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NAVAL STATION TREASURE ISLAND
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

PHASE 1A ECOLOGICAL RISK ASSESSMENT
TASK 3 SUMMARY REPORT

CHARACTERIZATION OF HABITATS AND BIOTA

APPENDIX X - OFFSHORE SURVEYS

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Naval Station Treasure Island, Hunters Point Annex

Technical Report

Demersal Fish Surveys

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1.0 Background

PRC Environmental Management, Inc. (PRC) is under contract to the Department of the Navy to implement the Ecological Risk Assessment Work Plan (WP) under the Comprehensive Long-term Environmental Action Navy (CLEAN) at the Naval Station Treasure Island, Hunters Point Annex (HPA), in San Francisco, California. BioSystems Analysis, Inc. (BioSystems) was contracted by PRC to perform the aquatic survey portion of the Phase 1A ecological risk assessment. The aquatic investigations in this phase of the ecological risk assessment are reconnaissance surveys that will help focus future quantitative data collection efforts. The objective of the WP is to identify the possible ecological impacts on biota of hazardous material used and disposed of within the project area at HPA. The scope of work required compiling information on the composition and abundance of biota at HPA. The results of this study and others will be used to design and implement a more comprehensive field sampling and analysis plan for subsequent phases of work. This report addresses the work BioSystems conducted for the demersal fish sampling program only. Results of the intertidal, benthic, and epibenthic sampling programs will be summarized in subsequent reports.

2.0 Technical Approach

BioSystems' study characterized the demersal fish community in the HPA project area and an "undisturbed" reference area in San Francisco Bay and compared the results. The reference site (just south of Candlestick Park) was selected by PRC after a review of studies in San Francisco Bay and agency consultation. To characterize aquatic resources, BioSystems collected samples from the intertidal, benthic, and epibenthic invertebrate communities and from the demersal fish community. Sampling methods for the demersal fish survey are outlined in Section 2.1. For each sample, we reported the collection date, time, location, species composition and abundance and other pertinent information. The location of each sampling site was placed on a map for future reference. The position (latitude and longitude) of each sampling location was also documented using a global positioning system (GPS) unit to ensure accurate site identification. Due to selective availability imposed by the U.S. Department of Defense, all GPS units have a maximum error range of about 100 meters. During fish trawling, we recorded the coordinates (latitude and longitude) at the start and end of each survey to allow for replication in future phases of the study, if necessary. The following section describes the demersal fish sampling program only. The intertidal, benthic, and epibenthic programs are addressed in separate reports.

2.1 Field and Laboratory Methods

2.1.1 Demersal Fish Sampling

The demersal fish survey was designed to provide information on the composition and abundance of demersal fish communities in the subtidal area of Hunters Point. We selected five stations in the same general areas as the epibenthic sampling stations (three in South Basin, one in India Basin, and one just south of Candlestick Park). The locations of the demersal fish trawls are documented in Table 2.1 and Figure 2.1.

BioSystems' fisheries biologists conducted the demersal fish surveys on 5 and 6 November 1993 by towing a 16-foot otter trawl behind an 18-foot Boston Whaler. The trawl consisted of a 1-1/8-inch stretch mesh outer net and an inner liner of 1/2 inch stretch mesh at the cod end. Two trawls were conducted at each station by towing perpendicular to and away from the shoreline for 6-9 minutes. The length of each trawl varied with tidal currents, depth, substrate and fish density. If the net became clogged with sediment or debris, we stopped towing, cleared the net and repeated the trawl.

Figure 2.2 summarizes the sampling and analysis procedures. After each trawl, all fish were identified to species, counted and measured. If many individuals of the same species were collected, we measured a subsample (n=25). The date, time, personnel, GPS coordinates, weather, water depths, trawl duration, number and measurements of species collected were noted on data sheets. In addition, we recorded any evidence of disease, tumors, or other physical abnormalities in all specimens collected.

Table 2.1 Description of demersal fish surveys conducted at the Naval Station Treasure Island, Hunters Point Annex.

Station Number	Trawl Number	Date	Start Time	End Time	Weather	Depth (ft)	Start Location		End Location	
1	1	11/06/93	10:09	10:17	Sunny	5.0-12.0	N: 37° 43' 5.82"	W: 122° 22' 13.56"	N: 37° 42' 45.18"	W: 122° 22' 2.28"
1	2	11/06/03	10:26	10:23	Sunny	5.0-12.0	N: 37° 43' 5.82"	W: 122° 22' 13.56"	N: 37° 42' 45.18"	W: 122° 22' 2.28"
2	1	11/06/93	11:35	11:44	Sunny	4.8-7.2	N: 37° 43' 7.2"	W: 122° 22' 20.76"	N: 37° 42' 43.2"	W: 122° 22' 30.42"
2	2	11/06/93	11:52	11:59	Sunny	4.4-7.2	N: 37° 43' 7.2"	W: 122° 22' 20.76"	N: 37° 42' 43.2"	W: 122° 22' 30.42"
5	1	11/05/93	15:16	15:23	Sunny	7.0-9.6	N: 37° 43' 13.14"	W: 122° 22' 46.68"	N: 37° 42' 59.88"	W: 122° 22' 26.52"
5	2	11/05/93	15:48	15:57	Sunny	7.0-9.6	N: 37° 43' 13.14"	W: 122° 22' 46.68"	N: 37° 42' 59.88"	W: 122° 22' 26.52"
8	1	11/05/93	12:58	13:05	Sunny	7.2-30.0	N: 37° 43' 58"	W: 122° 22' 5.0"	N: 37° 44' 15.7"	W: 122° 21' 39.7"
8	2	11/05/93	13:19	13:25	Sunny	7.0-28.0	N: 37° 43' 58.2"	W: 122° 22' 4.4"	N: 37° 44' 11.3"	W: 122° 21' 44.1"
9	1	11/06/93	08:02	08:11	Sunny	4.0-9.0	N: 37° 42' 35.64"	W: 122°° 23' 9.12"	N: 37° 42' 17.4"	W: 122° 22' 58.5"
9	2	11/06/93	08:21	08:28	Sunny	5.0-9.0	N: 37° 42' 35.64"	W: 122°° 23' 9.12"	N: 37° 42' 17.4"	W: 122° 22' 58.5"

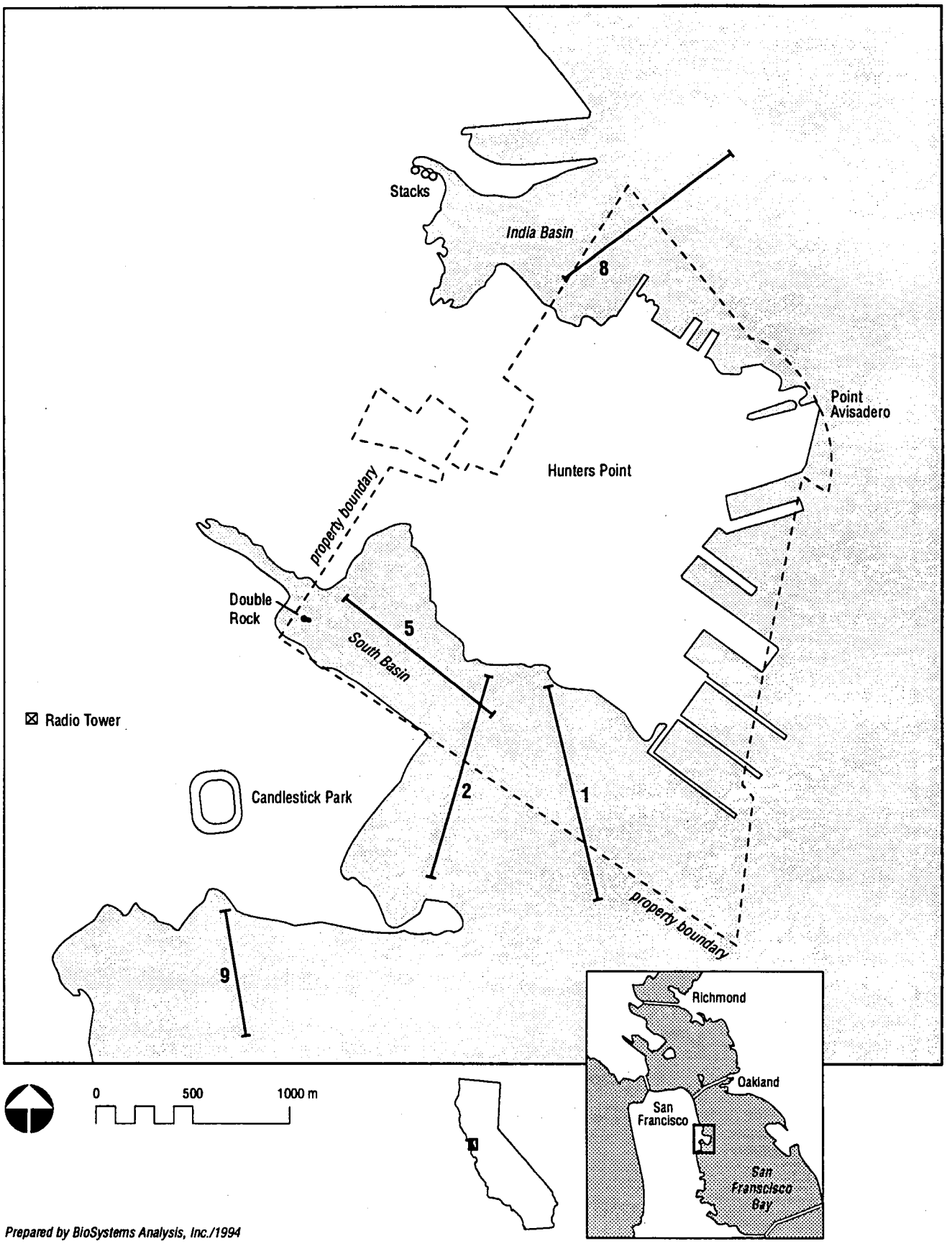
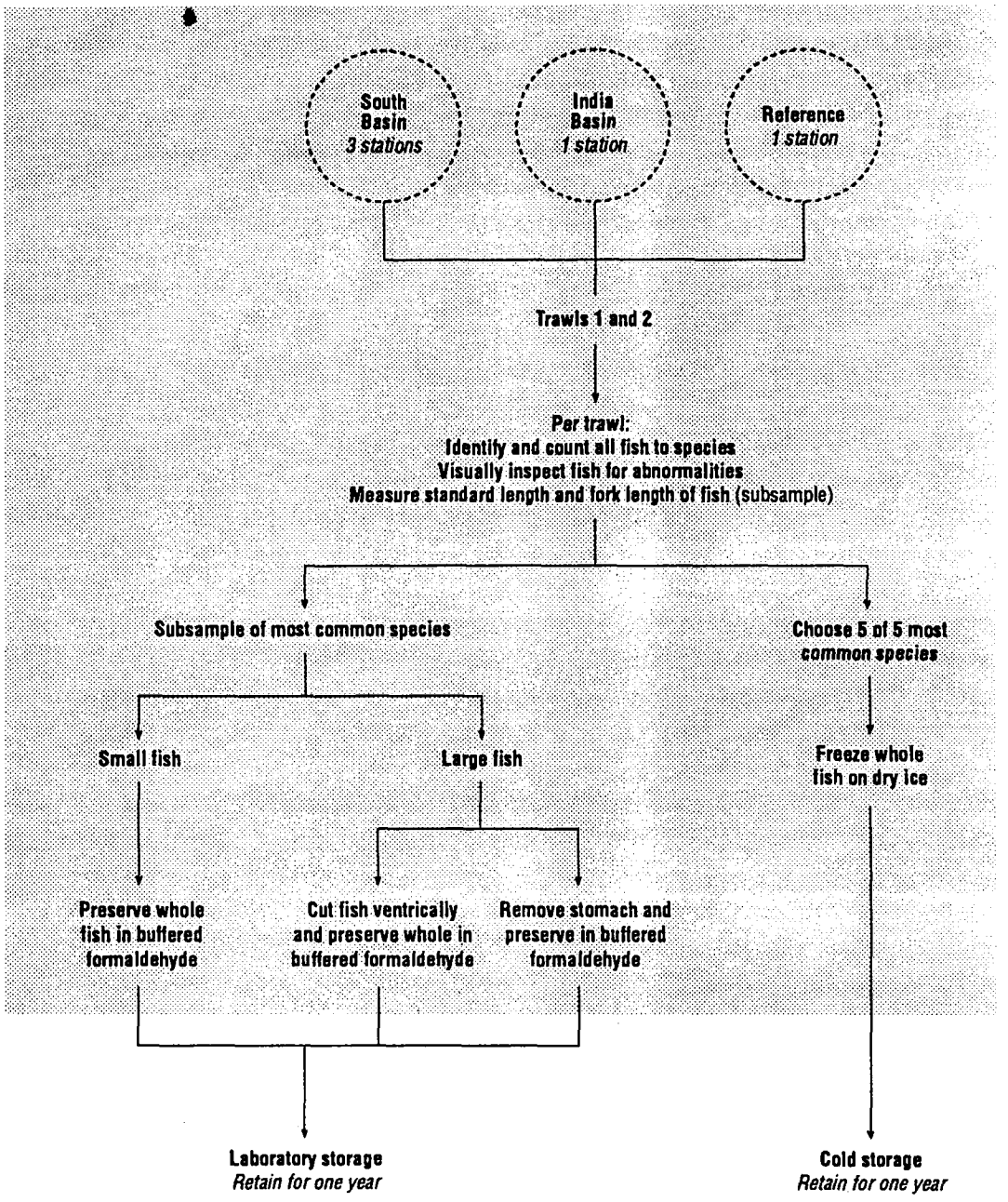


Figure 2.1 Location of demersal fish trawl surveys conducted at Naval Station Treasure Island, Hunters Point Annex.



