus oregonensis	Mud crab	0	0	2	0.7	0	0	1	0.3	0	0	1	0.3
Lironeca vulgaris	Marine sowbug	0	0	2	0.7	0	0	0	N/A	0	0	0	N/A
Nassarius obsoletus	Mud snail	22	6	20	16	31	10	18	20	0	0	3	1.0
Paguras hirsutiusculus	Hermit crab	5	4	3	4.0	5	2	1	2.7	0	2	2	1.3
Palaemon macrodactylus	Shrimp	13	4	6	7.7	31	11	22	21.3	0	19	9	9.3
Polyorchis sp.	Jellyfish	~700	~200	~400	~400	~200	~500	~250	~300	~200	~200	~150	~200
Pyromaia tuburculata	Kelp crab	18	8	2	9.3	7	7	13	9.0	0	3	3	2.0
Synidotea laticauda	Marine sowbug	0	0	0	N/A	0	0	0	N/A	0	1	1	0.7
Polynoidae, un-I.D.	Scale worm	1	0	0	0.3	0	0	0	N/A	0	0	0	N/A

SAN FRANCISCO BAY MARINE RESEARCH CENTER

REPORT ON U.S. ARMY CORPS OF ENGINEERS SISTER ISLANDS TRAWLING DONE 3 NOVEMBER 1977

Trawl type: Otter
Trawl size: 16' wide
5' high
Net mesh: ¼"

Ship speed: 2.5 kn.
Water current: 0.5 kn.
Actual trawl speed: 2.0 kn.
Trawling time: 10 min.
Trawling distance: 2,000 ft.

Weather: Sunny
Swells: 1.0'
Depth: 30'-40'

Salinity: 1 - 32.1 ppt
2 - 29.9 ppt
3 - 29.9 ppt

FISH SPECIES COLLECTED

Scientific Name	Common Name	Station 1				Station 2				Station 3			
		1-1	1-2	1-3	$\bar{x}$	2-1	2-2	2-3	$\bar{x}$	3-1	3-2	3-3	$\bar{x}$
Citharichthys stigmaeus	Speckled sanddab	3	6	7	5.3	6	2	2	3.3	0	0	2	0.7
Cymatogaster aggregata	Shiner surfperch	0	0	7	2.3	0	1	1	0.7	0	0	0	N/A
Dorosoma petenense	Threadfin shad	0	0	0	N/A	0	0	0	N/A	2	0	0	0.7
Hyposetta guttulata	Diamond turbot	0	0	1	0.3	0	0	0	N/A	0	0	0	N/A
Leptocottus armatus	Staghorn sculpin	0	0	3	1.0	0	0	1	0.3	1	2	0	1.0
Platichthys stellatus	Starry flounder	1	0	0	0.3	0	0	1	0.3	0	0	0	N/A
Spirinchus sp.*	Smelt	0	0	0	N/A	0	0	0	N/A	0	1	0	0.3
Symphurus atricauda	California tonguefish	0	1	0	0.3	0	0	0	N/A	0	0	0	N/A
Syngnathus leptorhynchus	Bay pipefish	0	0	0	N/A	1	0	1	0.7	0	0	0	N/A
Juvenile fish, un-I.D.	.....	0	0	0	N/A	1	0	0	0.3	1	0	0	0.3

* Specimen lost

SAN FRANCISCO BAY MARINE RESEARCH CENTER

REPORT ON U.S. ARMY CORPS OF ENGINEERS SISTER ISLANDS TRAWLING DONE 28 APRIL 1978

Trawl type: Otter
Trawl size: 16' wide
5' high
Net mesh: ¼"

Ship speed: 1.0 kn.
Water current: 1.0 kn.
Actual trawl speed: 2.0 kn.
Trawling time: 10 min.
Trawling distance: 2,000 ft.

Weather: Sunny
Swells: <0.5'
Depth: 30'-40'

INVERTEBRATE SPECIES COLLECTED

Scientific Name	Common Name	Station 1				Station 2				Station 3			
		1-1	1-2	1-3	$\bar{x}$	2-1	2-2	2-3	$\bar{x}$	3-1	3-2	3-3	$\bar{x}$
Crangon franciscorum	Bay shrimp	36	64	47	49	12	21	43	25	17	34	11	21
Crangon nigricauda	Bay shrimp	78	11	4	31	66	71	81	73	32	38	15	28
Hemigrapsus oregonensis	Mud crab	5	1		2.0		1		0.3	6	1		2.3
Lironeca vulgaris	Marine sowbug, parasitic				0		2		0.7				0
*Mysidacea**	Opposum shrimp	270	50	40	120	70	30	425	175	220	35	25	93
Nassarium obsoletus	Mud snail	5	44	1	17	16	2	4	7.3	4		6	3.3
Pagurus hirsutiusculus	Hermit crab	3	6		3.0		4		1.3		3	6	3.0
Palaeomon macrodactylus	Shrimp	13	12	2	9.0	21	25	22	23	13	48	18	26
Polyorchis sp.	Jellyfish	2	4	6	3.0	2	8	7	5.7	4	3	11	6.0
Synidotea laticauda	Estuarine salbug	2	1		1.0	1	1		1.7	3			1.0

*Counts include approximations of animals seen on deck after hauling in the net.

SAN FRANCISCO BAY MARINE RESEARCH CENTER

REPORT ON U.S. ARMY CORPS OF ENGINEERS SISTER ISLANDS TRAWLING DONE 28 APRIL 1978

Trawl type: Otter
Trawl size: 16' wide
5' high
Net mesh: ¼"

Ship speed: 1.0 kn.
Water current: 1.0 kn.
Actual trawl speed: 2.0 kn.
Trawling time: 10 min.
Trawling distance: 2,000 ft.

Weather: Sunny
Swells: <0.5'
Depth: 30'-40'

FISH SPECIES COLLECTED

Scientific Name	Common Name	Station 1				Station 2				Station 3			
		1-2	1-2	1-3	$\bar{x}$	2-1	2-2	2-3	$\bar{x}$	3-1	3-2	3-3	$\bar{x}$
Acanthogobius flavimanus	Yellowfin goby		2		0.7	2		3	1.7	4	1		2.7
Citharichtys stigmaeus	Speckled sanddab				0			2	0.7				0
Cymatogaster aggregata	Shiner surfperch		5	2	2.3		2		0.7	1			0.3
Genyonemus lineatus	White croaker		1		0.3				0		1		0.3
Hypomesus transpacificus	Delta smelt			1	0.3			1	0.3				0
Leptocottus armatus	Staghorn sculpin	1			0.3	1		1	0.7				0
Microgadus proximum	Pacific tomcod				0		2		0.7				0
Parophrys vetulus	English sole				0		1		0.3				0
Platichthys stellatus	Starry flounder				0		1		0.3				0
Porichthys notatus	Plainfin midshipman		1		0.3	2	1	1	1.3				0
Raja binoculata	Big skate	1	1		0.7		3		1.0			1	0.3
Roccus saxatilis	Striped bass				0			1	0.7	2	1		1.0
Sebastes sp. (juvenile)	Rockfish			1	0.3		1	1	0.7				0
	Larval herring	1			0.3				0	2	1		1.0
	Larval rockfish	5			1.7				0				0
	Larval smelt	2	1	1	1.3		1	10	3.7	3	1	41	15
	Larval fish, not I.D.				0				0	1			0.3
	Fish eggs (approx. volume in liters)	10			2.5		0.1	1	0.3				0

APPENDIX E

MASTER PHYLOGENETIC SPECIES LIST

MASTER PHYLOGENETIC SPECIES LIST
FORMAT OF TAXONOMIC CATEGORIES

PHYLUM

Subphylum

SUPERCLASS

Class

Subclass

ORDER

Suborder

FAMILY

Genus species

MASTER PHYLOGENETIC SPECIES LIST

PORIFERA

Unidentified fragments

Demospongia

HALICHONDRIDA

HALICHONDRIIDAE

Halichondria bowerbanki Burton, 1930

CNIDARIA

Hydrozoa

HYDROIDA

Unidentified hydroid

Anthomedusae

BOUGAINVILLIDAE

Bimeria sp.A

Leptomedusae

CAMPANULARIIDAE

Obelia bicuspidata Clark, 1876
Obelia sp.

Opercularella sp.

Anthozoa

Zoantharia

ACTINARIA

DIADUMENIDAE

cf. Diadumene franciscana Hand, 1955

Scyphozoa

Unidentified polyp stage

PLATYHELMINTHES

Turbellaria

Unidentified

NEMATODA

Unidentified spp.

ANNELIDA

Polychaeta

Unidentified sp.

AMPHARETIDAE

Unidentified sp.A

CAPITELLIDAE

Capitella capitata (Fabricus, 1780)
Heteromastus filiformis (Claperede, 1864)
Mediomastus californiensis Hartman, 1944
Unidentified sp.

CIRRATULIDAE

Cirriformia spirabrancha (Moore, 1904)
Tharyx parvus Berkeley, 1929
Tharyx sp.