= field activity

Prepared by BioSystems Analysis, Inc./1994

Figure 2.2 Summary of demersal fish sampling and analysis procedures.

When available, we reserved a maximum of 10 specimens of the five most common species collected at each station (both trawls combined) for future stomach content analyses and chemical/histo-pathological analysis. All other fish caught during trawling were released live at the collection site. We selected five specimens of each species for stomach content analysis. Small fish were preserved whole, whereas, for large fish, the stomach was removed and preserved in buffered formaldehyde in a glass or plastic jar. The chemically-preserved specimens were stored in the laboratory. The remaining five specimens were frozen in plastic bags and transferred to cold storage (0±5° F). These samples will be securely retained for one year from the date of collection.

2.2 Data Entry and Analytical Methods

All field and laboratory data forms were copied and retained at two locations for safety. Data from all other forms were entered into a database computer program for further analysis on species composition and abundance. Once data was entered into the database program, a hard copy was printed and checked for errors. Data entry was verified and corrected prior to analysis.

All data were backed up automatically on BioSystems' client/server computer network system (Novell Netware 3.11). All files stored on the network were automatically duplicated on tape every night using the grandfather/father/son rotation method that rotates 10 tapes over a 12 week period. This method provided a high degree of data redundancy and security.

The mean and standard error of the number of fish at each station were calculated for all species combined. Student-Newman-Keuls (SNK), Duncan, and Scheffe multiple comparison methods (Snedecor and Cochran 1980) were used to determine the differences in abundance estimates.

We used the Margalef (1958) index, R1, and the Menhinick (1964) index, R2, to measure species richness for each of the five stations. The R1 index can be calculated as follows:

$$R1 = \frac{S-1}{\ln(n)} \tag{1}$$

where S is the number of species in a community (i.e., sample); n is the number of individual observed in a sample.

The R2 index is:

$$R2 = \frac{S}{\sqrt{n}} . \tag{2}$$

Diversity indices incorporate both species richness and evenness into a single value (Ludwig and Reynolds 1988). We applied two of the most commonly used diversity indices, N1 and N2, presented by Hill (1973) in this study. The N1 index measures the number of abundant species in the sample which can be expressed as:

$$N1 = e^{H'} \tag{3}$$

where H′ is the Shannon index (Shannon and Weaver 1949). The value of H′ can be estimated from a sample as:

$$\hat{H} = -\sum_{i=1}^{S} [(\frac{n_i}{n})\ln(\frac{n_i}{n})] \tag{4}$$

where n_i is the number of individuals belonging to the *i*th of S species in the sample; n is the total number of individuals in the sample.

The N2 index measures the number of very abundant species which can be formulated as:

$$N2 = \frac{1}{\lambda} \tag{5}$$

where λ is the Simpson's index (Simpson 1949). The unbiased estimator for λ is:

$$\hat{\lambda} = \sum_{i=1}^{S} \frac{n_i(n_i-1)}{n(n-1)} . \tag{6}$$

Then, we used a modified Hill's ratio (Hill 1973, Alatalo 1981), E5, to quantify the evenness component of diversity. The E5 is:

$$E5 = \frac{(1/\lambda)-1}{e^{H'}-1} = \frac{N2-1}{N1-1} . \tag{7}$$

Since the SNK is one of the most powerful multiple comparison method (Snedecor and Cochran 1980), we used this method to compare each of the above indices among the five stations.

2.3 Quality Assurance/Quality Control (QA/QC) Methods

2.3.1 Field Equipment

Prior to sampling, all equipment was visually inspected, cleaned and tested to ensure proper performance. For all sampling equipment used, we used a checklist of components to be inspected, cleaned and tested. Data sheets documenting these inspections were completed prior to use at each station and retained by BioSystems. These inspections were especially critical for the epibenthic and otter trawls since nets may be torn during surveys. Any problems or repairs to the equipment during the surveys were documented.

2.3.2 Sample Tracking

Each specimen collected in the field for the reference collection or preserved for future stomach analysis or chemical or histopathological analysis was assigned a unique permanent number, which was recorded on a sampling log sheet. Each specimen container was labeled with the sample number; date, time and location of collection; and the names of personnel who collected the sample. For each sample, a chain of custody/sample tracking form was maintained that included the following information: sample number, sampling date, community type sampled, container type and size, and chain of custody information. The chain of custody/sample tracking forms were maintained in a binder in a secure central location and were available for review by the project manager at any time.

2.3.3 Verification of Identification

We developed a reference collection to allow verification of our species identification. Mr. Don Pearson, fisheries biologist with the National Marine Fisheries Service, reviewed the reference collection and verified our species identification. Neither BioSystems fisheries biologists nor Mr. Pearson were able to definitely identify to species the larval gobies collected.

3.0 Results

3.1 Abundance

The species composition and number of fish caught in each trawl (Trawl 1 and Trawl 2) at each station (Station 1, Station 2, Station 5, Station 8, and Station 9) are summarized in Table 3.1. A total of 1,861 fish representing 10 species were recorded for all stations combined. Northern anchovy (*Engraulis mordax*), a pelagic species, was the dominant species collected, comprising 97 percent of the catch. Few demersal fish were collected during our survey at any of the sampling stations.

The SNK and Duncan methods indicate the mean fish abundance was significantly higher at Station 9 ($P < 0.05$) than at the other four stations (Table 3.2). The more conservative Scheffe test, however, showed that although mean abundances at Stations 1, 2, 5, and 8 were not significantly different (Table 3.2), fish abundance at Station 9 was significantly higher than at Stations 1, 2, and 5. No significant difference in fish abundance at Stations 8 and 9 was detected using the Scheffe test.

3.2 Richness, Diversity, and Evenness Indices

Table 3.3 lists the richness, diversity and evenness indices calculated for each trawl and station. SNK tests indicated no significant differences among the stations for any of the indices (Table 3.4).

3.3 Fish Length

We measured the total forked length (FL) and standard length (SL) of a subsample of fish collected at each station. The mean SL and associated standard error for each of the species are presented in Table 3.5. Because northern anchovy made up 97 percent of the total catch, we used the SNK test to compare mean SL only for northern anchovy among the five stations. Figure 3.1 shows the SL length frequency for northern anchovy at each station. The results of multiple comparison indicated that fish at Stations 2 and Station 9 were significantly larger than those at Stations 1, 5, and 8 (Table 3.6).

3.4 Fish Health

We observed external parasites on 38 northern anchovies collected at Stations 5, 8, and 9 (Table 3.7). At Station 2, we collected seven northern anchovies with unusual colorations and markings on their lateral side. One silver surfperch collected at Station 5 had deformed maxilla.

Table 3.1 Species composition and abundance of demersal fish collected during trawl surveys at the Naval Station Treasure Island, Hunters Point Annex.

Taxa		Number of Fish Caught at Station									
Family Species	Scientific Name	Station 1		Station 2		Station 5		Station 8		Station 9	
		Trawl 1	Trawl 2	Trawl 1	Trawl 2	Trawl 1	Trawl 2	Trawl 1	Trawl 2	Trawl 1	Trawl 2
Embiotocidae											
silver surfperch	*Hyperprosopon ellipticum*	2	2	2	9	9	3	4	2	6	
white surfperch	*Phanerodon furcatus*							1	1		
Engraulididae											
northern anchovy	*Engraulis mordax*	18	143	220	5	16	62	148	165	449	574
Syngnathidae											
bay pipefish	*Syngnathus leptorhynchus*					2					
Batrachoididae											
plainfin midshipman	*Porichthys notatus*									1	
Gobiidae											
chameleon goby	*Tridentiger trigonocephalus*									1	
cheekspot goby	*Ilypnus gilberti*				2						
larval goby spp.				1	4	7				1	
Bothidae											
California halibut	*Paralichthys californicus*			1							
speckled sanddab	*Citharichthys stigmaeus*		1								
Total number of fish captured			20	146	224	20	34	65	153	168	458574
Mean		83.0		122.0		49.5		160.0		516.0	
Standard error		63.0		102.0		15.5		7.5		58.0	

Table 3.2 Mean number of fish collected during trawl surveys at the Naval Station Treasure Island, Hunters Point Annex including results of the SNK, Duncan, and Scheffe multiple comparison tests. (The same letters between stations for each test indicate no significant difference at $P \geq 0.05$.)

Station	N	Mean	S.E.	SNK	Duncan	Scheffe
1	2	83.0	63.0	B	B	B
2	2	122.0	102.0	B	B	B
5	2	49.5	15.5	B	B	B
8	2	160.5	7.5	B	B	A B
9	2	516.0	58.0	A	A	A

Table 3.3 Summary of richness diversity and evenness indices for demersal fish surveys conducted at the Naval Station Treasure Island, Hunters Point Annex.

	Station 1		Station 2		Station 5		Station 8		Station 9	
Index	**Trawl 1**	**Trawl 2**	**Trawl 1**	**Trawl 2**	**Trawl 1**	**Trawl 2**	**Trawl 1**	**Trawl 2**	**Trawl 1**	**Trawl 2**
Margalef's Index (R1)	0.33	0.40	0.55	1.00	0.85	0.24	0.40	0.39	0.65	0.00
Menhinick's Index (R2)	0.45	0.25	0.27	0.89	0.69	0.25	0.24	0.23	0.23	0.04
Hill's Diversity Number 1 (N1)	1.38	1.12	1.11	3.52	3.32	1.21	1.17	1.11	1.12	1.00
Hill's Diversity Number 2 (N2)	1.23	1.04	1.04	3.58	3.15	1.10	1.07	1.04	1.04	1.00
Modified Hill's Ratio (E5)	0.61	0.35	0.32	1.03	0.93	0.48	0.39	0.35	0.33	—

R1 and R2 are richness indices
N1 and N2 are diversity indices
E5 is an evenness index

Table 3.4 Mean values of richness, evenness, and diversity indices for demersal fish collected during trawl surveys at the Naval Station Treasure Island, Hunters Point Annex, including results of SNK multiple comparison tests on the means. (The same letters between means for each index indicate no significant difference at ≥ 0.05.)

	Margalef Index (R1)			Menhinick Index (R2)			Hill's Diversity No. 1 (N1)			Hill's Diversity No. 2 (N2)			Modified Hill's Ratio (E5)		
Station	**Mean**	**SE**	**SNK**	**Mean**	**SE**	**SNK**	**Mean**	**SE**	**SNK**	**Mean**	**SE**	**SNK**	**Mean**	**SE**	**SNK**
1	0.37	0.03	A	0.35	0.10	A	1.25	0.13	A	1.14	0.10	A	0.48	0.13	A
2	0.78	0.22	A	0.58	0.31	A	2.32	1.20	A	2.31	1.27	A	0.67	0.35	A
5	0.55	0.31	A	0.47	0.22	A	2.26	1.05	A	2.12	1.03	A	0.70	0.23	A
8	0.39	0.00	A	0.24	0.01	A	1.14	0.03	A	1.05	0.02	A	0.37	0.24	A
9	0.33	0.33	A	0.14	0.10	A	1.06	0.06	A	1.02	0.02	A	0.33		A

Table 3.5 Mean standard length of demersal fish collected during trawl surveys at the Naval Station Treasure Island, Hunters Point Annex.

Taxa		Station 1			Station 2			Station 5			Station 8			Station 9		
Family Species	Scientific Name	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE
Embiotocidae																
silver surfperch	*Hyperprosopon ellipticum*	4	80.8	6.2	11	77.9	1.6	12	89.9	3.5	6	77.2	3.3	6	84.5	4.0
white surfperch	*Phanerodon furcatus*										2	201.0	12.0			
Engraulididae																
northern anchovy	*Engraulis mordax*	43	57.9	0.7	31	62.7	1.1	41	59.7	0.9	50	59.3	0.8	50	63.6	1.2
Syngnathidae																
bay pipefish	*Syngnathus leptorhynchus*							2	123.0	16.0						
Batrachoididae																
plainfin midshipman	*Porichthys notatus*													1	36.0	
Gobiidae																
chameleon goby	*Tridentiger trigonocephalus*													1	72.0	
cheekspot goby	*Ilypnus gilberti*				3	73.0	28.1									
goby spp.														1	26.0	
Bothidae																
California halibut	*Paralichthys californicus*				1	197.0										
speckled sanddab	*Citharichthys stigmaeus*	1	33.0													

Table 3.6 Mean lengths of northern anchovies collected during trawl surveys at the Naval Station Treasure Island, Hunters Point Annex, including the results of the Duncan's multiple comparison tests. (The same letters between stations for each test indicate no significant difference at $P \geq 0.05$.)

Station	N	Mean	S.E.	SNK	Duncan
1	43	57.86	0.70	B	B
2	31	62.74	1.11	A	A
5	41	59.73	0.89	B	B
9	50	63.56	1.17	A	A
8	50	59.30	0.81	B	B

Table 3.7 Physical abnormalities or presence of parasites on fish collected during demersal fish surveys at Naval Station Treasure Island, Hunters Point Annex.

Station Number	Trawl Number	Species	Number of Fish with Abnormality	Description of Abnormality
2	1	northern anchovy	7	unusual coloration and markings on lateral side
5	1	silver surfperch	1	deformed premaxilla
5	2	northern anchovy	11	external parasites
8	1	northern anchovy	12	external parasites
8	2	northern anchovy	4	external parasites
9	1	northern anchovy	6	external parasites
9	2	northern anchovy	5	external parasites

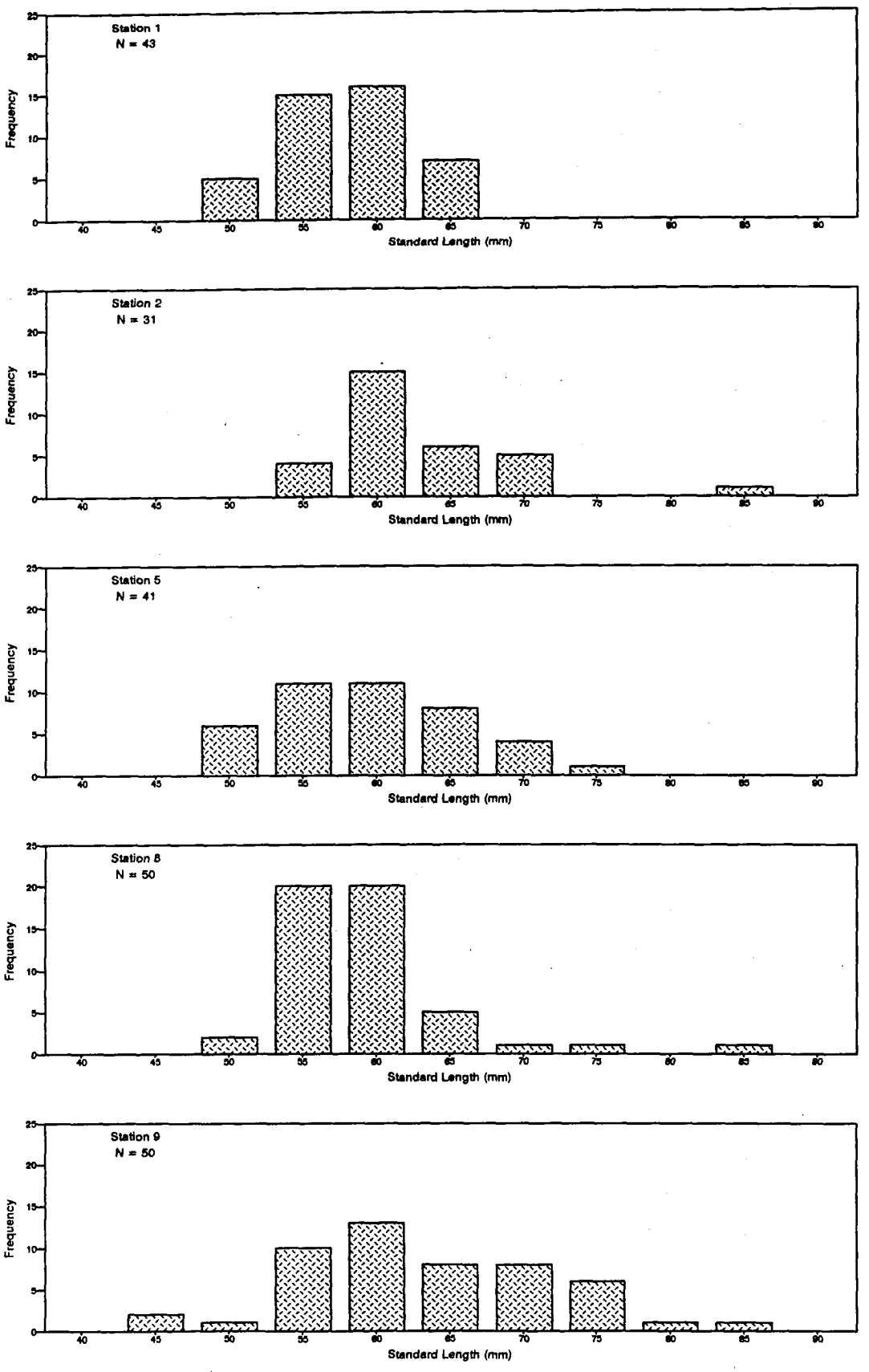


Figure 3.1 Length frequency of northern anchovy collected during trawl surveys at the Naval Station Treasure Island, Hunters Point Annex.

4.0 Conclusions

The aquatic investigations in this phase of the ecological risk assessment were designed as qualitative reconnaissance surveys to help focus future quantitative data collection efforts. The demersal fish surveys consisted of only two trawls per station. The study design did not attempt to document seasonal or diel changes in species composition or abundance. Although we statistically analyzed the data, the small number of trawls per station must be considered in interpretating the survey results.

Few demersal fish were collected during our trawling survey. Northern anchovy, a pelagic species, was the most dominant species collected, comprising 97 percent of the catch. Although our statistical analysis indicates that more fish were caught at the control site (Station 9), we feel additional data is needed to document this observation. More fish may have been collected at Station 9 simply because of the coincidental migration of a school of anchovies through the sampling station during the time of our trawl. The similarity of species richness and diversity of fish at all the sample sites suggests that environmental conditions are not markedly different. Although 46 of the fish collected had parasites or abnormalities, we do not feel this is unusual given the large numbers of fish examined (N= 1,861).

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1.0 Background

PRC Environmental Management, Inc. (PRC) is under contract to the Department of the Navy to implement the Ecological Risk Assessment Work Plan (WP) under the Comprehensive Long-term Environmental Action Navy (CLEAN) contract at Naval Station Treasure Island, Hunters Point Annex (HPA), in San Francisco, California. BioSystems Analysis, Inc. (BioSystems) was contracted by PRC to perform the aquatic survey portion of the Phase 1A ecological risk assessment. The aquatic investigations in this phase of the ecological risk assessment are reconnaissance surveys that will help focus future quantitative data collection efforts. The objective of the WP is to identify the possible ecological impacts on biota of hazardous material used and disposed of within the project area at HPA. The scope of work required compiling information on the composition and abundance of biota at HPA. The results of this study and others will be used to design and implement a more comprehensive field sampling and analysis plan for subsequent phases of work. This report presents the results of BioSystems' epibenthic sampling program only. Results of the demersal fish, intertidal, and benthic sampling programs are summarized in separate reports.

2.0 Technical Approach

BioSystems' study characterized the epibenthic community in the HPA project area and an "undisturbed" reference area in San Francisco Bay and compared the results. The reference site (just south of Candlestick Park) was selected by PRC after a review of studies in San Francisco Bay and agency consultation. To characterize aquatic resources, BioSystems collected samples from the intertidal, subtidal, and epibenthic invertebrate communities and from the demersal fish community. Sampling methods for the epibenthic survey are outlined in Section 2.1. For each sample, we reported the collection date, time, location, species composition and abundance and other pertinent information. The location of each sampling site was placed on a map for future reference. The position (latitude and longitude) of each sampling site was also documented using a global positioning system (GPS) unit to ensure accurate transect identification. Due to selective availability imposed by the U.S. Department of Defense, all GPS units have a maximum error range of about 100 meters. The following section describes the epibenthic sampling program only. The demersal fish, intertidal, and subtidal benthic programs are addressed in separate reports.

2.1 Field and Laboratory Methods

2.1.1 Epibenthic Sampling

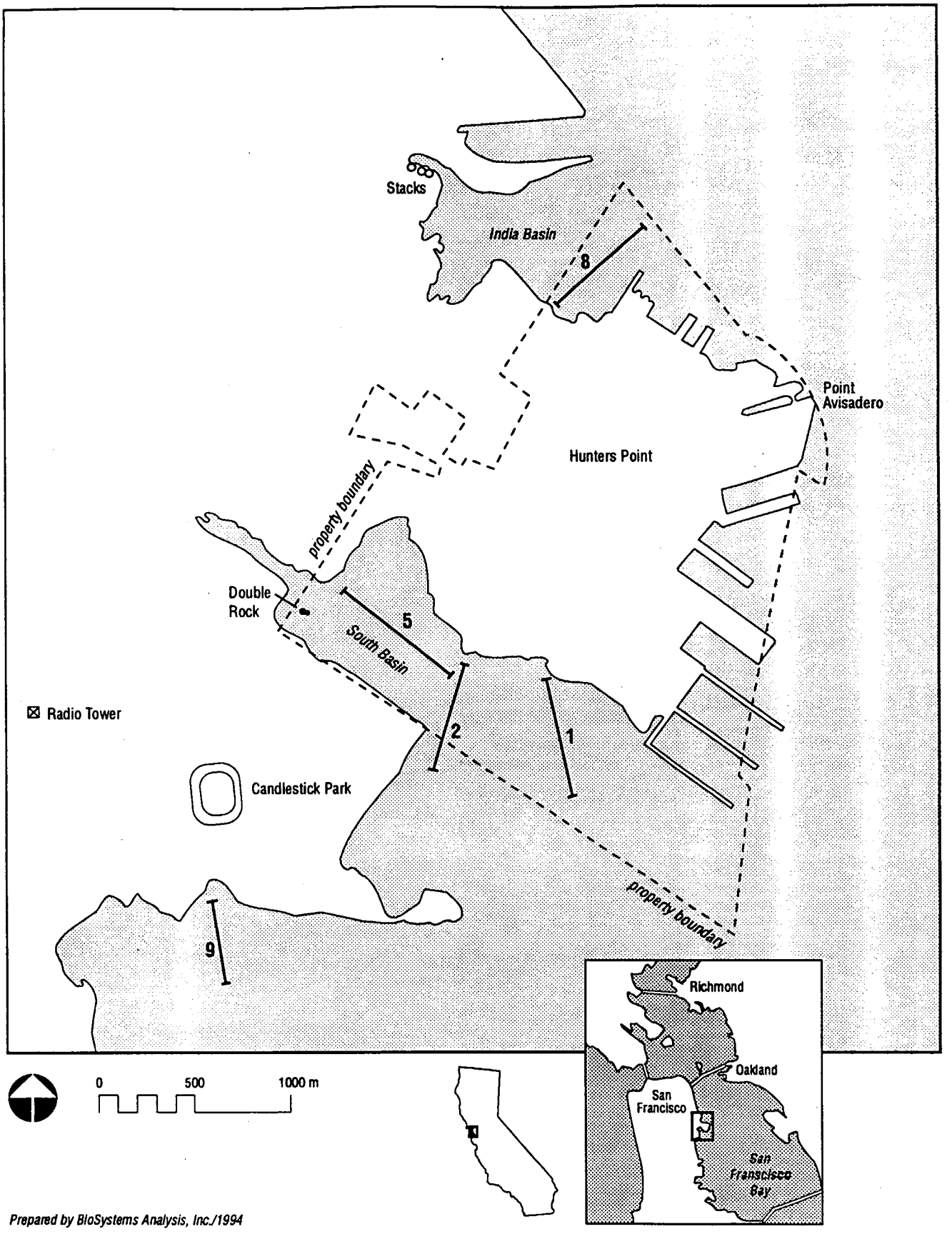
The purpose of the epibenthic survey was to provide information on the composition and abundance of epibenthic communities in the subtidal area of Hunters Point. Five stations were located in the same general area as the intertidal stations (three in South Basin, one in India Basin, and one at the reference station). The locations of the five epibenthic transect sites are summarized in Table 2.1 and Figure 2.1.

Epibenthic sampling was carried out on 20 November, 1993. We conducted three trawls at each station, using an epibenthic sled with an attached 2 meter net (0.571 mm mesh size). During each trawl, the sled was towed perpendicular to shore for 2 minutes. Attempts to trawl for longer than 2 minutes resulted in clogging of the net. If the mouth of the net became clogged with mud, filamentous algae, or debris, the tow was abandoned and repeated.

The first two trawls (A & B) were used to collect biota for identification. After each trawl, samples were rinsed from the net into 1.0 mm and 0.5 mm screen trays. Double screening was necessary to separate the organisms from filamentous algae. All organisms collected from each trawl were placed in a separate glass or plastic container and immediately preserved with 10 percent formalin. In the field, samples collected, date, time, personnel, GPS coordinates, weather, duration of tow, depth, and approximate length of tow were recorded on a sampling log sheet.

Table 2.1 Collection date, time, and location of samples collected from the epibenthic community at five transects at Naval Station Treasure Island, Hunters Point Annex.