COSSURIDAE

Cossura pygodactylata Jones, 1956

GLYCERIDAE

Glycera convoluta Keferstein, 1962
Glycera tenuis Hartman, 1944

GONIADIDAE

Glycinde polygnatha Hartman, 1950

HESIONIDAE

?*Heteropodarke heteromorpha* Hartman-Schroeder, 1962

MALDANIDAE

Asychis elongata (Verrill, 1873)

OPHELIIDAE

Armandia brevis (Moore, 1906)

ORBINNIDAE

Haploscolopos elongatus (Johnson, 1901)

PHYLLODOCIDAE

Hesionura sp.A

PILARGIIDAE

Unidentified sp.A

POLYNOIDAE

Harmothoe imbicata (Linnaeus, 1767)

SABELLIDAE

Chone gracilis Moore, 1906

SPIONIDAE

Polydora brachycephala Hartman, 1936
Polydora ligni Webster, 1879
Polydora socialis (Schmarda, 1861)
Pseudopolydora paucibranchiata (Okuda, 1937)
Streblospio benedicti Webster, 1879

SYLLIDAE

Exogone lourei Berkeley and Berkeley, 1938

TEREBELLIDAE

Amaena occidentalis (Hartman, 1944)

Oligochaeta

TUBIFICIDAE

Peloscolex gabriellae Marcus, 1950

ARTHROPODA

Crustacea

Ostracoda

Sarsiella zostericola Cushman, 1906

Copepoda

Unidentified spp.

CYCLOPOIDA

NOTODELPHYDAE

Unidentified sp.A

Cirripedia

Unidentified sp.A

Malacostraca (Division Peracarida)

CUMACEA

Unidentified

TANAIDACEA
Dikonophora

PARATANAIDAE

Leptochelia dubia (Kroyer, 1842)

ISOPODA
Valvifera

IDOTEIDAE

Synidotea laticauda Benedict, 1897

Asellota

JAEROPSIDAE

Jaeropsis dubia dubia Menzies, 1951

AMPHIPODA
Gammaridea

AMPELISCIDAE

Ampelisca milleri Barnard, 1954

COROPHIIDAE

Corophium acherusicum Costa, 1817
Corophium uenoi Stephensen, 1932
Corophium cf. *insidiosum* Crawford, 1937
Corophium sp.
Gammaropsis sp.A
Grandidierella japonica Stephensen, 1938

ISCHYROCERIDAE

Jassa falcata (Montagu, 1808)

PLEUSTIDAE

Parapleustes pugettensis (Dana, 1853)

PODOCERIDAE

Microdeutopus schmitti Shoemaker, 1942

Caprellidea

Unidentified

Malacostraca (Division Eucarida)

DECAPODA
Reptantia

Grapsoid megalops sp.A

TROMBIDIFORMES

HALACARIDAE

Unidentified

MOLLUSCA

Gastropoda

Prosobranchia

NEOGASTROPODA

NASSARIIDAE

Nassarius obsoletus (Say, 1822)

Bivalvia

Unidentified juvenile

Pterimorphia

MYTILOIDA (Superfamily Mytilacea)

MYTILIDAE

Adula diegensis (Dall, 1911)
Musculus senhousia (Benson, 1842)

Heterodonta

VENEROIDA (Superfamily Galeommatacea)

MONTACUTIDAE

cf. Orobitella sp.A

VENEROIDA (Superfamily Veneracea)

VENERIDAE

Gemma gemma (Totten, 1834)
Tapes japonica Deshayes, 1853
Unidentified juvenile

COOPERELLIDAE

Cooperella subdiaphana Carpenter, 1864

VENEROIDA (Superfamily Tellinacea)

Unidentified juvenile

TELLINIDAE

Macoma balthica (Linnaeus, 1758)
Macoma nasuta (Conrad, 1837)
Macoma cf. secta (Conrad, 1837)

ECTOPROCTA

Unidentified fragments
Unidentified encrusting Nassarius obsoletus

CYCLOSTOMATA

cf. Lichenopora sp.

CHEILOSTOMATA
Anasca

Membranipora sp.

Ascophora

Hippothoa sp.

ENTOPROCTA

PEDICELLINIDAE

Barentsia benedeni (Foettinger, 1887)

CHORDATA
Urochordata

Ascidiacea

PLEUROGONA
Stolidobranchia

Molgula manhattensis (DeKay, 1843)

APPENDIX F

BENTHIC INFAUNA DATA

TABLE F-1 : BENTHIC SPECIES AND ABUNDANCE BY STATION AND PERIOD - SAN PABLO BAY DREDGE DISPOSAL SITE

SPECIES	I-1	I-2	I-3	PER I TOT	II-1	II-2	II-3	PER II TOT	III-1	III-2	III-3	PER III TOT	IV-1	IV-2	IV-3	PER IV TOT	TOTAL SPECIES ABUND.
PORIFERA																	
Halichondria bowerbanki		P		P													
* Porifera unidentified		P		P													
CNIDARIA																	
* Bimeria sp.										P		P					
cf. Diadumene franciscana															1	1	1
* Hydrozoa unidentified							P	P									
* Obelia bicuspidata			P	P													
* Obelia sp.			P	P					P		P	P					
* Opercularella sp.			P	P		P		P	P	P		P					
* Scyphozoa unidentified						P		P	P	P		P			P	P	
PLATYHELMINTHES																	
* Turbellaria unidentified		1		1					3		1	4					5
NEMATODA																	
* Nematoda unidentified	P	P	P	P			P	P	P		P	P			P	P	
ANNELIDA																	
POLYCHAETA																	
Amaena occidentalis									1			1					1
Ampharetidae unidentified sp.A									1			1					1
Armandia brevis									3			3					3
Asychis elongata	3		6	9	5		8	13			6	6			9	9	37
Capitella capitata			6	6													6
* Capitellidae unidentified						1		1									1
Chone gracilis									37			37					37
Cirriformia spirabrancha			1	1													1
Cossura pygodactylata			2	2							7	7					9
Exogone lourei	2	9	125	136	35	20		55	207	27	8	242	2	15	118	135	568
Glycera convoluta						1		1									1
Glycera tenuis					1			1	2			2	1			1	4
Glycinde polygnatha	2		5	7	1		1	2	5	1	2	8		1	2	3	20
Haploscolopos elongatus			1	1													1
Harmothoe imbricata									1			1					1
?Heteropodarke heteromorpha						2		2	1	24		25	1			1	28
Hesionura sp.A									7	35	1	43	8			8	51
Heteromastus filiformis						1		1		1		1		6	8	14	16
Mediomastus californiensis	1	1	3	5	5	1	3	9			2	2					16
Pilargiidae unidentified sp.A					1			1									1
* Polychaeta unidentified					1			2									1
Polydora brachycephala	59	2		61	7	3		10	14	6		20	20	44		64	155
Polydora ligni	24			24	18			18	2			2			3	3	47
Polydora socialis			2	2					1			1					3

TABLE F-1 (cont.)

SPECIES	I-1	I-2	I-3	PER I TOT	II-1	II-2	II-3	PER II TOT	III-1	III-2	III-3	PER III TOT	IV-1	IV-2	IV-3	PER IV TOT	TOTAL SPECIES ABUND.
ANNELIDA (cont.)																	
POLYCHAETA (cont.)																	
Pseudopolydora paucibranchiata			2	2					1			1					3
Streblospio benedicti									5	1	3	9		1	5	6	15
Tharyx parvus	1		8	9	33			33	22		1	23					65
* Tharyx sp.					1			1									1
OLIGOCHAETA																	
Peloscolex gabriellae	2	1	46	49	4		1	5	82	10	138	230	4	5	212	221	505
ARTHRPODA																	
Ampelisca milleri	3	2	1298	1303	1252	1	2	1255	2569			2569	2	34	45	81	5208
* Caprellidae unidentified			2	2													2
Cirripedia sp. A										1		1					1
* Copepoda unidentified	3	1	106	110	5	6	1	12	17	32	1	50	1		10	11	183
Corophium acherusicum														2	7	9	9
* Corophium cf. insidiosum			3	3													3
Corophium uenoi			3	3													3
* Corophium sp.														2		2	2
* Cumacea unidentified			12	12					1			1		1	37	38	51
Gammaropsis sp. A			3	3													3
Grandidierella japonica	1		11	12	2			2	26			26			1	1	41
Grapsoid megalops sp. A	1			1													1
* Halacaridae unidentified									2			2					2
Jaeropsis dubia dubia									1			1					1
Jassa falcata	1			1	1	1		2									3
Leptochelia dubia	1		92	93					9			9					102
Microdeutopus schmitti			1	1													1
Notodelphydae sp. A			2	2		1		1									3
Parapleustes pugettensis									4			4					4
Sarsiella zostericola	2	3	46	51	26	2	3	31	137			137	1	8	43	52	271
Synidotea laticauda									4			4		1	2	3	7
MOLLUSCA																	
Adula diegensis							4	4	3			3					7
* Bivalvia unidentified										1		1					1
Cooperella subdiaphana									1			1					1
Gemma gemma											44	44			12	12	56
Macoma balthica													1	2	1	4	4
Macoma nasuta			5	5					5			5			1	1	11
* Macoma cf. secta											1	1					1
Musculus senhousia			9	9					6			6			9	9	24
Nassarius obsoletus															1	1	1
cf. Orobitella sp. A									1			1					1

TABLE F-1 (cont.)