Sample	Date	Time	Depth Range (m)	Start Location		End Location	
1A	11/20/93	11:53	2.5 – 2.9	N: 37° 43′ 05″	W: 122° 22′ 14.9″	N: 37° 42′ 52.5″	W: 122° 22′ 13″
1B	11/20/93	12:15	2.3 – 2.4	N: 37° 43′ 02″	W: 122° 22′ 14.5″	N: 37° 42′ 55″	W: 122° 22′ 13″
1C	11/20/93	12:15	2.4 – 2.5	N: 37° 43′ 02″	W: 122° 22′ 14.5″	N: 37° 42′ 55″	W: 122° 22′ 13″
2A	11/20/93	12:55	2.2 – 2.3	N: 37° 43′ 05″	W: 122° 22′ 24″	N: 37° 42′ 57″	W: 122° 22′ 26″
2B	11/20/93	13:13	2.2 – 2.3	N: 37° 43′ 02″	W: 122° 22′ 25″	N: 37° 42′ 57″	W: 122° 22′ 27″
2C	11/20/93	13:13	2.3 – 2.3	N: 37° 43′ 02″	W: 122° 22′ 25″	N: 37° 42′ 57″	W: 122° 22′ 27″
5A	11/20/93	15:05	1.8 – 2.1	N: 37° 43′ 15″	W: 122° 22′ 45″	N: 37° 43′ 10″	W: 122° 22′ 40″
5B	11/20/93	15:27	1.8 – 2.1	N: 37° 43′ 15″	W: 122° 22′ 45″	N: 37° 43′ 08″	W: 122° 22′ 38″
5C	11/20/93	15:27	2.0 – 2.3	N: 37° 43′ 15″	W: 122° 22′ 45″	N: 37° 43′ 08″	W: 122° 22′ 38″
8A	11/20/93	16:15	2.3 – 2.4	N: 37° 43′ 58″	W: 122° 22′ 05″	N: 37° 44′ 03″	W: 122° 22′ 00″
8B	11/20/93	16:45	2.4 – 2.7	N: 37° 43′ 57″	W: 122° 22′ 09″	N: 37° 44′ 03″	W: 122° 22′ 00″
8C	11/20/93	16:45	2.4 – 2.8	N: 37° 43′ 57″	W: 122° 22′ 09″	N: 37° 44′ 03″	W: 122° 22′ 00″
9A	11/20/93	14:00	1.8 – 2.4	N: 37° 42′ 29″	W: 122° 23′ 07″	N: 37° 42′ 25″	W: 122° 23′ 06″
9B	11/20/93	14:16	2.0 – 2.6	N: 37° 42′ 29″	W: 122° 23′ 09″	N: 37° 42′ 25″	W: 122° 23′ 07″
9C	11/20/93	14:16	2.2 – 2.4	N: 37° 42′ 29″	W: 122° 23′ 09″	N: 37° 42′ 25″	W: 122° 23′ 07″



Prepared by BioSystems Analysis, Inc./1994

Figure 2.1 Location of epibenthic surveys conducted at Naval Station Treasure Island, Hunters Point Annex.

A third trawl (C) was completed at each station to collect biota for future chemical/histopathologic analysis. A subsample of organisms was placed in a small plastic container and flash-frozen using liquid nitrogen or dry ice, depending on sample size. These frozen samples were transferred to cold storage (0±5° F) in the laboratory. Another subsample of large organisms (>1.0 mm) was reserved with buffered formaldehyde in a plastic container and also stored in the laboratory. These samples will be retained for one year from the date of collection. Figures 2.2 and 2.3 summarize the epibenthic sampling and analysis procedures.

In the laboratory, samples collected for biota analysis were transferred to 70-75 percent ethanol within 24 to 48 hours of collection. All of the 0.5 millimeter samples were subsampled because they contained a large number of organisms (>3,800). Following standard techniques, samples were split repeatedly with a Folsom plankton splitter until the subsample contained a minimum of 200 organisms.

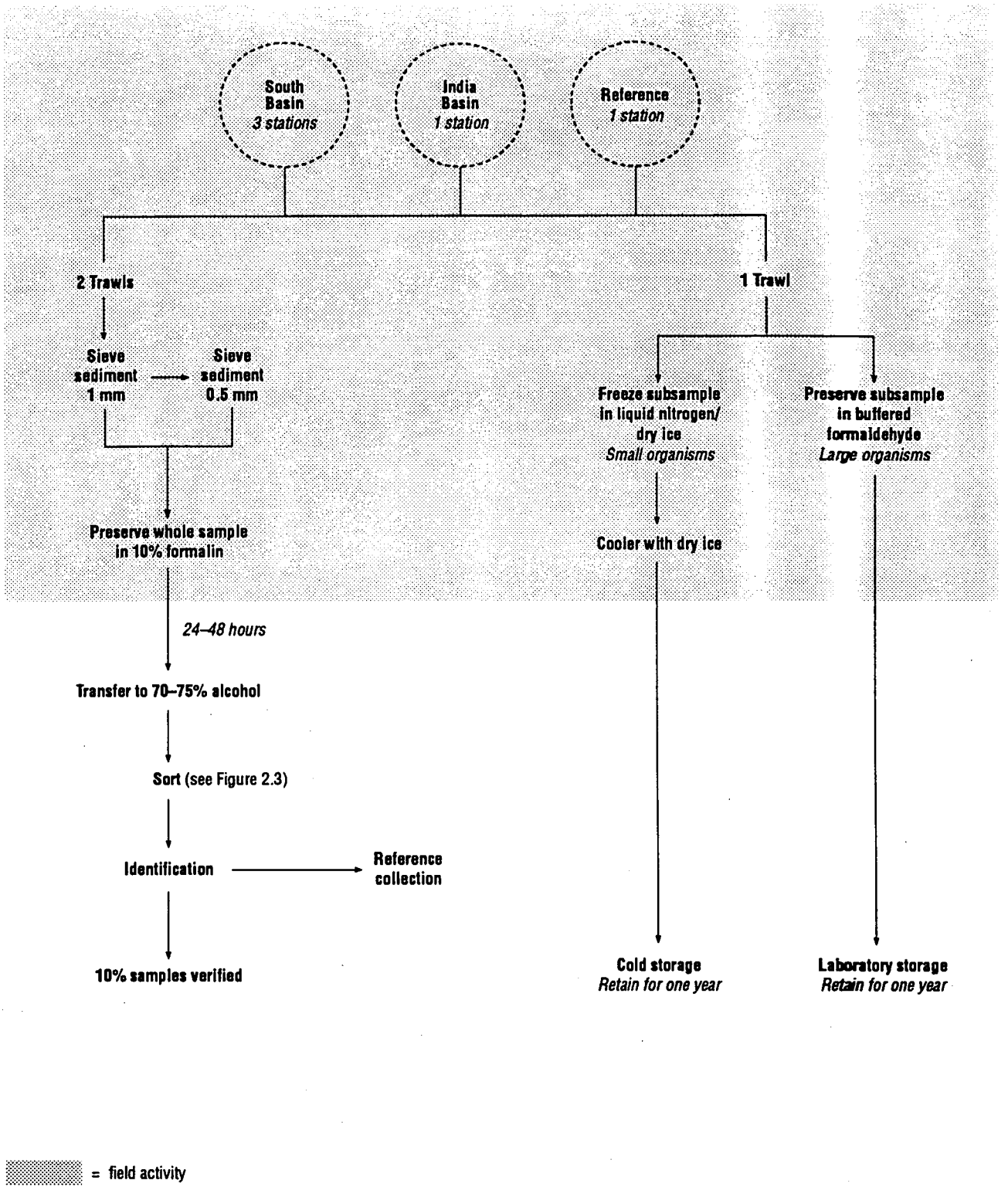
The 1.0 millimeter portions from Stations 1B, 2B, and 8A were not subsampled because of the low overall abundance of organisms (<1,700) and the large number of tubeworm casings in the samples. Upon analysis, most of the tubeworm casings were found to be empty. For the remaining 1.0 millimeter portions, we employed one of three subsampling methods. The method selected depended on the amount of red filamentous algae and whether or not the organisms were entangled in the algae. We used the Folsom plankton splitter to subsample organisms in samples with a large number of organisms and little or no algae. If the sample contained large amounts of red filamentous algae with most of the organisms entangled in the algae, we subsampled using a numbered grid system. For samples containing large amounts of filamentous algae and numerous free-floating organisms, we subsampled the liquid portion using the plankton splitter and subsampled the solid portion using a numbered grid system. Two grid systems (56 cm × 56 cm and 38 cm × 46 cm) were used, depending on the size of the sample. We spread the contents of each sample evenly across the grid and randomly selected grids for subsampling. All organisms within the grids were removed sequentially until a minimum of 200 organisms were collected.

All organisms collected during the sorting procedures were placed in labeled jars with 70-75 percent ethanol. All sample processing and organism sorting was performed by BioSystems laboratory technicians. Specimens were identified to species and counted by a taxonomist. Any evidence of disease, tumors, or other physical abnormalities in specimens were noted. Data from each site were recorded on a separate data sheet.

All samples will be retained in the laboratory for one year from date of collection.

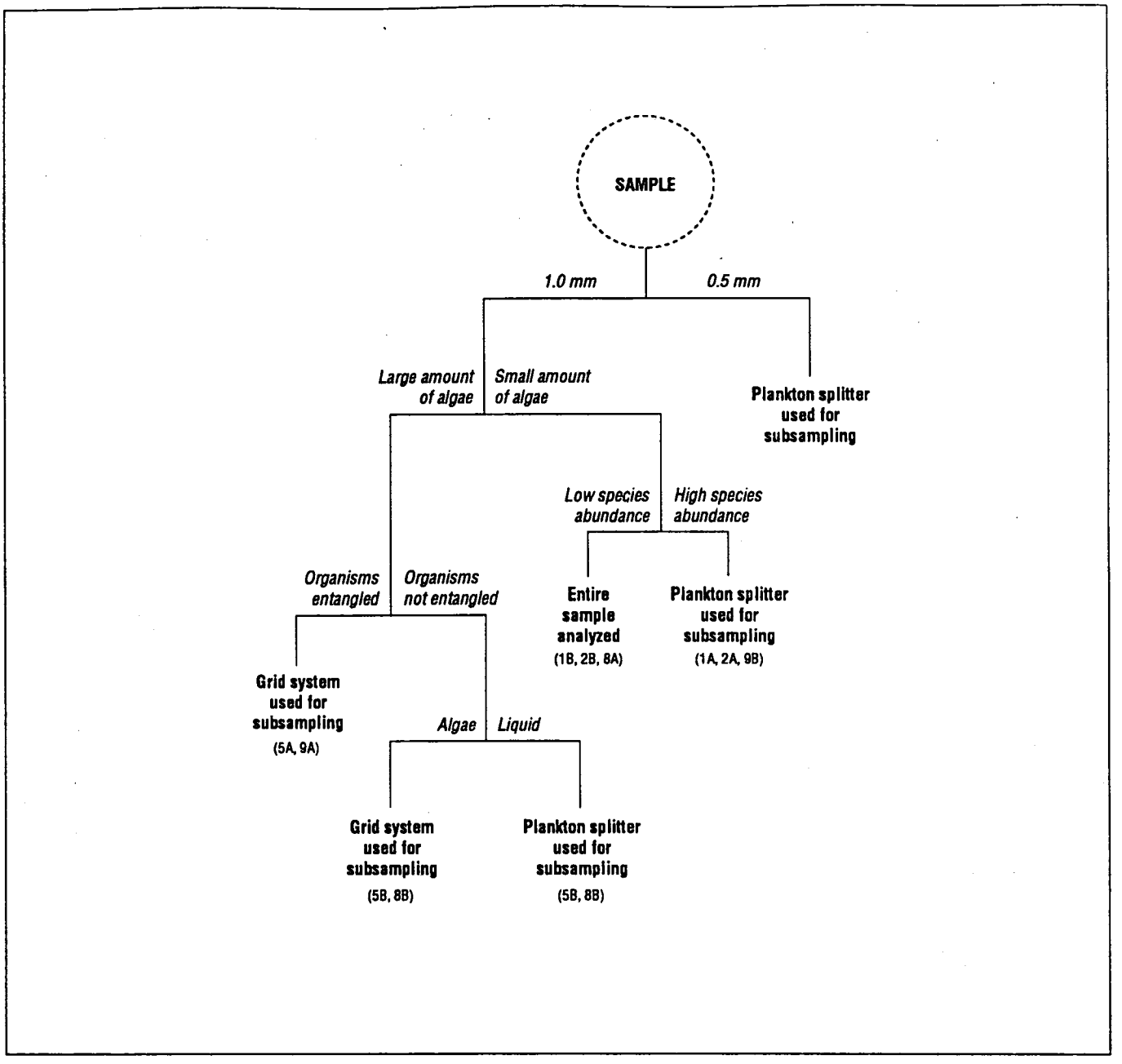
2.2 Data Entry and Analytical Methods

All field and laboratory data forms were copied and retained at two locations for safety. Data from all other forms were entered into a database computer program for further analysis of species composition and abundance. Once data was entered into the database program, a hard copy was printed and checked for errors. Data entry was verified and corrected prior to analysis.



Prepared by BioSystems Analysis, Inc./1994

Figure 2.2 Summary of epibenthic sampling and analysis procedures.



Prepared by BioSystems Analysis, Inc./1994

Figure 2.3 Summary of epibenthic sample sorting procedures.

All data were backed up automatically on BioSystems' client/server computer network system (Novell Netware 3.11). All files stored on the network were automatically duplicated on tape every night using the grandfather/father/son rotation method that rotates 10 tapes over a 12 week period. This method provided a high degree of data redundancy and security.

We determined the total number of individuals in each portion of a sample (1.0 mm and 0.5mm) by multiplying the number of organisms identified in each subsample by the reciprocal of the fraction of the sample analyzed. We then combined the number of organisms present in both the 1.0 and 0.5 mm portions of a sample to determine overall species abundance. The mean and standard error (SE) of the number of organisms from the epibenthic community at each of the nine transects were then calculated for all species combined. Student-Newman-Keuls (SNK), Duncan, and Scheffe multiple comparison methods (Snedecor and Cochran 1980) were used to determine the differences in abundance estimates.

We used the Margalef (1958) index, R1, and the Menhinick (1964) index, R2, to measure species richness for each of the nine transects. The R1 index can be calculated as follows:

$$R1 = \frac{S-1}{\ln(n)} \tag{1}$$

where S is the number of species in a community (i.e., sample); n is the number of individuals observed in a sample.

The R2 index is:

$$R2 = \frac{S}{\sqrt{n}} . \tag{2}$$

Diversity indices incorporate both species richness and evenness into a single value (Ludwig and Reynolds 1988). We applied two of the most commonly used diversity indices, N1 and N2, presented by Hill (1973) in this study. The N1 index measures the number of abundant species in the sample which can be expressed as:

$$N1 = e^{H'} \tag{3}$$

where H′ is the Shannon index (Shannon and Weaver 1949). The value of H′ can be estimated from a sample as:

$$\hat{H} = -\sum_{i=1}^{S} [(\frac{n_i}{n})\ln(\frac{n_i}{n})] \tag{4}$$

where n_i is the number of individuals belonging to the *i*th of S species in the sample; n is the total number of individuals in the sample.

The N2 index measures the number of very abundant species which can be formulated as:

$$N2 = \frac{1}{\lambda} \tag{5}$$

where λ is the Simpson's index (Simpson 1949). The unbiased estimator for λ is:

$$\hat{\lambda} = \sum_{i=1}^{S} \frac{n_i(n_i-1)}{n(n-1)} . \tag{6}$$

Then, we used a modified Hill's ratio (Hill 1973, Alatalo 1981), E5, to quantify the evenness component of diversity. The E5 is:

$$E5 = \frac{(1/\lambda)-1}{e^{H'}-1} = \frac{N2-1}{N1-1} . \tag{7}$$

Since the SNK is one of the most powerful multiple comparison methods (Snedecor and Cochran 1980), we used this method to compare each of the above indices among the nine transects.

2.3 Quality Assurance/Quality Control (QA/QC)

2.3.1 Field Equipment

Prior to sampling, all equipment was visually inspected, cleaned and tested to ensure proper performance. For all sampling equipment, we used a checklist of components to be inspected, cleaned and tested. Data sheets documenting these inspections were completed prior to use at each station and retained by BioSystems. Any problems or repairs to the equipment during the surveys were documented.

2.3.2 Sample Tracking

Each sample collected in the field was assigned a unique and permanent number, which was recorded on a sampling log sheet. All sample containers were labelled with sample number, date and time, location of collection, and personnel. For each sample, a chain of custody/sample tracking form was maintained that included the following information: sample number, sampling date, community type

sampled, container type and size, and chain of custody information. In addition, this form was used to record any event relating to the sample (e.g., transfer to ethanol or sorting).

If a sample was split during sorting, resulting split samples were labeled with the original sample number and a prefix to designate it as a sorted sample. Since sorted samples from the same sampling location were physically kept together, tracking of sorted samples was maintained on the original chain of custody/sample tracking form.

The chain of custody/sample tracking forms were maintained in a binder in a secure central location and were available for review by the project manager at any time.

2.3.3 Verification of Identification

To verify species identifications, one sample (including both the 1.0 mm and 0.5 mm portions) was randomly selected and sent to a second taxonomist who recorded the findings on a separate data sheet. The identifications were compared and any discrepancy in species composition or abundance was investigated and corrected. We also resorted the 0.5 mm and 1.0 mm portions of one sample to verify that we had not missed significant numbers of organisms during processing.

3.0 Results

3.1 Species Composition and Abundance

The species composition and number of organisms collected from the epibenthic community at each of the two sites (A and B) along the five sampling transects (Transect 1, 2, 5, 8, and 9) are summarized in Table 3.1. The 10 samples (2 sites × 5 transects) contained more than 168,000 organisms representing 8 phyla and 85 species. The number of species (S) collected at a site (Trawls A and B) ranged from 60 at Transect 1 to 38 at Transect 9. The number of species collected in each trawl within a site was similar. The total number of organisms (n) collected from a site, however, vary greatly within and among those transects. For example, n varied from 37,092 at Site 8A to 10,891 at Site 8B, a difference of 26,201. Similarly, we estimated a total of 57,514 organisms were collected in the two trawls at Transect 5 compared to only 9,414 at Transect 2.

The mean number of individuals per transect and associated standard error are presented in Table 3.2. The SKN, Duncan, and Scheffe methods indicated mean abundances were not significantly different among the transects (Table 3.2). This is not surprising given the high variability observed between trawls at a transect.

3.2 Richness, Diversity, and Evenness Indices

Table 3.3 lists the richness (R1 and R2), diversity (N1 and N2) and evenness (E5) indices calculated for each transect. The SNK test indicated no significant differences among the stations for R1, but the R2 richness index was significantly higher for Transect 2 than Transect 5. The SNK tests revealed that for both diversity indices (N1 and N2), Transects 5 and 9 were significantly higher than those at Transect 8. The evenness component of diversity (E5) at Transect 5 was significantly higher than those at Transects 1, 2, and 8.

3.3 Quality Control

Sample 5B was randomly selected for verification of species identification and abundance estimates. No significant discrepancies were found in species identification between the taxonomists. The ability of the taxonomists to identify organisms to similar levels in the order Amphipoda differed slightly, but the numbers of individuals identified by each taxonomist were similar for that order. An unexplained discrepancy was noted in the number of ostracods enumerated by the two taxonomists in the 1.0 mm liquid portion of Sample 5B.

We completely resorted both the 0.5 and 1.0 mm portions of Sample 1A. Overall, we missed approximately 4 percent (32 of 691) of the organisms in the initial sorting.

Table 3.1 Species composition and abundance of organisms from the epibenthic community at five transects at Naval Station Treasure Island, Hunters Point Annex.

Taxa	1A	1B	2A	2B	5A	5B	8A	8B	9A	9B	TOTAL
Phylum Cnidaria											0
Class Anthozoa											0
Stylatula elongata							275	9			284
Anthozoa - unidentified	64		272	83		72				2	493
											0
Phylum Nematoda											0
Nematoda - unidentified	64		16								80
											0
Phylum Annelida											0
Class Oligochaeta											0
Family Tubificidae											0
Tubificidae - unidentified	68	23	40	50	54	26	5,047	342	42	9	5,701
Class Polychaeta											0
Family Polynoidae											0
Harmothoe imbricata	94	33	10	69	283	152	1	58	127	160	986
Polynoidae - unidentified								9			9
Family Phyllodocidae											0
Eteone spp.	4						1				5
Family Syllidae											0
Exogone lourei	614	214	560	521	3,420	1,398	142	82	862	946	8,760
Sphaerosyllis californiensis		43	22	18	36	150	55	73		43	440
Typosyllis sp. A	51	134	24	63	2,898	2,572	5,301	3,993	693	1,174	16,903
Family Goniadidae											0
Glycinde polygnatha	9	7	2	3			21		21		62
Family Nephtyidae											0
Nephtys caecoides		1					130				131
Nephtys cornuta franciscana		2	2				258	43			305
Family Dorvilleidae											0
Dorvillea rudolphi				2							2
Family Orbiniidae											0
Leitoscoloplos elongatus	149	52	24	50			1,173	132			1,580
Orbiniidae - unidentified								22			22
Family Spionidae											0
Polydora ligni	9		18	25	18	34	1				104
Psuedopolydora brachycephala						18					18

Table 3.1 Species composition and abundance of organisms from the epibenthic community at five transects at Naval Station Treasure Island, Hunters Point Annex (cont.).

Taxa	1A	1B	2A	2B	5A	5B	8A	8B	9A	9B	TOTAL
Psuedopolydora kempi							1				1
Pseudopolydora paucibranchiata		1	3	1		4	1				10
Spiophanes missionensis							128				128
Streblospio benedicti		1			18						19
Family Cirratulidae											0
Ciriformia spp. (juv.)							713	140			853
Cirratulidae - unidentified (juv.)								38			38
Family Cossuridae											0
Cossura pygodactylata				8			256				264
Family Opheliidae											0
Armandia brevis				1			513	75			589
Family Capitellidae											0
Heteromastus spp. (juv.)			51	84	18			8	32		193
Family Maldanidae											0
Asychis elongata							3				3
Family Ampharetidae											0
Ampharete labrops							1				1
Family Terebellidae											0
Ameana occidentalis	209	4					128				341
Family Sabellidae											0
Euchone nr. limnicola	1,067	607	152	329	49	128	783	77	422	326	3,939
											0
Phylum Arthropoda											0
Class Crustacea											0
Subclass Ostracoda											0
Sarsiella zosteracola	64	2		8	1,576	1,682	256	43	160	226	4,018
Ostracoda - unidentified				8							8
Subclass Copepoda											0
Order Calanoida											0
Calanoida - unidentified		43	32	9	252	364	257	184	32		1,173
Order Harpacticoida											0
Harpacticoida - unidentified					972	206				32	1,210
Subclass Malacostraca											0
Order Cumacea											0
Hemileucon hinumensis	9,698	3,159	1,968	2,051	7,907	4,840	19,618	3,685	4,537	2,660	60,123

Table 3.1 Species composition and abundance of organisms from the epibenthic community at five transects at Naval Station Treasure Island, Hunters Point Annex (cont.).

Taxa	1A	1B	2A	2B	5A	5B	8A	8B	9A	9B	TOTAL
Order Tanaidacea											0
Leptochelia dubia							1				1
Order Isopoda											0
Excirolana spp.	4										4
Paranthura elegans	73	6	3	19	72	40	2	8	106	353	682
Sphaeromatidae - unidentified		1									1
Order Amphipoda											0
Ampelisca abdita	909	505	120	171	816	1,510	219	170	180	76	4,677
Ampithoe lacertosa		14			468	202	1		63	32	780
Ampithoe spp. (juv.)	9	23			248	682		73	265	313	1,611
Corophium heteroceratum	1,903	539	283	186	98	136	2		244	225	3,617
Corophium insidiosum					2,027	1,372			32	11	3,441
Corophium spp. (juv. and mut.)			18	1		528			64	118	729
Grandierella japonica	324	112	27	82	1,807	1,488	133	22			3,995
Podocerus sp. A	64	22	16	9	36	18			64	11	240
Synchelidium shoemakeri	346	44	67	46	417	528	9	56	32	32	1,576
Synchelidium spp.	64					8					72
Stenothoe valida	4	2		1	80	4	1		255	44	391
Rhacotropis spp.	77	32	66	15	1,401	846	7	168	1,371	1,450	5,432
Caprella californica	13	26	5	2	36		6		42		130
Caprella scaura	30	49	5	9	5,135	4,254	19	211	1,450	1,142	12,304
Caprella spp.		22			1,260	56					1,338
Caprellidae - unidentified	265		32	8	53	1,714	1	26	817	374	3,290
Order Decapoda											0
Acanthomysis macropsis	68	47	3	29	36					32	215
Acanthomysis spp.		22									22
Crangon franciscorum			5	3					1		9
Crangon nigricauda	13	20	27	20			4	8	3		95
Crangon nigromaculata	21	24	6	4			5		5		65
Crangon spp.		1	3	2			1				7
Hetocarpus cristatus		2					3				5
Neomysis rayii			3	17	18	18					56
Pyromaia tuberculata		2					1				3
Mysidae - unidentified	4	67	6	7		8	1		42		135
Anomura larva		43	16	17							76

Table 3.1 Species composition and abundance of organisms from the epibenthic community at five transects at Naval Station Treasure Island, Hunters Point Annex (cont.).

Taxa	1A	1B	2A	2B	5A	5B	8A	8B	9A	9B	TOTAL
Caridea larva								9			9
Brachyura zoea	64	65	48	8							185
Phylum Mollusca											0
Class Gastropoda											0
Subclass Opistobranchia											0
Cephalaspidea - unidentified		3	2				60	8	1	4	78
Opistobranchia - unidentified		2			31	340	1	16		4	394
Subclass Prosobranchia											0
Lacuna marmorata							1				1
Class Bivalvia											0
Subclass Paleotoxodonta											0
Nuculana taphria		1		1							2
Subclass Pteriomorpha											0
Musculista senhousia	3,042	1,823	630	747	323	74	316	821	1,110	1,029	9,915
Subclass Heterodonta											0
Gemma gemma		2			18						20
Macoma spp.			2	1							3
Mysella sp. A							1				1
Potamocorbula ameurensis		7		1	72	36					116
Tapes japonica	998	363	5	15			259		225	83	1,948
Theora lubrica	17	17		1			716	149		2	902
Bivalvia - unidentified	73	22	16				128				238
Phylum Chaetognatha											0
Chaetognatha - unidentified		108					131	114			353
Phylum Echinodermata											0
Holothuroidea - unidentified	192					18					210
Ophiuroidea - unidentified	128	43						22			193
Phylum Chordata											0
Subphylum Urochordata											0
Urochordata - unidentified		5				36				25	66
# of organisms in sample	20,868	8,406	4,610	4,804	31,953	25,562	37,092	10,891	13,300	10,937	168,423
# of species in sample	39	52	41	46	34	37	52	34	31	30	396
# of phyla represented in sample	6	6	5	4	3	6	5	6	3	5	49
# of species at transect		60		50		42		58		38	

Table 3.2 Mean number of organisms from the epibenthic community at five stations at Naval Station Treasure Island, Hunters Point Annex. The results of the SNK, Duncan and Scheffe multiple comparison tests are also reported. The same letters between stations for each test indicate no signficant difference at $P \geq 0.05$.

				Multiple Comparison Method		
Transect	**N**	**Mean**	**Standard Error**	**SNK**	**Duncan**	**Scheffe**
1	2	14,637.2	6,231.1	A	A	A
2	2	4,707.0	97.4	A	A	A
5	2	28,757.4	3,195.4	A	A	A
8	2	23,991.4	13,100.6	A	A	A
9	2	12,118.7	1,181.3	A	A	A

Table 3.3 Mean values of five richness, evenness and diversity indices for organisms collected from the epibenthic community at five stations at Naval Station Treasure Island, Hunters Point Annex. The results of the SNK multiple comparison tests are also reported. The same letters between means for each index indicate no significant difference at $P \geq 0.05$.