SPECIES	I-I	I-2	I-3	PER I TOT	II-1	II-2	II-3	PER II TOT	III-1	III-2	III-3	PER III TOT	IV-1	IV-2	IV-3	PER IV TOT	TOTAL SPECIES ABUND.
MOLLUSCA (cont.)																	
Tapes japonica							1	1	4			4					5
* Tellinacea unidentified									4								4
* Veneridae unidentified			2	2													2
ECTOPROCTA																	
* Ectoprocta unidentified sp. A	P	P	P	P		P	P	P						P		P	
* Ectoprocta unidentified sp. B										P	P	P					
* Hippothoa sp.	P			P													
* cf. Lichenopora sp.	P			P													
* Membranipora sp.	P	P		P													
ENTOPROCTA																	
Barentsia benedeni		P		P													
CHORDATA																	
Molgula manhattensis			3	3		1		1	2			2					6
Number of Individuals (N)	103	110	1587	1800	1392	34	23	1449	3159	105	218	3482	40	119	480	639	7370
Number of Species (S)	14	7	22	27	15	11	8	21	30	8	10	36	9	11	18	22	52
Shannon-Wiener Diversity (H')	1.44	.68	.83	1.22	.53	1.59	1.82	.68	.87	1.57	1.21	1.17	1.57	1.71	1.70	1.99	1.32
Evenness (J)	.55	.35	.27	.37	.19	.66	.88	.22	.26	.76	.53	.33	.71	.71	.59	.64	.33

Asterisk (*) indicates organism does not count as a species in statistics

TABLE F-2 BENTHIC SPECIES AND ABUNDANCE BY REPLICATE FOR EACH STATION

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
		PERIOD I STATION 1				
NEMATODA						
Unidentified		P				
ANNELIDA						
POLYCHAETA						
Asychis elongata	1	2		1.0	1.0	
Exogone lourei		2		0.7	1.2	
Glycinde polygnatha	2			0.7	1.2	1 juvenile
Mediomastus californiensis			1	0.3	0.6	
Polydora brachycephala	50	4	5	19.7	26.3	
Polydora ligni	23		1	8.0	13.0	1 juvenile
Tharyx parvus			1	0.3	0.6	
OLIGOCHAETA						
Peloscolex gabriellae	2			0.7	1.2	
ARTHROPODA						
Ampelisca milleri		3		1.0	1.7	
Copepoda, unidentified		3		1.0	1.7	
Grandidierella japonica		1		0.3	0.6	
Grapsoid megalops	1			0.3	0.6	
Jassa falcata			1	0.3	0.6	
Leptochelia dubia		1		0.3	0.6	
Sarsiella zostericola	1	1		0.7	0.6	

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
	PERIOD I STATION 1 (cont.)					
ECTOPROCTA						
Hippothoa sp.	P					
cf. *Lichenopora* sp.			P			
Membranipora sp.			P			
Unidentified		P				Encrusting *Nassarius obsoletus*
	PERIOD I STATION 2					
PORIFERA						
Halichondria bowerbanki			P			on shell
Unidentified		P	P			fragments attached to sand grains, large triaenes
TURBELLARIA						
Unidentified	1			0.3	0.6	
NEMATODA						
Unidentified			P			

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
	PERIOD I STATION 2 (cont.)					
ANNELIDA						
POLYCHAETA						
Exogone lourei		4	5	3.0	2.7	
Mediomastus californiensis	1			0.3	0.6	
Polydora brachycephala	1		1	0.7	0.6	
OLIGOCHAETA						
Peloscolex gabriellae	1			0.3	0.6	
ARTHROPODA						
Ampelisca milleri	1	1		0.7	0.6	
Copepoda, unidentified			1	0.3	0.6	
Sarsiella zostericola	2	1		1.0	1.0	
ECTOPROCTA						
Membranipora sp			P			
Unidentified		P				encrusting Nassarius obsoletus
ENTOPROCTA						
Barentsia benedeni		P	P			

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
	PERIOD I STATION 3					
CNIDARIA						
Obelia bicuspidata	P	P	P			
Obelia sp.			P			
Operculariella sp.	P	P				perforating *Ampelisca* empty tubes
NEMATODA						
Unidentified	P	P				
ANNELIDA						
POLYCHAETA						
Asychis elongata		1	5	2.0	2.7	
Capitella capitata			6	2.0	3.5	
Cirriformia spirabrancha			1	0.3	0.6	
Cossura pygodactylata			2	0.7	1.2	
Exogone lourei	16	3	106	41.7	56.1	4 females w/larvae
Glycinde polygnatha	1		4	1.7	2.1	3 juveniles
Haploscolopos elongatus			1	0.3	0.6	
Mediomastus californiensis			3	1.0	1.7	
Polychaeta, unidentified			1	0.3	0.6	
Polydora socialis		1	1	0.7	0.6	
Pseudopolydora paucibranchiata			2	0.7	1.2	
Tharyx parvus	1		7	2.7	3.8	

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
		PERIOD 1 STATION 3 (cont.)				
ANNELIDA (cont.)						
OLIGOCHAETA						
Peloscolex gabriellae	8		38	15.3	20.0	
ARTHROPODA						
Ampelisca milleri	193	154	951	429.3	452.0	65 females with eggs
Caprellidea, unidentified	1		1	0.7	0.6	
Copepoda, unidentified	90	13	3	35.3	47.6	
Copepoda sp.A	2			0.7	1.2	commensal in pharynx *Molgula manhattensis*
Corophium uenoi	3			1.0	1.7	
Corophium cf. *insidiosum*		1	2	1.0	1.0	
Cumacea, unidentified	2		10	4.0	5.3	
Gammaropsis sp.A	2	1		1.0	1.0	
Grandidierella japonica			11	3.7	6.4	1 female with eggs
Leptochelia dubia	56		36	30.7	28.4	3 females with eggs many small specimens
Microdeutopus schmitti			1	0.3	0.6	
Sarsiella zostericola	22	2	22	15.3	11.6	6 females with eggs
MOLLUSCA						
Macoma nasuta	2		3	1.7	1.5	
Musculus senhousia	8		1	3.0	4.4	
Veneridae, juvenile	2			0.7	1.2	

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
		PERIOD I STATION 3 (cont.)				
ECTOPROCTA						
Unidentified		P				encrusting Nassarius obsoletus
CHORDATA						
Molgula manhattensis	3			1.0	1.7	
		PERIOD II STATION 1				
ANNELIDA						
POLYCHAETA						
Asychis elongata		5		1.7	2.9	
Exogone lourei	31	1	3	11.7	16.8	
Glycera tenuis	1			0.3	0.6	
Glycinde polygnatha	1			0.3	0.6	
Mediomastus californiensis	4	1		1.7	2.1	
Pilargiidae, unident, sp. A	1			0.3	0.6	
Polydora brachycephala	5	1	1	2.3	2.3	
Polydora ligni	18			6.0	10.4	
Tharyx parvus		1		0.3	0.6	
Tharyx sp.		1		0.3	0.6	
OLIGOCHAETA						
Peloscolex gabriellae	4			1.3	2.3	

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
		PERIOD II STATION 1 (cont.)				
ARTHROPODA						
Ampelisca milleri	1246	6		417.3	717.7	23 females with eggs
Copepoda, unidentified	2	3		1.7	1.5	
Grandidierella japonica	2			0.7	1.2	
Jassa falcata	1			0.3	0.6	
Sarsiella zostericola	25	1		8.7	14.2	5 females with eggs
		PERIOD II STATION 2				
CNIDARIA						
Operculariella sp.		P				perforating empty *Ampelisca* tubes
Unidentified scyphozoan polyp stage		P				
ANNELIDA						
POLYCHAETA						
Capitellidae, unident.	1			0.3	0.6	
Exogone lourei		11	9	6.7	5.9	
Glycera convoluta			1	0.3	0.6	
?Heteropodarke heteromorpha			2	0.7	1.2	
Heteromastus filiformis			1	0.3	0.6	
Mediomastus californiensis		1		0.3	0.6	
Polydora brachycephala		3		1.0	1.7	juveniles

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TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
	PERIOD II STATION 2 (cont.)					
ARTHROPODA						
Ampelisca milleri			1	0.3	0.6	
Copepoda, unidentified		2	4	2.0	2.0	
Copepoda sp.A		1		0.3	0.6	commensal in pharynx *Molgula manhattensis*
Jassa falcata			1	0.3	0.6	
Sarsiella zostericola	2			0.7	1.2	
ECTOPROCTA						
Membranipora sp.		P				
Unidentified		P				encrusting *Nassarius obsoletus*
CHORDATA						
Molgula manhattensis		1		0.3	0.6	

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
		PERIOD II STATION 3				
CNIDARIA						
Unidentified hydroid		P				
NEMATODA						
Unidentified		P				
ANNELIDA						
POLYCHAETA						
Asychis elongata	5	2	1	2.7	2.1	
Glycinde polygnatha			1	0.3	0.6	
Mediomastus californiensis			3	1.0	1.7	
OLIGOCHAETA						
Peloscolex gabriellae	1			0.3	0.6	
ARTHROPODA						
Ampelisca milleri	1	1		0.7	0.6	
Copepoda, unidentified		1		0.3	0.6	
Sarsiella zostericola	1	2		1.0	1.0	1 female with eggs
MOLLUSCA						
Adula diegensis		3	1	1.3	0.6	
Tapes japonica			1	0.3	0.6	
ECTOPROCTA						
Unidentified			P			encrusting *Nassarius obsoletus*