	Margalef Index (R1)			Menhinick Index (R2)			Hill's Diversity No. 1 (N1)			Hill's Diversity No. 2 (N2)			Modified Hill's Ratio (E5)		
Transect	Mean	SE	SNK	Mean	SE	SNK	Mean	SE	SNK	Mean	SE	SNK	Mean	SE	SNK
1	4.73	0.91	A	0.42	0.15	A B	8.31	0.71	B C	4.41	0.48	B C	0.46	0.02	B
2	5.03	0.29	A	0.63	0.03	A	8.38	0.00	B C	4.42	0.02	B C	0.46	0.00	B
5	3.37	0.19	A	0.21	0.02	B	13.06	1.13	A	9.17	0.98	A	0.68	0.02	A
8	4.20	0.65	A	0.30	0.09	A B	6.29	0.53	C	3.50	0.39	C	0.47	0.03	B
9	3.14	0.02	A	0.28	0.01	A B	11.09	0.51	A B	7.28	1.01	A B	0.62	0.07	A B

4.0 Conclusions

The aquatic investigations in this phase of the ecological risk assessment were designed as qualitative reconnaissance surveys to help focus future quantitative data collecting. The sample design for this survey called for only two replicates at the five sampling sites. No differences in the abundance of organisms between sampling locations were detected because of small sample size and large variations in the numbers of organisms collected in trawls along a transect. There was no consistent trend evident in the richness, diversity and evenness indices. Since filamentous algae was present at some of the sample sites not all of the samples could be processed using the same methodology. Although we do not feel that this influenced our results, we cannot exclude this variable. The presence of the algae may also influence the abundance and composition of organisms in the epibenthic community and may prevent meaningful comparison of the sites. Additional studies are needed to determine if the epibenthic community is depressed as a result of contamination at the naval base.

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Naval Station Treasure Island, Hunters Point Annex

Technical Report

Intertidal Surveys

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1.0 Background

PRC Environmental Management, Inc. (PRC) is under contract to the Department of the Navy to implement the Ecological Risk Assessment Work Plan (WP) under the Comprehensive Long-term Environmental Action Navy (CLEAN) at the Naval Station Treasure Island, Hunters Point Annex (HPA), in San Francisco, California. BioSystems Analysis, Inc. (BioSystems) was contracted by PRC to perform the aquatic survey portion of the Phase 1A ecological risk assessment. The aquatic investigations in this phase of the ecological risk assessment are reconnaissance surveys that will help focus future quantitative data collection efforts. The objective of the WP is to identify the possible ecological impacts on biota of hazardous material used and disposed of within the project area at HPA. The scope of work required compiling information on the composition and abundance of biota at HPA. The results of this study and others will be used to design and implement a more comprehensive field sampling and analysis plan for subsequent phases of work. This report presents the results of BioSystems' intertidal sampling program only. Results of the demersal fish, benthic, and epibenthic sampling programs are summarized in separate reports.

2.0 Technical Approach

BioSystems' study characterized the benthic community in the HPA project area and an "undisturbed" reference area in San Francisco Bay and compared the results. The reference site (just south of Candlestick Park) was selected by PRC after a review of studies in San Francisco Bay and agency consultation. To characterize aquatic resources, BioSystems collected samples from the intertidal, benthic, and epibenthic invertebrate communities and from the demersal fish community. Sampling methods for the intertidal survey are outlined in Section 2.1. For each sample, we reported the collection date, time, location, species composition and abundance and other pertinent information. The location of each sampling site was placed on a map for future reference. The position (latitude and longitude) of the end of each intertidal transect was also documented using a global positioning system (GPS) unit to ensure accurate transect identification. Due to selective availability imposed by the U.S. Department of Defense, all GPS units have a maximum error range of about 100 meters. The following section describes the intertidal sampling program only. The demersal fish, benthic, and epibenthic programs will be addressed in separate reports.

2.1 Field and Laboratory Methods

2.1.1 Intertidal Sampling

The intertidal survey was designed to provide information on the composition and abundance of large invertebrates in the intertidal area of Hunters Point Annex. We selected nine sampling stations for study; seven in the South Basin, one in India Basin, and one reference site located just south of Candlestick Park. The location of the intertidal transects are documented in Figure 2.1.

The intertidal surveys were conducted 9-11 November 1993 during low tide conditions. For the purpose of this survey, we defined the intertidal zone as the area between mean high tide and mean low tide. At each station, we measured a transect line in the intertidal zones and divided the length into four equal sections. The four sampling sites (A-D) were equally spaced along the transect line, resulting in a total of 36 (9 × 4) samples. Along each transect line, the sampling sites began at the high water mark (Site A) and proceeded seaward to the boundary of the intertidal zone (Site D). We recorded the location of the ends of the intertidal transects using GPS and used a compass to determine the orientation of each transect from this location. Transect lengths varied with the width of the intertidal zone.

Figure 2.2 summarizes our intertidal sampling and analysis program. At each site, we collected all large organisms (crabs, clams) visible on the surface within a 2 meter square quadrant constructed of PVC. When barnacles were present, we noted the percentage cover within the quadrant and removed a sample of specimens for species identification. In addition, a subsurface sample was col-

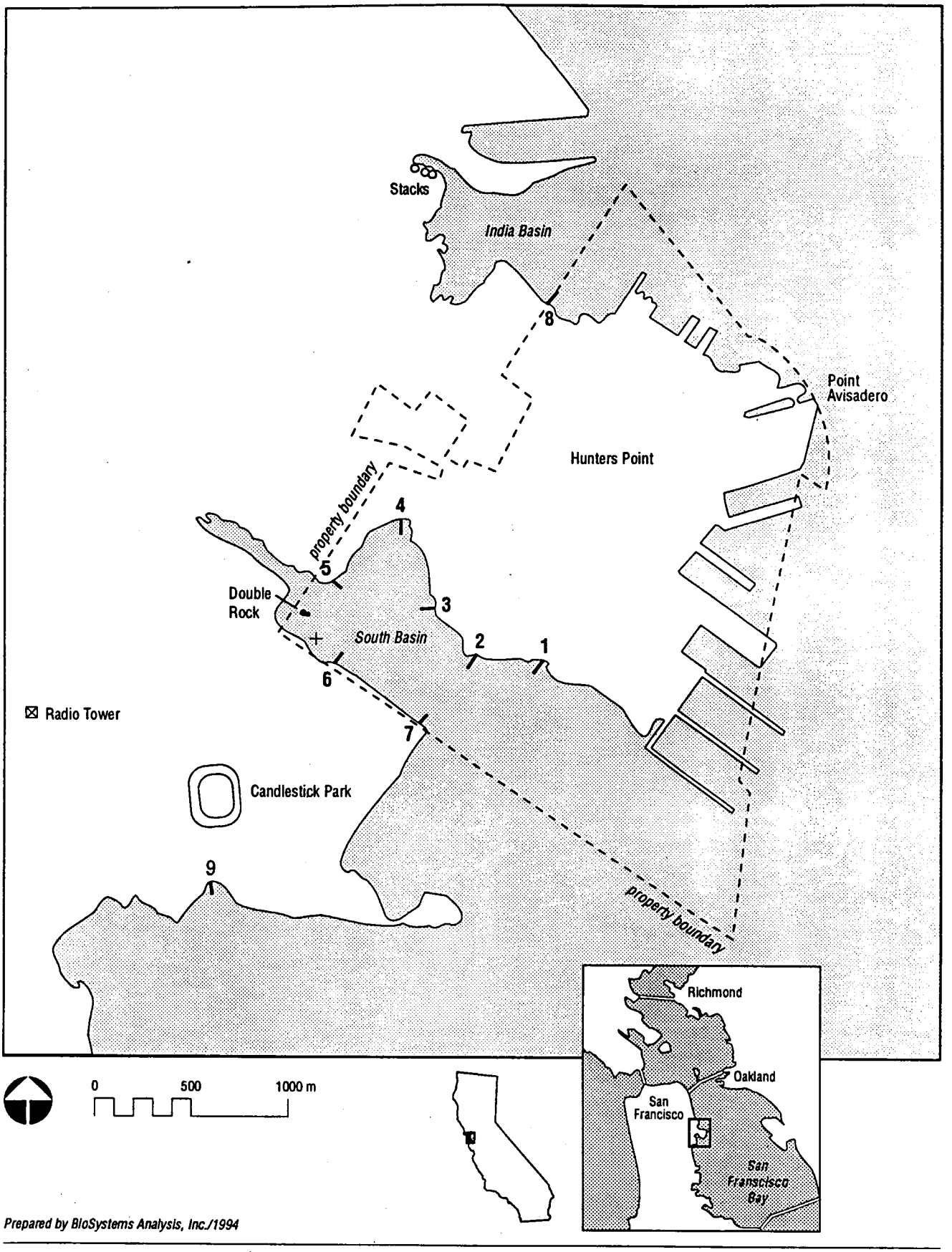
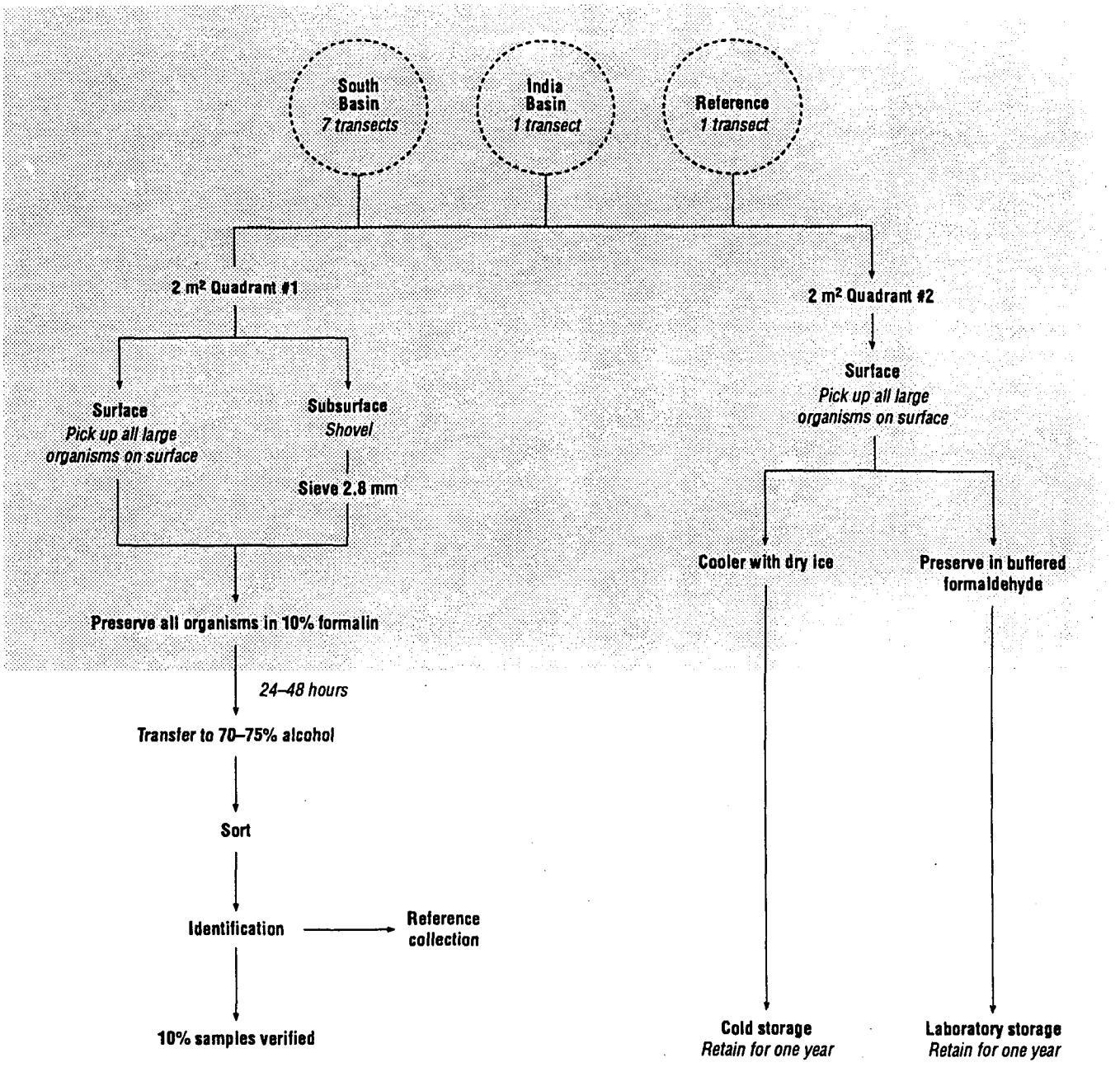


Figure 2.1 Location of intertidal transects surveyed at Naval Station Treasure Island, Hunters Point Annex.



= field activity

Prepared by BioSystems Analysis, Inc./1994

Figure 2.2 Summary of intertidal sampling and analysis procedures.

lected from the middle of the quadrant using a marked shovel. The volume of sediment excavated was equivalent to that sampled by a standard Ponar Grab (9 × 9 × 9 in. or 23 × 23 × 23 cm). Each sediment sample was passed through a 2.8 millimeter screen to retrieve large burrowing invertebrates. All collected organisms were immediately preserved in a 10 percent formalin solution in glass or plastic containers. The following information was recorded on a log sheet at each station: date, time, personnel, transect length, GPS coordinates, compass orientation, weather, number of samples collected and general substrate composition (mud, sand, gravel, rock).