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
	PERIOD III STATION 1					
CNIDARIA						
Obelia sp.	P		P			
Operculariella sp.			P			perforating empty *Ampelisca* tubes
Unidentified scyphozoan polyp stage		P	P			
PLATYHELMINTHES						
Unidentified	3			1.0	1.7	
NEMATODA						
Unidentified	P		P			
ANNELIDA						
POLYCHAETA						
Amaena occidentalis			1	0.3	0.6	
Ampharetidae, unidentified sp. A	1			0.3	0.6	
Armandia brevis	3			1.0	1.7	
Chone gracilis	29		8	12.3	15.0	
Exogone lourei	133	13	61	69.0	60.4	6 females with larvae
Glycera tenuis		2		0.7	1.2	
Glycinde polygnatha	1		4	1.7	2.1	
Harmothoe imbricata	1			0.3	0.6	

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
		PERIOD III STATION 1 (cont.)				
ANNELIDA (cont.)						
POLYCHAETA (cont.)						
?Heteropodarke heteromorpha		1		0.3	0.6	
Hesionura sp. A		7		2.3	4.0	
Polydora brachycephala	3		11	4.7	5.7	
Polydora ligni	1		1	0.7	0.6	1 juvenile
Polydora socialis			1	0.3	0.6	juvenile
Pseudopolydora paucibranchiata	1			0.3	0.6	
Tharyx parvus	13		9	7.3	6.7	
OLIGOCHAETA						
Peloscolex gabriellae	68	1	13	27.3	35.7	
ARTHROPODA						
Ampelisca milleri	1835		734	856.3	923.6	1 female with eggs
Copepoda, unidentified	4	1	2	2.3	1.5	
Cumacea, unidentified	1			0.3	0.6	
Grandidierella japonica	22		4	8.7	11.7	
Jaeropsis dubia dubia	1			0.3	0.6	
Leptochelia dubia	9			3.0	5.2	
Parapleustes pugettensis	3		1	1.3	1.5	
Sarsiella zostericola	128		9	45.7	71.4	
Synidotea laticauda	4			1.3	2.3	

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
	PERIOD III STATION 1 (cont.)					
MOLLUSCA						
Adula diegensis	2		1	1.0	1.0	
Cooperella subdiaphana	1			0.3	0.6	
Macoma nasuta	5			1.7	2.9	
Musculus senhousia	5		1	2.0	2.7	
cf. *Orobitella* sp.A	1			0.3	0.6	
Tapes japonica	1	2	1	1.3	0.6	
Tellinacea, juvenile	4			1.3	2.3	
CHORDATA						
Molgula manhattensis			2	0.7	1.2	

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
		PERIOD III STATION 2				
CNIDARIA						
Bimeria sp. A		P				
Operculatella sp.	P					perforating empty *Ampelisca* tubes
Unidentified scyphozoan polyp stage		P	P			
ANNELIDA						
POLYCHAETA						
Exogone lourei	19	2	6	9.0	8.9	4 females with larvae
Glycinde polygnatha		1		0.3	0.6	
?Heteropodarke hetermorpha		19	5	8.0	9.9	
Hesionura sp. A	7	27	1	11.7	13.6	
Heteromastus filiformis		1		0.3	0.6	
Polydora brachycephala	1	5		2.0	2.7	
OLIGOCHAETA						
Peloscolex gabriellae	3	7		3.3	3.5	
ARTHROPODA						
Cirripedia sp.A			1	0.3	0.6	
Copepoda, unidentified	7	17	8	10.7	5.5	
Halacaridae, unidentified	2			0.7	1.2	

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
		PERIOD III STATION 2 (cont.)				
MOLLUSCA						
Unidentified bivalve, juvenile	1			0.3	0.6	
ECTOPROCTA						
Membranipora sp.		P				
Unidentified			P			
		PERIOD III STATION 3				
CNIDARIA						
Obelia sp.		P				
PLATYHELMINTHES						
Unidentified		P				
NEMATODA						
Unidentified	P	P	P			

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
	PERIOD III STATION 3 (cont.)					
ANNELIDA						
POLYCHAETA						
Asychis elongata	1	3	2	2.0	1.0	
Cossura pygodactylata	5		2	2.3	2.5	
Exogone lourei	2	5	1	2.7	2.1	1 female with larvae
Glycinde polygnatha		2	1	1.0	1.0	
Hesionura sp. A			1	0.3	0.6	
Mediomastus californiensis	2			0.7	1.2	
Streblospio benedicti	5	1	3	3.0	2.0	
Tharyx parvus			1	0.3	0.6	
OLIGOCHAETA						
Peloscolex gabriellae	41	25	72	46.0	23.9	
ARTHROPODA						
Copepoda, unidentified		1		0.3	0.6	
MOLLUSCA						
Gemma gemma	7	31	6	14.7	14.2	numerous empty shells
Macoma cf. *secta*		1		0.3	0.6	
ECTOPROCTA						
Unidentified	P	P				

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
		PERIOD IV STATION 1				
ANNELIDA						
POLYCHAETA						
Exogone lourei		1	1	0.7	0.6	
Glycera tenuis			1	0.3	0.6	
?Heteropodarke heteromorpha		1		0.3	0.6	
Hesionura sp. A			8	2.7	4.6	
Polydora brachycephala	3	15	2	6.7	7.2	1 juvenile
OLIGOCHAETA						
Peloscolex gabriellae	1	3		1.3	1.5	
ARTHROPODA						
Ampelisca milleri	1		1	0.7	0.6	1 female with eggs
Copepoda, unidentified		1		0.3	0.6	
Sarsiella zostericola	1			0.3	0.6	
MOLLUSCA						
Macoma balthica			1	0.3	0.6	

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
		PERIOD IV STATION 2				
ANNELIDA						
POLYCHAETA						
Exogone lourei	2	7	6	5.0	2.7	
Glycinde polygnatha		1		0.3	0.6	
Heteromastus filiformis		2	4	2.0	2.0	
Polydora brachycephala		9	35	14.7	18.2	32 juveniles
Streblospio benedicti	1			0.3	0.6	
OLIGOCHAETA						
Peloscolex gabriellae	3	2		1.7	1.5	
ARTHROPODA						
Ampelisca milleri	16	8	10	11.3	4.2	18 females with eggs
Corophium acherusicum			2	0.7	1.2	
Corophium sp.	2			0.7	1.2	
Cumacea, unidentified			1	0.3	0.6	
Sarsiella zostericola	1	3	4	2.7	1.5	
Synidotea laticauda			1	0.3	0.6	
MOLLUSCA						
Macoma balthica	2			0.7	1.2	
ECTOPROCTA						
Unidentified	P					encrusting *Nassarius obsoletus*

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
	PERIOD IV STATION 3					
CNIDARIA						
cf. Diadumene franciscana			1	0.3	0.6	
Unidentified scyphozoan, polyp stage		P				
NEMATODA						
Unidentified	P		P			
ANNELIDA						
POLYCHAETA						
Asychis elongata	5	1	3	3.0	2.0	
Exogone lourei	70	7	41	39.3	31.5	
Glycinde polygnatha			2	0.7	1.2	
Heteromastus filiformis	4		4	2.7	2.3	
Polydora ligni	1	1	1	1.0	0.0	2 juveniles
Streblospio benedicti	4		1	1.7	2.1	
OLIGOCHAETA						
Peloscolex gabriellae	103	13	96	70.7	50.1	
ARTHROPODA						
Ampelisca milleri	31		14	15.0	15.5	15 females with eggs
Copepods, unidentified	3		7	3.3	3.5	
Corophium acherusicum	4		3	2.3	2.1	
Cumacea, unidentified	33		4	12.3	18.0	
Grandidierella japonica			1	0.3	0.6	

TABLE F-2 (cont.)

Taxa	Replicates 1	2	3	Mean	Std. Dev.	Remarks
	PERIOD IV STATION 3 (cont.)					
ARTHROPODA (cont.)						
Sarsiella zostericola	32	1	10	14.3	16.0	1 female with eggs
Synidotea laticauda	1		1	0.7	0.6	
MOLLUSCA						
Gemma gemma	4		8	4.0	4.0	
Macoma balthica	1			0.3	0.6	
Macoma nasuta	1			0.3	0.6	
Musculus senhousia	5		4	3.0	2.7	
Nassarius obsoletus	1			0.3	0.6	

APPENDIX G

TEN MOST

ABUNDANT SPECIES

BY

STATION AND PERIOD

IN

NUMBERS PER LITER

TABLE G-1: TEN MOST ABUNDANT SPECIES AND ABUNDANCE (NOS./LITER) BY STATION FOR EACH PERIOD

	TOTAL ABUND. PER I-IV	ORGANISMS PER LITER											
		I-1	I-2	I-3	II-1	II-2	II-3	III-1	III-2	III-3	IV-1	IV-2	IV-3
Ampelisca milleri	5208	0.3	0.2	135.2	130.4	0.1	0.2	285.5	0.0	0.0	0.2	3.7	5.0
Exogone lourei	568	0.2	1.0	13.8	3.6	22	0.0	23.0	3.0	0.9	0.2	1.7	13.1
Peloscolex gabriellae	505	0.2	0.1	5.1	0.4	0.0	0.1	9.1	1.1	15.4	0.4	0.5	23.6
Sarsiella zostericola	271	0.2	0.3	5.1	2.7	0.2	0.3	15.3	0.0	0.0	0.1	0.9	4.8
Polydora brachycephala	155	6.5	0.2	0.0	0.7	0.3	0.0	1.6	0.6	0.0	2.2	4.9	0.0
Leptochelia dubia	102	0.1	0.0	10.2	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Tharyx parvus	65	0.1	0.0	0.9	3.4	0.0	0.0	2.5	0.0	0.1	0.0	0.0	0.0
Gemma gemma	56	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	0.0	1.4
Hesionura sp.A	51	0.0	0.0	0.0	0.0	0.0	0.0	0.7	3.8	0.1	0.9	0.0	0.0
Polydora ligni	47	2.7	0.0	0.0	1.9	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.3

SEDIMENTS AND SEDIMENT

DISTURBANCE DURING DREDGING

SEDIMENTS AND SEDIMENT DISTURBANCE DURING DREDGING

By John F. Sustar

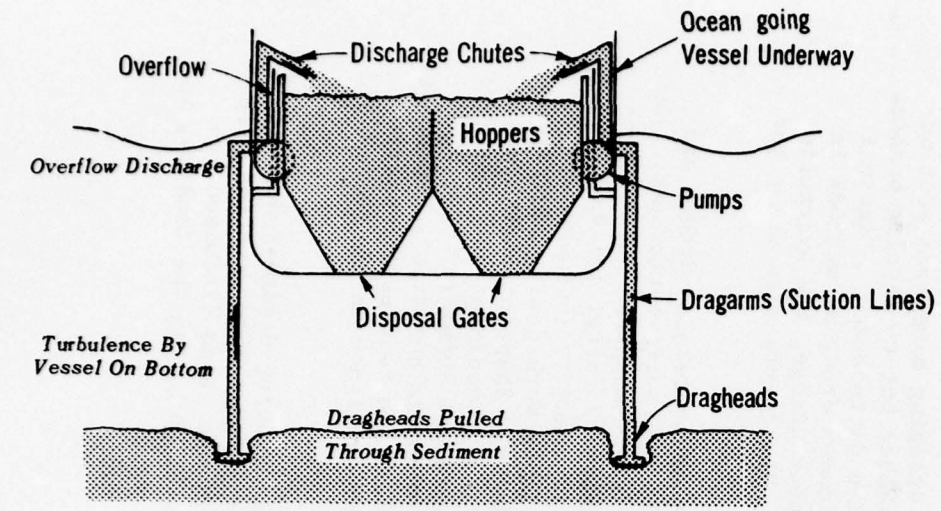
INTRODUCTION

During the past ten years numerous studies have been conducted in the field to quantify the disturbance during dredging operations. The results have generated wide ranges of data. The conclusions, however, do state that improving the dredging efficiency will decrease impacts or possible impacts of dredging operations. Despite extensive studies in San Francisco Bay, significant chemical and physical stresses on the biological communities have not been identified. The conclusion on improving dredging efficiency, however, is still valid in terms of not only minimizing the disturbance to the biological system, but also minimizing the investment in maintaining channels. Minimizing disturbance is also important where known isolated contamination is being removed.

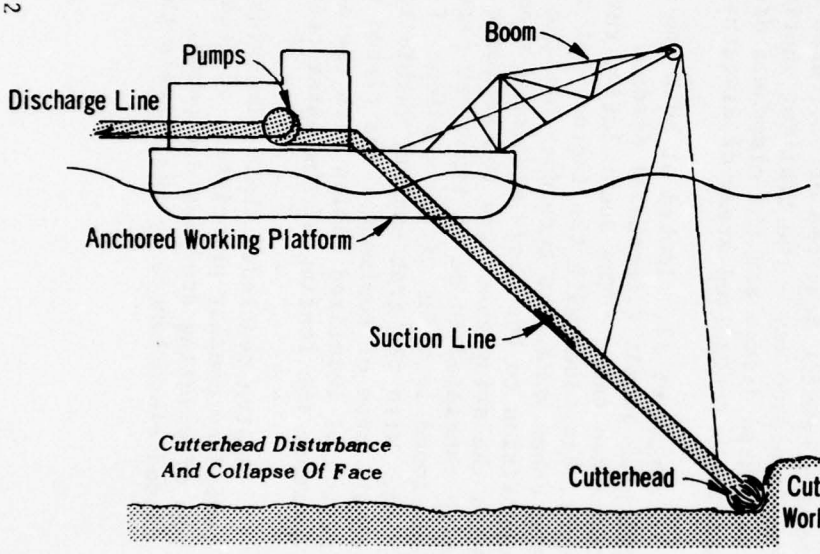
Studies of sediment disturbance during dredging have been continuously modified to not only locate the disturbance but to develop handles on identifying the parameters that control the disturbance. Figure 1 shows schematic diagrams of the three most common dredging methods in San Francisco Bay - the trailing suction hopper dredge, the hydraulic cutterhead dredge and the clamshell dredge. The figure also shows the generally recognized areas of disturbance.

Yagi, et al, looked at both the hydraulic cutterhead dredge and the grab bucket (clamshell) dredge. For the hydraulic cutterhead, they concluded that: "The accumulative ratio of short-absorbed soil, however, decreases with the increase of the number of cutter swings. On the other hand, the turbidity has the general trend to increase in opposition to the above mentioned trend". Their work dealt primarily with the swing speed and the sediment thickness. Shape of bottom was also concluded to be an important parameter. The sediment type was only mentioned in terms of the gradient of the vertical turbidity distribution. With the grab bucket, turbidity was found to be largely dependent on the type of sediment. The closed bucket, which reduces the interaction of localized eddies with the sediment interface in the bucket did decrease the loading of the water column.

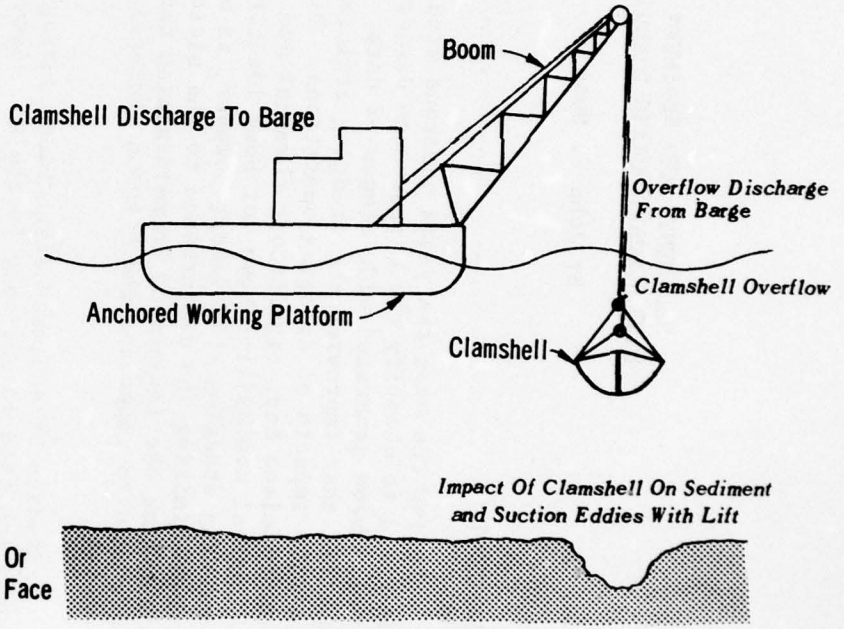
Huston concluded that: "Techniques for reducing dredge-induced turbidity consist principally of good dredging procedures and the proper use of existing dredging equipment. Some of the items discussed included disturbances by the vessels themselves including the tenders, the



TRAILING SUCTION HOPPER DREDGE



HYDRAULIC CUTTERHEAD DREDGE



CLAMSHELL DREDGE

FIGURE 1

inefficiency of cleanup operations and the effectiveness or skills of the personnel. His work did not discuss the relationship of the equipment and the type of sediment in disturbing both the bottom and the water column, although proper use of equipment does imply the selection of the type of equipment for a given project. With the spectrum of dredging operations and available equipment, this selection process is not necessarily controlled by the optimization of the operation efficiency.

The work by Wechsler, et al, does employ a settling jar to evaluate sediment characteristics for use in a numerical model. The mention, however, does not explain what actually occurs in the system.

Studies by Johnson, et al, showed the large scale heterogeneous loading characteristics of both the hopper dredge and the clamshell with dump scow. With the operation (elevation changes) of the dragheads on the hopper dredge, major differences were observed.

Sustar, et al, identified initial dispersion patterns related to the type of sediment and the dredging equipment. The major portion of their studies with the dredging operation concentrated on locating the plume and describing the plume vertically and horizontally by percent transmission and suspended solids loading. Although patterns were discernible, variation of data was very large. Studies were equipment oriented and project oriented.