Specimens for chemical and histopathological analyses were also collected by placing a 2 meter square quadrant adjacent to the quadrant in which we collected specimens for biota identification. Specimens were collected on the surface of the quadrant. Half of this subsample was placed in a plastic bag, frozen in the field with dry ice, and transferred to cold storage (0±5°F). The other half was preserved with buffered formaldehyde in a plastic container and stored in the laboratory. These samples will be securely retained for one year from the date of collection.

In the laboratory, samples collected for the biota analysis were transferred to a 70-75 percent ethanol solution within 24 to 48 hours of collection. Each sample was sorted into appropriate categories and specimens were counted and identified to species by a taxonomist. Any evidence of disease, tumors, or other physical abnormalities was noted. Data from each site were recorded on a separate data sheet.

2.2 Data Entry and Analytical Methods

All field and laboratory data forms were copied and retained at two locations for safety. Data from all other forms were entered into a database computer program for further analysis on species composition and abundance. Once data was entered into the database program, a hard copy was printed and checked for errors. Data entry was verified and corrected prior to analysis.

All data were backed up automatically on BioSystems' client/server computer network system (Novell Netware 3.11). All files stored on the network were automatically duplicated on tape every night using the grandfather/father/son rotation method that rotates 10 tapes over a 12 week period. This method provided a high degree of data redundancy and security.

The mean and standard error (SE) of the number of organisms from the intertidal community at each of the nine transects were calculated for all species combined. We excluded several species from the analysis (*Balanus crenatus*, unidentified *Bryozoa*, *Urochordata* sp. D and E) because they could not be accurately enumerated. We also excluded larval fish from the analysis since our sampling procedures were not designed to include this group. Student-Newman-Keuls (SNK), Duncan, and Scheffe multiple comparison methods (Snedecor and Cochran 1980) were used to determine the differences in abundance estimates.

We used the Margalef (1958) index, R1, and the Menhinick (1964) index, R2, to measure species richness for each of the nine transects. The R1 index can be calculated as follows:

$$R1 = \frac{S-1}{\ln(n)} \tag{1}$$

where S is the number of species in a community (i.e., sample); n is the number of individuals observed in a sample.

The R2 index is:

$$R2 = \frac{S}{\sqrt{n}} . \tag{2}$$

Diversity indices incorporate both species richness and evenness into a single value (Ludwig and Reynolds 1988). We applied two of the most commonly used diversity indices, N1 and N2, presented by Hill (1973), in this study. The N1 index measures the number of abundant species in the sample which can be expressed as:

$$N1 = e^{H'} \tag{3}$$

where H′ is the Shannon index (Shannon and Weaver 1949). The value of H′ can be estimated from a sample as:

$$\hat{H} = -\sum_{i=1}^{S} [(\frac{n_i}{n})\ln(\frac{n_i}{n})] \tag{4}$$

where n_i is the number of individuals belonging to the *i*th of S species in the sample; n is the total number of individuals in the sample.

The N2 index measures the number of very abundant species which can be formulated as:

$$N2 = \frac{1}{\lambda} \tag{5}$$

where λ is the Simpson's index (Simpson 1949). The unbiased estimator for λ is:

$$\hat{\lambda} = \sum_{i=1}^{S} \frac{n_i(n_i-1)}{n(n-1)} . \tag{6}$$

Then, we used a modified Hill's ratio (Hill 1973, Alatalo 1981), E5, to quantify the evenness component of diversity. The E5 is:

$$E5 = \frac{(1/\lambda)-1}{e^{H'}-1} = \frac{N2-1}{N1-1} . \qquad (7)$$

Since the SNK is one of the most powerful multiple comparison methods (Snedecor and Cochran 1980), we used this method to compare each of the above indices among the nine transects.

2.3 Quality Assurance/Quality Control (QA/QC)

2.3.1 Field Equipment

Prior to sampling, all equipment was visually inspected, cleaned and tested to ensure proper performance. For all sampling equipment used, we used a checklist of components to be inspected, cleaned and tested. Data sheets documenting these inspections were completed prior to use at each station and retained by BioSystems. Any problems or repairs to the equipment during the surveys were documented.

2.3.2 Sample Tracking

Each sample collected in the field was assigned a unique and permanent number, which was recorded on a sampling log sheet. All sample containers were labelled with sample number, date and time, location of collection, and personnel. For each sample, a chain of custody/sample tracking form was maintained that included the following information: sample number, sampling date, community type sampled, container type and size, and chain of custody information. In addition, this form was used to record any event relating to the sample (e.g., transfer to ethanol or sorting).

If a sample was split during sorting, resulting split samples were labeled with the original sample number and a prefix was added to designate it as a sorted sample. Since sorted samples from the same sampling location were physically kept together, tracking of sorted samples was maintained on the original chain of custody/sample tracking form.

The chain of custody/sample tracking forms were maintained in a binder in a secure central location and were available for review by the project manager at any time.

2.3.3 Verification of Identification

To verify species identifications, four samples were randomly selected and sent to a second taxonomist who recorded his findings on a separate data sheet. The identifications were compared and any discrepancy in species composition or abundance was investigated and corrected. As a final check, the first taxonomist prepared a reference collection for each of the species identified during the study and the second taxonomist verified the identifications.

3.0 Results

3.1 Site Description

The intertidal areas surveyed can be categorized into four general habitat types, based on habitat characteristics (Table 3.1) and substrate composition (Table 3.2). These are: sandy beach intertidal (Transects 1, 3, 8), rocky intertidal (Transects 2, 5, 7), mudflat intertidal (Transect 4, 6) and sandy/ mudflat intertidal (Transect 9). We observed oil residues and noted a strong petroleum odor at three of the four sites sampled along Transect 2. We did not smell or observe any other pollutant at any of the other eight transects. The date, time, location and length of the transect surveyed are summarized in Table 3.3.

Table 3.1 General habitat description of intertidal sampling sites at the nine transects surveyed at Naval Station Treasure Island, Hunters Point Annex.

Transect	Site Description
1	Sandy beach with shells
2	Rocky intertidal zone with some beach; part of substrate is heavily tainted with oil
3	Sandy beach with shells
4	Extensive mudflat
5	Rocky (riprap) intertidal zone with a narrow beach (mudflat)
6	Moderately wide mudflat; rocky intertidal zone
7	Rocky intertidal zone consisting of riprap and fill; narrow strand of mudflat at edge
8	Sandy beach with heavy vegetation at end; some debris (tires, etc.)
9	Sandy beach and mudflat

Table 3.2 Physical characteristics of substrate at intertidal sampling sites at Naval Station Treaure Island, Hunters Point Annex.

Station/ Site	Percentage of:						Oil Visible	Strong Petroleum Odor
	Anaerobic Mud	Aerobic Mud	Sand	Gravel	Cobble	Boulder		
1A			95	5				
1B			100					
1C		25	75					
1D	50		50					
2A	50		50					
2B	70		20		10		X	X
2C	100						X	X
2D	30				50	20	X	X

Table 3.2 Physical characteristics of substrate at intertidal sampling sites at Naval Station Treaure Island, Hunters Point Annex (cont.).

Station/ Site	Percendage of:						Oil Visible	Strong Petroleum Odor
	Anaerobic Mud	Aerobic Mud	Sand	Gravel	Cobble	Boulder		
3A			100					
3B		13	54	33				
3C			50	50				
3D			65	35				
4A	75	10	15					
4B	85	5	10					
4C	90	8	2					
4D	95	5						
5A					40	60		
5B			5	15		80		
5C			45	45	10			
5D	10	80	10					
6A	55	10	5	5	10	15		
6B	20	60	20					
6C	50	30	20					
6D	50	30	20					
7A		5	15	25	45	10		
7B	5	15	40	20	10	10		
7C			50			50		
7D	2	85	13					
8A			95	5				
8B			75	25				
8C			50	30	20			
8D			50	40	10			
9A	20	30	50					
9B	40	40	20					
9C	40	40	20					
9D	20	70	10					

Table 3.3 Date, time, transect length and location of intertidal surveys at nine transects at Naval Station Treasure Island, Hunters Point Annex.

Transect	Date	Start Time	Transect Length (m)	End Location	
1	11/11/93	15:18	36.0	N: 37° 43′ 57.4″	W: 122° 22′ 14.4″
2	11/09/93	14:23	26.0	N: 37° 43′ 2″	W: 122° 22′ 23″
3	11/09/93	13:28	22.0	N: 37° 43′ 11″	W: 122° 22′ 42″
4	11/10/93	13:55	43.0	N: 37° 43′ 23″	W: 122° 22′ 38″
5	11/10/93	15:19	11.6	N: 37° 43′ 15″	W: 122° 22′ 45″
6	11/11/93	16:00	26.0	N: 37° 43′ 08″	W: 122° 22′ 48″
7	11/11/93	15:05	16.0	N: 37° 42′ 58″	W: 122° 22′ 33″
8	11/11/93	16:02	18.0	N: 37° 43′ 59″	W: 122° 22′ 06″
9	11/11/93	16:50	50.0	N: 37° 42′ 32″	W: 122° 23′ 10″

3.2 Species Composition and Abundance

The species composition and number of organisms collected from the intertidal community at each site (A-D) along the sampling transect (Transects 1 to 9) are summarized in Table 3.4. More than 1,500 organisms representing 8 phyla and 80 species, were identified from the 36 sampling sites (4 sites × 9 transects). The number of species (S) collected from a site varied widely within and among the nine transects. For example, S varied from 33 at Site 5C (i.e., Site C, Transect 5) to 5 at Site 5A. Similarly, we identified a total of 42 species at Transect 5 compared to only one species at Transect 8. The total number of organisms (n) collected from a site also varied greatly, ranging from more than 249 at 5C to 0 at 8B.

The sampling design for this reconnaissance survey did not call for collection of replicate samples at each site. Therefore, differences in abundance estimates between the 36 sampling sites could not be examined statistically. We plotted the number of organisms caught at each of the 36 sites in ascending order (Figure 3.1) to determine if general trends in abundances could be detected. These plots showed the four sites sampled at Transect 8 had fewer individuals than any of the other sites. The abundance of organisms at three of the four sites sampled at Transects 3 and 6 also ranked in the lower one third of the 36 sites. Conversely, the abundance of organisms at Transects 5 and 7 was relatively high, with three out of four sites at these transects ranking in the upper third of all sites.

The mean number of individuals per transect and associated standard error are presented in Table 3.5. The SKN and Scheffe methods indicated mean abundances were not significantly different among the transects (Table 3.5). This is not surprising given the high variability observed among sites within a transect. The Duncan method (Snedecor and Cochran 1980), a less robust statistical test, indicated the mean abundance at Transect 5 was significantly higher than at Transects 3 and 8.

3.3 Richness, Diversity, and Evenness Indices

Table 3.6 lists the mean and standard error of the richness, diversity, and evenness indices calculated for each transects. SNK tests showed the R1 value (Menhinick richness index) at Transect 5 was significantly higher than at Transect 8. No significant differences among the transects were detected for any of the other four indices (R2, N1, N2, and E5).

3.4 Quality Control

Samples 2A, 3D, 4D and 8C were randomly selected for verification of species identification and abundance estimations. No discrepancies were found between the samples processed by the two taxonomists.