The type of sediment being dredged has generally been ignored in terms of interpreting the disturbances that occur in the dredging area. Based on previous studies in San Francisco Bay on the release pattern during open water disposal, dredging operations in the Bay were evaluated in terms of the type of sediment and the efficiency of the operation. An interpretation of the bottom and water column disturbance using actual dredging operations and sediment testing is given.

DREDGING EFFICIENCY

If the basic premise (increased efficiency decreases disturbance) were reversed, a greater disturbance during the dredging should reduce the efficiency of the operation. To test this, three dredging periods in Mare Island using the trailing suction hopper dredge HARDING were evaluated. Figure 2 shows the location of Mare Island Strait.

The shoaling in Mare Island Strait is silty-clay. The October-November 1975 dredging period represented a shoal formed over a several month period with sediments recirculating in the northern portion of the Bay. The second period was February-March 1976. The shoaling generally represents new sediments entering the system with outflows from the Sacramento-San Joaquin Delta.

The third period was July-August 1978. Following an extended drought, flood flow brought new sediments from the Delta. The delayed dredging from the usual February-March cycle probably developed with progressive movement of sediments through the Delta and Carquinez Strait with each storm following the drought. The total dredging cycles for each of the periods were 606, 430 and 396, respectively. Shoaling patterns in Mare Island Strait are very definite with buildups concentrating in three to four areas.

From the vessel's records, the cubic yards per pumping minute was obtained for each cycle using the load meter and the pumping time. The data was averaged in ten cycle groups to reduce the variability between successive cycles. The variability between cycles results from the heterogeneous nature of the bottom and variations in dredging location with movement of vessels and day/night time dredging. The average efficiency and plus and minus one standard deviation are shown in figures 3 through 5.

All three periods show a decrease in loading efficiency with time. The first and second periods show definite cycles of decreasing efficiency indicating a work pattern of removing one shoal at a time. The type of equipment (trailing drags) working the shoal of silty-clay causes both trenching of the shoal and disturbance with mixing of water in the shoal. After a number of passes through the shoal, the dragheads will cross previous trenches resulting in the intermittent variation of suction at the intake, increased water in the slurry and subsequent reduction in the density of the pumped sediment. The decreased loading efficiency of each of the discernible cycles (low ten cycle average divided by preceding high ten cycle average) are as follows:

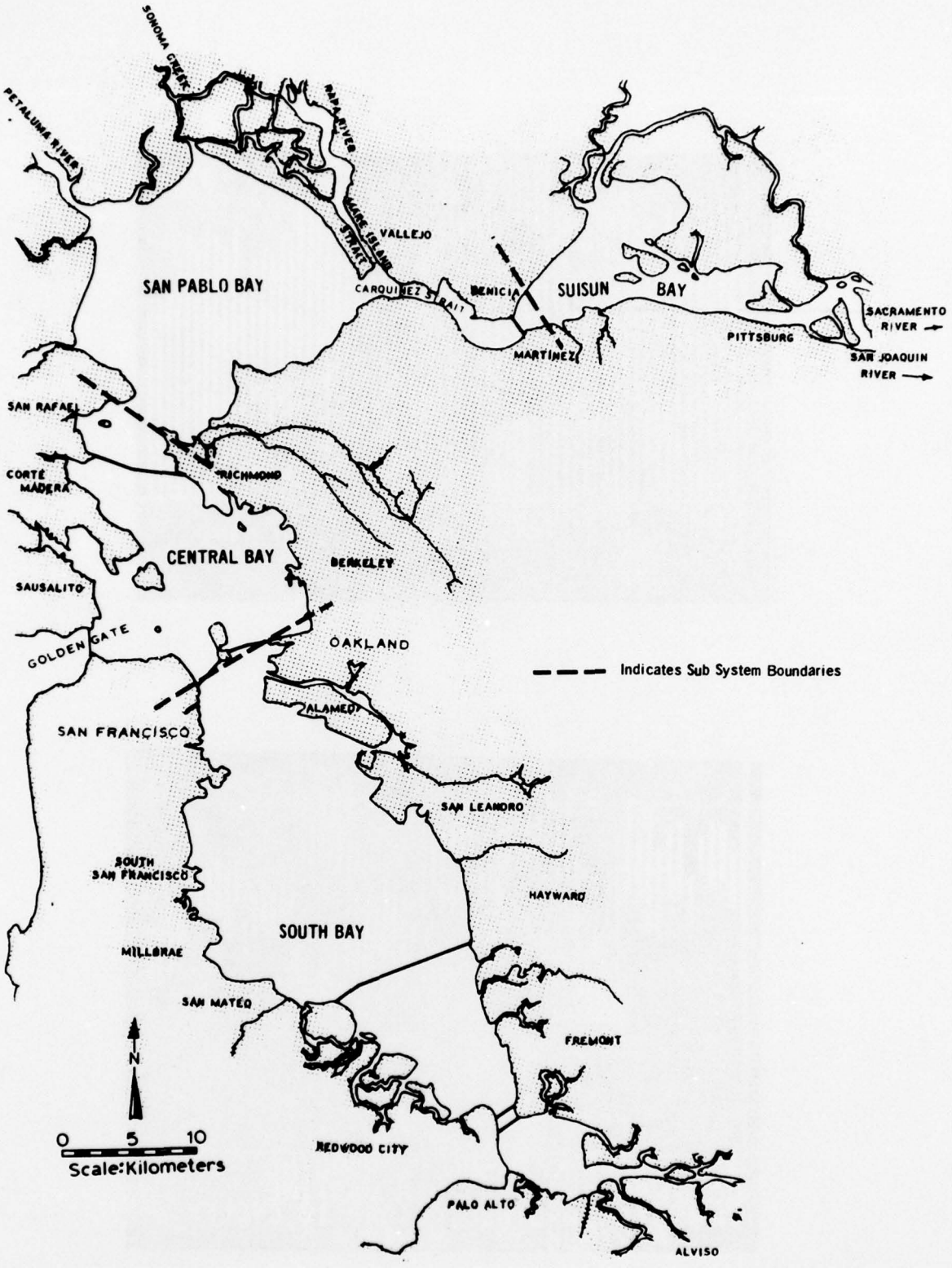

SONOMA CREEK
PETALUMA RIVER
NAPA RIVER
MARE ISLAND STRAIT
VALLEJO
SAN PABLO BAY
CARQUINEZ STRAIT
BENICIA
SUISUN BAY
SACRAMENTO RIVER
PITTSBURG
SAN JOAQUIN RIVER
MARTINEZ
SAN RAFAEL
RICHMOND
CORTE MADERA
CENTRAL BAY
BERKELEY
SAUSALITO
GOLDEN GATE
OAKLAND
ALAMEDA
SAN FRANCISCO
SAN LEANDRO
SOUTH SAN FRANCISCO
HAYWARD
SOUTH BAY
MILLBRAE
SAN MATEO
FREMONT
REDWOOD CITY
PALO ALTO
ALVISO
N
0 5 10
Scale: Kilometers
Indicates Sub System Boundaries

FIGURE 2


MARE ISLAND DREDGING-HARDING
OCT-NOV 1975 YO3/MIN VS TIME
AVERAGE 10 CYCLES
HIGH 117 LOW 68

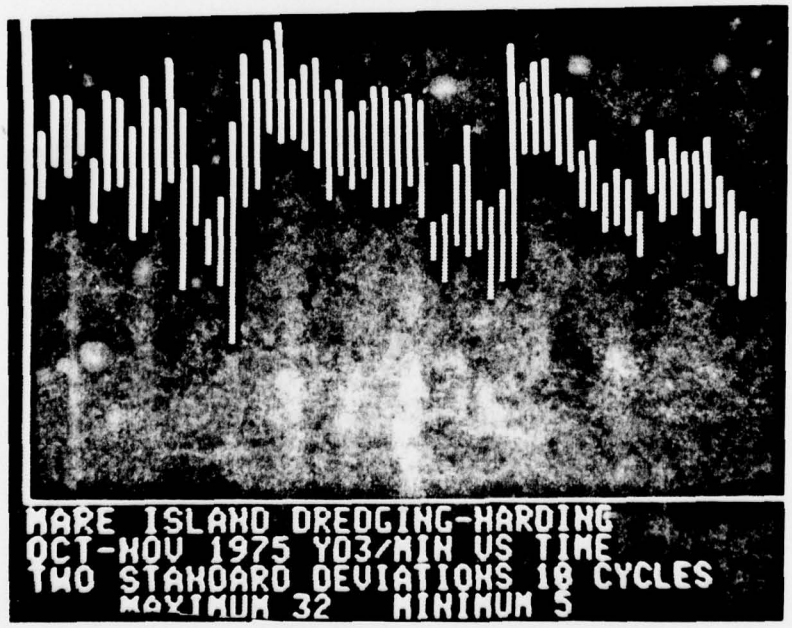
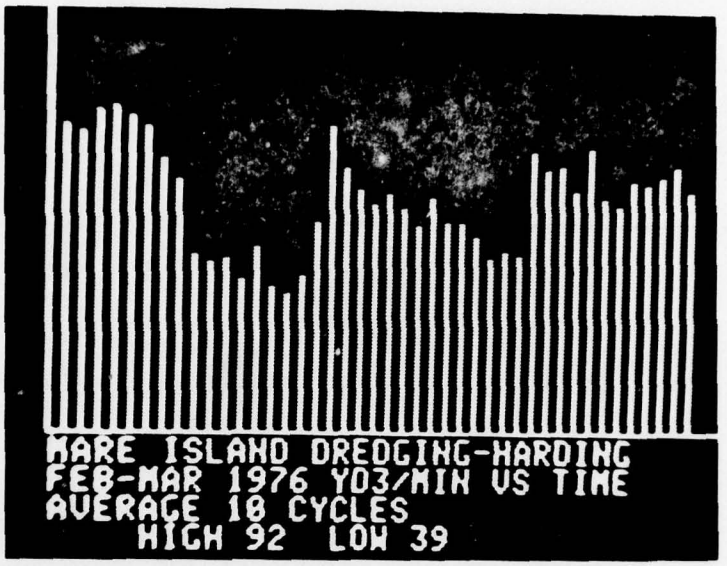

MARE ISLAND DREDGING-HARDING
OCT-NOV 1975 YO3/MIN VS TIME
TWO STANDARD DEVIATIONS 10 CYCLES
MAXIMUM 32 MINIMUM 5

FIGURE 3


MARE ISLAND DREDGING-HARDING
FEB-MAR 1976 YD3/MIN VS TIME
AVERAGE 10 CYCLES
HIGH 92 LOW 39

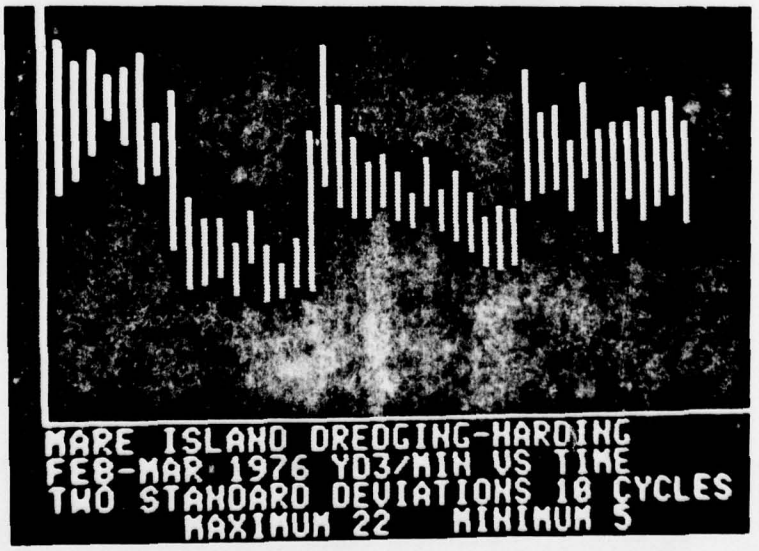
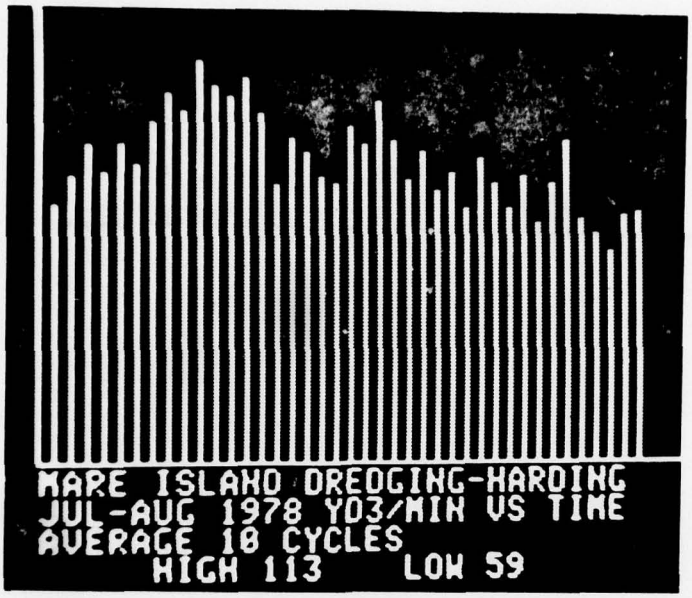

MARE ISLAND DREDGING-HARDING
FEB-MAR 1976 YD3/MIN VS TIME
TWO STANDARD DEVIATIONS 10 CYCLES
MAXIMUM 22 MINIMUM 5

FIGURE 4


MARE ISLAND DREDGING-HARDING
JUL-AUG 1978 YO3/MIN VS TIME
AVERAGE 10 CYCLES
HIGH 113 LOW 59

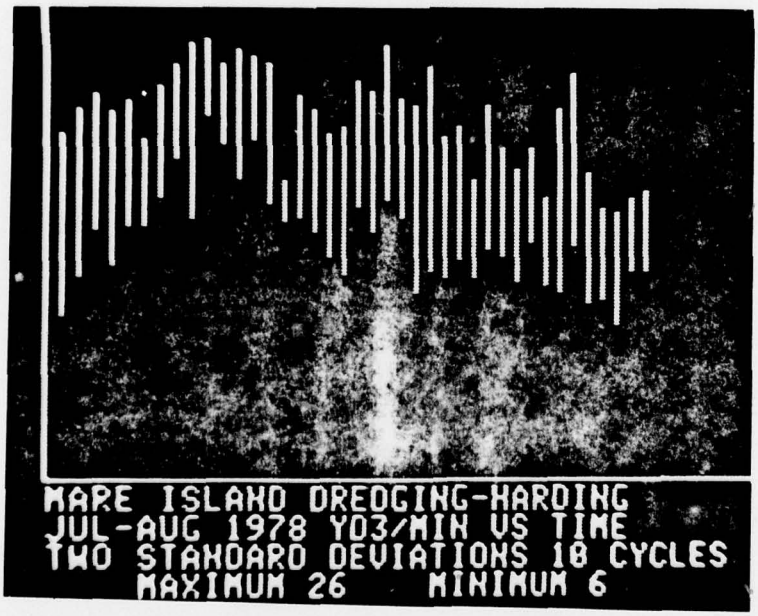

MARE ISLAND DREDGING-HARDING
JUL-AUG 1978 YO3/MIN VS TIME
TWO STANDARD DEVIATIONS 10 CYCLES
MAXIMUM 26 MINIMUM 6

FIGURE 5

	Oct-Nov 75	Feb-Mar 76	Jul-Aug 78
1st cycle	72%	42%	55%
2nd cycle	59%	57%	-
3rd cycle	62%	81%	-

The decrease is based on an "average optimum" condition with the initial dredging of an undisturbed area.

Although patterns of decreasing efficiency of pumping are evident, the analysis also shows some increases in efficiency. As the shoals form with time, different densities occur in the bottom. Assuming optimal operation of the vessel including the control of the dragheads and the speed of the vessel relative to the bottom, pumping efficiency is dependent on the density of the sediment. As the bottom sediments are disturbed, increasing the water content, an initial increase in pumping efficiency will occur until an optimum pumping density is reached. As the disturbance continues, the density continues to decrease, decreasing the pumping efficiency.

SEDIMENT RELATIONSHIPS

Three types of sediments were collected in San Francisco Bay to examine qualitatively the comparative degree of disturbance with resulting bottom configuration (trenching) and suspended particulate. The classification of the sediments is as follows:

	Classification	Liquid Limit	Plastic Limit	PI
1	Silty Sand (SM)	31	26	5
2	Sand (SP)	-	-	-
3	Clay (CH)	99	38	61

The gradation curves are shown in Figure 6.

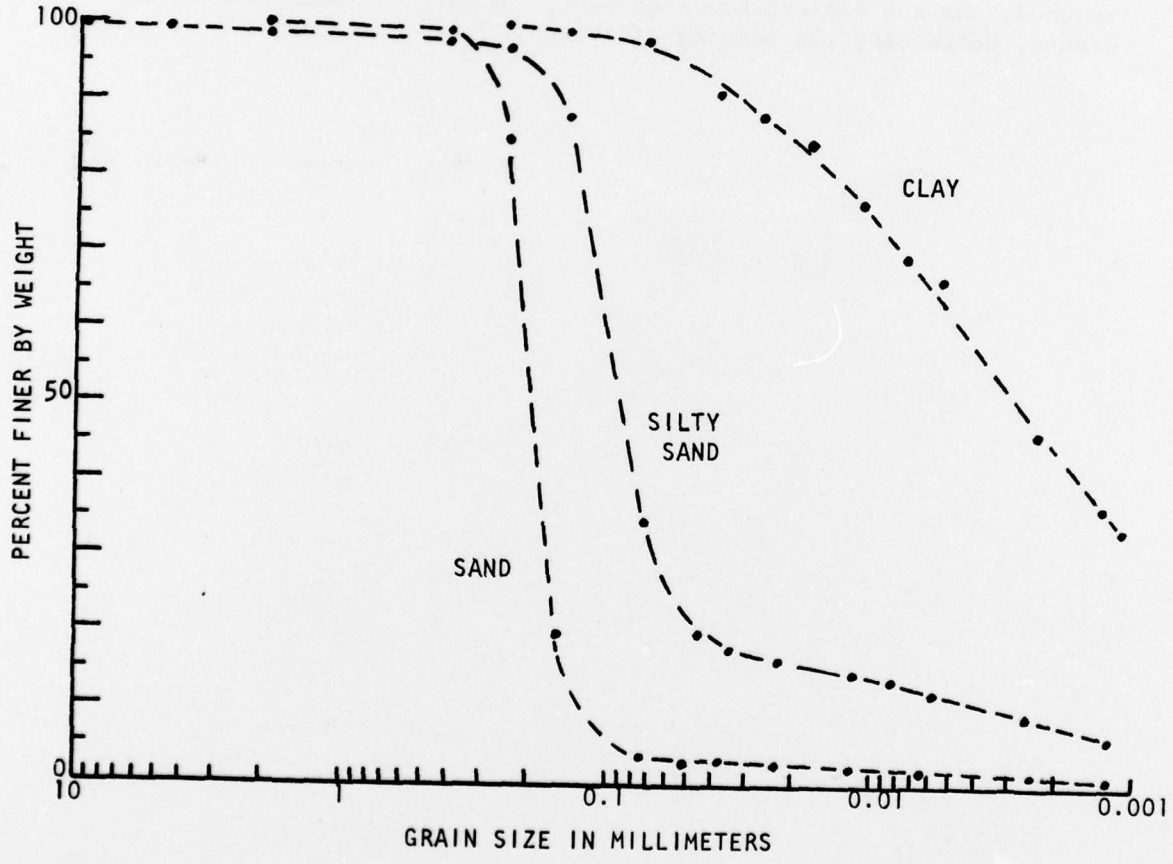


FIGURE 6

The sediments were placed in clear 30 cm x 16 cm containers with nine centimeters of salt water over the sediments. A standard disturbance was made in each container using a nine millimeter diameter rod. The rod was pulled along the same line in groups of five pulls. Uniform speed and pressure was maintained.

The clay, sample 3, produced the best defined trench with vertical side walls. The width of the trench (15 cm) was not significantly changed with increased disturbances along the same line. The silty sand, sample 1, also developed a trench. Vertical walls were present, but were not as well defined as with the clay. The width of the trench (25 cm) increased with increasing disturbance. The sand, sample 2, developed a V-shaped trench, 30 cm at the top.

Sand produced very little turbidity when comparing the suspended particulate to a photo density scale (visual observation). The silty sand almost immediately produced high turbidity with very little increase in turbidity with additional disturbance. The clay produced successive increase in turbidity with each additional disturbance. The maximum turbidity with the clay was greater than with the silty sand.

The differences in the trenches can be explained by the type of sediment irrespective of the type of disturbance. Following a disturbance the sand comes to an angle of repose, resulting in a V-shaped trench. The silty sand maintains some vertical wall because it is a low cohesive sediment. The increased width of the trench results from the susceptibility of the sediments to erode with successive disturbances. As the cohesive properties of the sediment increase, the direct action by the disturbing instrument is required to move the sediments. The narrow width of the clay trench is an example.

Within San Francisco Bay, the type of sediment does influence the pumping efficiency when comparing Mare Island Strait (clay), Richmond Harbor (silt) and the San Francisco Bay (fine sand). Mare Island Strait sediment is conducive to the most efficient pumping. The San Francisco Bar sediment results in the least pumping efficiency. Pumping efficiency is defined by cubic yards of load per pumping minute.

In Mare Island Strait, the sediments are less susceptible to mixing with water; that is, more energy or disturbance is required to decrease the density. It should be noted that efforts are made to control the dredging lines (i.e., reduce the crossing of trenches). Dredging cycles have been conducted in Mare Island Strait with a hopper dredge in which no overflow was required to attain an economic load. This means that the sediments were near optimum pumping density and excellent control of dredging lines was maintained.

The silts in Richmond Harbor are easily disturbed, resulting in a sediment density below the optimum pumping density. The sands on the San Francisco Bar are independent of the disturbance. The pumping efficiency is controlled by the efficiency of the pumps rather than the disturbance of the sediment. The speed of the dredge over the bottom largely influences the loading characterization.

The same dredging operations in San Francisco Bay illustrate the levels of suspended particulates during dredging. Greater turbidity (reduced light transmission) results from clays because of the increased number of particles in suspension per unit weight as compared with silts. The level of clay loading (weight suspended solids) is dependent on the duration of disturbance (addition and mixing of water to decrease the cohesive properties) and the flocculation rate. The flocculation rate is dependent on the concentration of suspended solids, salinity of the system and collision of particles (disturbance in the operation, i.e., overflow, and in the water column, i.e., passage of the vessel). With Mare Island Strait sediments, the non-dispersed grain size is about 20 micron. Without additional disturbance, the clays within the hydraulic regime will react as silts. Although the level of suspended solids in the water column between clays and silts may be similar, percent transmission will be dramatically different. Figure 7 presents a logarithmic regression analysis of seven sets of data. The data presents in-situ percent transmission readings, using a ten centimeter light pattern, compared with suspended solids analysis of samples pumped from adjacent to the transmissometer. The analysis does fit the above description. The clays of Mare Island Strait generate the highest turbidity (decreased light transmission) as compared to the coarser silts in other areas such as Richmond Harbor and Alameda Naval Air Station. Within the three regression curves of Mare Island Strait, the lowest of the curves is at a time of lower salinity with freshwater flows coming from the Sacramento-San Joaquin Delta. The lower salinity of both the sediment and the water decreases the rate of flocculation and increases the time of sediments in suspension. Dredging with stratified conditions in Mare Island Strait have been monitoring in which the operation introduced the saline water from the lower water column into the freshwater in the upper water column. The results were a decrease in turbidity in the upper water column due to flocculation.



Line	Location	Date	n	f(x)	r^2
A	Mare Island Strait	Sep-Oct 74	104	55.91-9.22 lnx	0.56
B	Mare Island Strait	Mar 75	24	7.87-1.41 lnx	0.46
C	Alameda NAS	Oct 75	30	46.33-8.30 lnx	0.54
D	Alameda NAS	Dec 74	38	120.59-15.58 lnx	0.26
E	Alameda NAS	Jan 75	99	117.09-20.66 lnx	0.42
F	Richmond Harbor	Nov 74	83	135.17-21.22 lnx	0.35
G	Petaluma Channel	Sep 77	268	114.66-18.68 lnx	0.75

(1) f(x) = % transmission 10 cm light path
(2) Samples greater than 500 mg/l suspended solids excluded
(3) Samples 0% transmission entered as 0.01%

FIGURE 7

The turbidity associated with sand is limited to the percent silts and clays in the sediment and the type and size of equipment. The type and size of equipment relates to the disturbances and the absorption ratio. The absorption ratio is the ratio of sediment removed divided by sediment disturbed. The hopper dredge, working with sand, does introduce grading of sediments during dredging. Fines are separated through the overflow. The reduced fines level in the hopper does result in lower turbidity during disposal. This also is reflected in the contaminant levels. Contaminants in the disposed sediments are less than the in-situ project sediments. A large clamshell dredge will maintain a greater percentage of fines for transport. The turbidity during disposal, however, will be greater than with a hopper dredge because the fines are still present. The turbidity from a hydraulic cutterhead will depend on the ratio of absorbed sediments which in turn relates to the suction's pickup capacity, swing speed, working face and type of sediment. The four elements are interdependent.

CONCLUSIONS

The type of sediment being dredged is a major parameter in evaluating both the disturbance generated by the operation and the efficiency of the operation. The disturbance and the efficiency are related. With silts and clays a less efficient operation means that more energy is being expended in adding and mixing water with the sediment. As the disturbance increases, the efficiency continues to decrease.

Many studies have been conducted during the past several years to define the disturbance during dredging. The great variation of results within and between studies probably could be correlated if the type of sediment, the shape and condition of the shoal, the type of equipment, the method of operation and relative time of sampling were entered into the analysis. The liquid limit and water content (presented as multiples of the liquid limit) of the sediments at any particular time and location of the operation are proposed as a common basis for evaluating levels of suspended solids in the water column.

Continuous "optimum" efficiency of a dredging operation can not be expected. Other constraints override the optimum conditions, such as the availability of a particular type and size of dredges, requirements to minimize interruptions of commerce, localized channel requirements and safety. Some of the factors can be controlled or developed to increase or maintain the efficiency of the operation. Training operating personnel to become familiar with the equipment in various types of sediments and shoal configurations is probably the most effective. Use of instrumentation for horizontal and vertical control will also increase efficiency. With hydraulic systems such as the hopper dredge and the cutterhead dredges, recently developed instrumentation should be utilized to indicate immediate pumping response to both increase and decrease in pumping densities. Clogging of pumps or breakage of sediment suction will be reduced and a more "optimum" density will be maintained. The design of the dredging operation should minimize feather shoals and cleanup requirements. This may mean an evaluation of neat line payment schedules in favor of some combination of neat line and pumpage quantities.

ACKNOWLEDGEMENT

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Critical comments by Mr. William Dickson of the District's Operations Division is appreciated. Special thanks is extended to my two oldest children, Peter and Mary, who have reached the age of a scientific appreciation to play with mud. Their assistance in mixing the mud, making observations and measurement and cleaning up afterwards was a great help.

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