Taxa	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D	4A	4B	4C	4D	5A	5B	5C	5D	6A	6B	6C	6D	7A	7B	7C	7D	8A	8B	8C	8D	9A	9B	9C	9D	TOTAL
Phylum Porifera																																					
unidentified Porifera																																			1		1
Phylum Cnidaria																																					
unidentified Anthozoa																			3								1										4
Phylum Nemertea																																					
unidentified Nemertea																											1										1
Phylum Annelida																																					
Class Oligochaeta																																					
Tubificidae													1	4				3	4									1									13
Class Polychaeta																																					
Family Polynoidae																																					
Harmothe imbricata																			1																		1
Family Phyllodocidae																																					
Eteone californica																												1									1
Family Syllidae																																					
Exogone lourei				1															19		3						10	4									37
Pionosyllis magnifica																												1									1
Typosyllis hyalina			1																3																		4
Typosyllis nr. pulchra																			3																		3
Typosyllis nr. armarillis																			2																		2
Spaerosyllis californiensis																			2								2										4
unidentified Syllidae																												1									1
Family Nereidae																																					
Nereis succinea						11	1	8					2	9	11	1		1	8		4						4						1		1		62
Family Nephtyidae																																					
Nephtys caecoides																1																					1
Family Goniadidae																																					
Glycinde polygnatha						2								24	16	8				1								1					1				53
Family Spionidae																																					
Polydora brachycephala																												1									1
Polydora socialis			1																																		1
Polydora ligni																		1	4		3						1										9
Psuedopolydora paucibranchiata			1																																		1
Family Cirratulidae																																					
Cirriformia spirabrancha		5	5	4				2			1	1						1			1						2							1		1	24
Cirratulus cirratus																											12										12
Family Capitellidae																																					
Heteromastis filiformis												1			1																			1			3
Phylum Arthropoda																																					
Class Crustacea																																					
Subclass Ostracoda																																					
unidentified Ostracoda														1																							1
Subclass Cirripedia																																					
Balanus crenatus							+	+										+	+		+					+	+										
Subclass Malacostraca																																					
Order Cumacea																																					
unidentified Cumacea														1					1																		2
Order Tanaidacea																																					
Tanais sp. A																					18																18
Tanais spp.																		3	11		18																32
Order Isopoda																																					
Cirolana harfordi					10		7		2																4												23
"Dynamenella" glabra																		1	1																		2
"Dynamenella" sp. B																			2																		2
"Dynamenella" spp.																					3																3
Exosphaeroma amplicauda																		3																			3
Exosphaeroma spp.																			1																		1
Gnorisphaeroma oregonensis / rayi																		16	15		28																59
Paranthura elegans																											1										1
Sphaeroma pentodon																		8	10		8																26
unidentified Sphaermatidae																			3		1																4
unidentified Janiridae																			1																		1
unidentified Isopoda																					1																1
Order Amphipoda																																					
Ampithoe spp.																		3	1		7							1								1	13
Corophium spp.																		1	6		2						2										11
Corophium insidiosum																					2																2
Grandierella japonica							1												14		7																22
Melita spp.																		2			3						1										6
Orchestia chilensis																		12																			12
Orchestia spp.																					5																5
Caprella sp. A																			1																		1
Caprellidae																			2																		2
unidentified Amphipoda																			1																		1
Order Decapoda																																					
Callianassa californiensis	1																																				1
Hemigrapsus oregonensis							4	24										1	1		9		1		7	14		1									62
Pachygrapsus crassipes																	3																				3
Class Hexapoda																																					
Order Diptera																																					
Dipteran larva																					1																1
Phylum Molusca																																					
Class Gastropoda																																					
Subclass Prosobranchia																																					
Littorina littorea																									3												3
Notacmea fenestrata / persona																	1																				1
Nucella lamellosa			1	1																																	2
Odostomia fetella																		2	9								3										14
Odostomia spp.																					5																5
Subclass Opistobranchia																																					
unidentified Cephalaspidea																							1														1
Class Bivalvia																																					
Subclass Pteriomorphia																																					
Musculista senhousia			1	16			2			2	7						1	1	48	1	11	1		1			8	23					1	1	2	4	131
Mytilus edulis							8	20									7	34	11		17					8	10										115
Ostrea lurida							5	21										8	20		12					2	6										74
Subclass Heterodonta																																					
Cryptomya californica																							3	2				7					2	8		5	27
Gemma gemma														54	24	4																					82
Macoma balthica													3	40	17	4																					64
Macoma nasuta																					1																1
Mya arenaria						1				1			8		1	3																					14
Potamocorbula ameurensis				1		1					2			2	1	2				5			1					1					5	2	1		24
Tapes japonica	3	10	12	2	1		3	38	1	4	6	1	1	4	1		24	10	35	7	31	3	2	3	6	27	47	17	2		2		5	11	6	10	335
Theora lubrica																1																					1
Phylum Bryozoa																																					
unidentified Bryozoa																											+										
Phylum Chordata																																					
Subphylum Urochordata																																					
Ascidia ceratodes																											1										1
Mogula manhattenensis																											1							1			2
Styella clava								1										1	6		4						20										32
Urochordata sp. C																											10										10
Urochordata sp. D																											+										
Urochordata sp. E																											+										
unidentified Urochordata																		2																1			3
Number of phyla represented	2	2	2	2	2	2	3	4	2	1	2	2	2	3	2	2	2	4	5	2	4	1	2	1	2	2	7	3	1		1		2	4	3	3	84
Number of species	2	2	7	6	2	4	9	8	2	3	4	3	5	9	8	8	5	22	33	4	27	2	5	3	4	5	24	13	1		1		6	8	5	5	255
Total number of organisms	4	15	22	25	11	15	31	114	3	7	16	3	15	139	72	24	36	114	249	14	205	4	8	6	20	51	143	60	2		2		15	26	11	21	1503

+ = indicates colonies of organisms

Table 3.4 Species composition and abundance for organisms from the intertidal community at nine transects at Naval Station Treasure Island, Hunters Point Annex.

Table 3.5 Mean abundance of organisms from the intertidal community at nine transects at Naval Station Treasure Island, Hunters Point Annex. The results of the SNK, Duncan and Scheffe multiple comparison tests are also reported. The same letters between transects for each test indicate no signficant difference at $P \geq 0.05$.

			Multiple Comparison Method		
Transect	**Mean**	**Standard Error**	**SNK**	**Duncan**	**Scheffe**
1	16.5	4.7	A	A B	A
2	42.8	24.1	A	A B	A
3	7.3	3.0	A	B	A
4	62.5	28.4	A	A B	A
5	103.3	53.1	A	A	A
6	55.8	49.8	A	A B	A
7	68.5	26.3	A	A B	A
8	1.0	0.6	A	B	A
9	18.3	3.3	A	A B	A

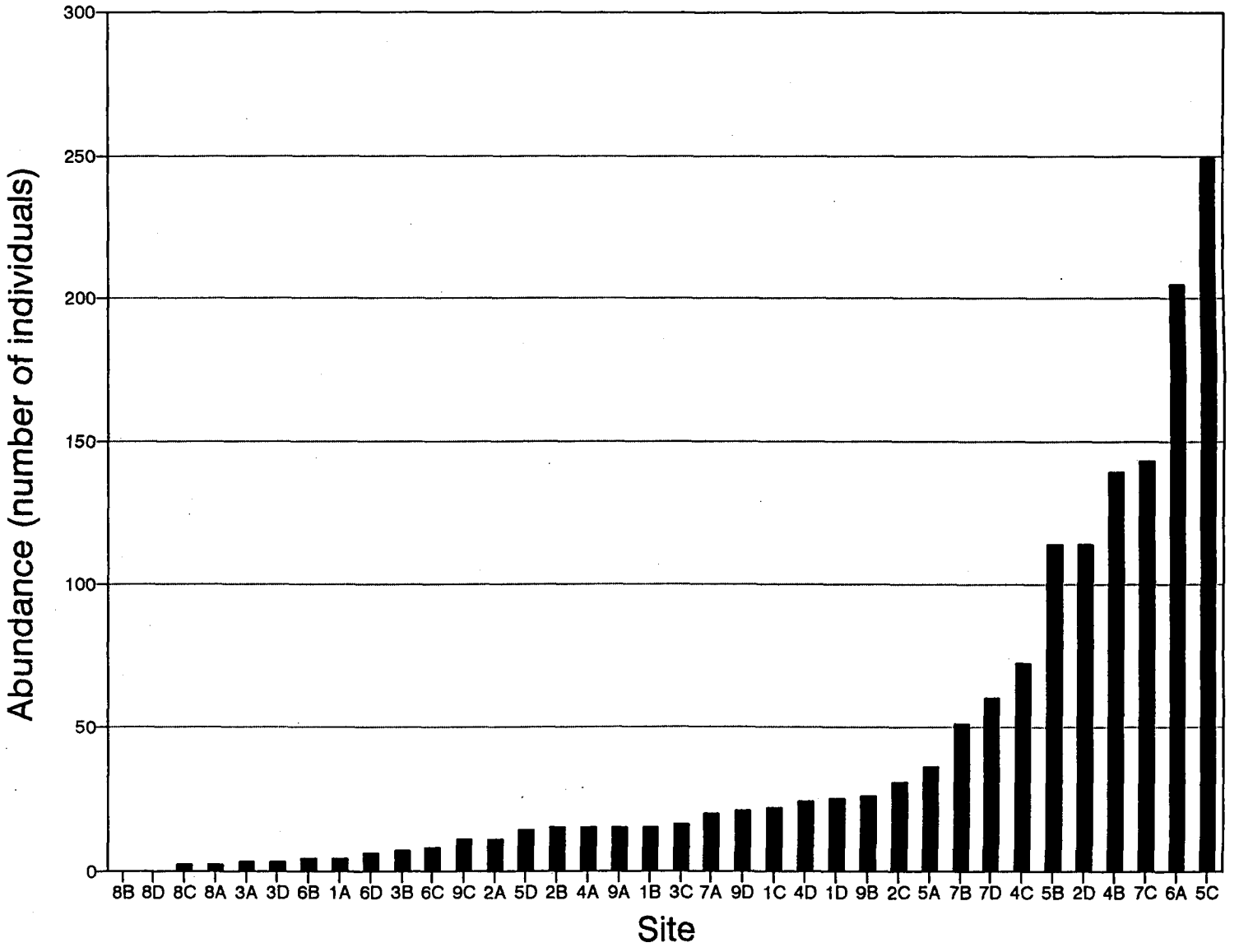


Figure 3.1 Abundance of organisms from the intertidal community at 36 sites (nine transects) at Naval Station Treasure Island, Hunters Point Annex.

Table 3.6 Mean values of five richness, diversity, and evenness indices of organisms from the intertidal community at nine transects at Naval Station Treasure Island, Hunters Point Annex. The results of the SNK, Duncan and Scheffe multiple comparison tests are also reported. The same letters between transects for each test indicate no significant difference at $P \geq 0.05$.

	Margalef Index (R1)			Menhinick Index (R2)			Hill's Diversity No. 1 (N1)			Hill's Diversity No. 2 (N2)			Modified Hill's Ratio (E5)		
Transect	Mean	SE	SNK	Mean	SE	SNK	Mean	SE	SNK	Mean	SE	SNK	Mean	SE	SNK
1	1.1	0.4	A B	1.1	0.2	A	2.7	0.5	A	2.3	0.3	A	0.9	0.2	A
2	1.2	0.3	A B	0.9	0.2	A	3.8	1.2	A	3.6	1.3	A	0.8	0.1	A
3	1.2	0.2	A B	1.3	0.2	A	2.7	0.3	A	3.1	0.1	A	1.5	0.4	A
4	1.7	0.2	A B	1.2	0.2	A	4.8	0.5	A	4.4	0.7	A	0.9	0.1	A
5	3.0	1.1	A	1.5	0.3	A	8.4	3.5	A	6.1	2.3	A	0.7	0.1	A
6	2.1	0.9	A B	1.5	0.2	A	6.4	3.5	A	6.5	2.5	A	1.4	0.2	A
7	2.1	0.7	A B	1.2	0.3	A	5.4	1.7	A	4.5	0.8	A	1.0	0.3	A
8	0.0	0.0	B	0.7	0.0	A	1.0	0.0	A	1.0	0.0	A			A
9	1.7	0.2	A B	1.4	0.1	A	4.2	0.3	A	3.9	0.4	A	0.9	0.1	A

4.0 Conclusions

The aquatic investigations in this phase of the ecological risk assessment were designed as qualitative reconnaissance surveys to help focus future quantitative data collecting. The sampling design for this surveys did not call for collection of replicate samples at each site. Therefore, difference in abundance estimates between the 36 sites could not be examined statistically. The study design also did not attempt to document seasonal or diel changes in species composition or abundance.

Our survey results suggest that the number of organisms at Transects 3, 6 and 8 are depressed relative to the other sampling stations and the number of organisms collected per site at Transect 8 was consistently low. Conversely, the abundance of organisms at Transects 5 and 7 was relatively high. It was interesting to note that the abundance of organisms at the reference site (Transect 9) was lower than at many of the other transects. The number of organisms collected at Transect 2, where we observed oil residues, did not appear to be substantially lower than the other transects.

Habitat differences at the sampling stations, unrelated to the presence of hazardous material, may be influencing community structure substantially, thereby minimizing the interpretive value of direct comparisons of species composition or abundance among transects. The rocky intertidal stations generally contained higher species diversity and abundances than the sandy or mudflat intertidal stations. Additional studies are needed to identify these relationships.

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Naval Station Treasure Island, Hunters Point Annex

Technical Report

Subtidal Benthic Surveys

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J- 779

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1.0 Background

PRC Environmental Management, Inc. (PRC) is under contract to the Department of the Navy to implement the Ecological Risk Assessment Work Plan (WP) under the Comprehensive Long-term Environmental Action Navy (CLEAN) at the Naval Station Treasure Island, Hunters Point Annex (HPA), in San Francisco, California. BioSystems Analysis, Inc. (BioSystems) was contracted by PRC to perform the aquatic survey portion of the Phase 1A ecological risk assessment. The aquatic investigations in this phase of the ecological risk assessment are reconnaissance surveys that will help focus future quantitative data collection efforts. The objective of the WP is to identify the possible ecological impacts on biota of hazardous material used and disposed of within the project area at HPA. The scope of work required compiling information on the composition and abundance of biota at HPA. The results of this study and others will be used to design and implement a more comprehensive field sampling and analysis plan for subsequent phases of work. This report presents the results of BioSystems' subtidal benthic sampling program only. Results of the demersal fish, intertidal, and epibenthic sampling programs are summarized in separate reports.

2.0 Technical Approach

BioSystems' study characterized the benthic community in the HPA project area and an "undisturbed" reference area in San Francisco Bay and compared the results. The reference site (just south of Candlestick Park) was selected by PRC after a review of studies in San Francisco Bay and agency consultation. To characterize aquatic resources, BioSystems collected samples from the intertidal, benthic, and epibenthic invertebrate communities and from the demersal fish community. Sampling methods for the subtidal benthic survey are outlined in Section 2.1. For each sample, we reported the collection date, time, location, species composition and abundance and other pertinent information. The location of each sampling site was placed on a map for future reference. The position (latitude and longitude) of each sampling site was also documented using a global positioning system (GPS) unit to ensure accurate transect identification. Due to selective availability imposed by the U.S. Department of Defense, all GPS units have a maximum error range of about 100 meters. The following section describes the subtidal benthic sampling program only. The demersal fish, intertidal, and epibenthic programs are addressed in separate reports.

2.1 Field and Laboratory Methods

2.1.1 Subtidal Benthic Sampling

The purpose of this survey was to provide information on the composition and abundance of small benthic invertebrates in the subtidal area of Hunters Point Annex. Nine transect stations were selected: seven in the South Basin, one in India Basin, and one at the off-site reference area, located just south of Candlestick Park (Figure 2.1).

The subtidal benthic sampling was conducted from 16-19 November 1993. For the purpose of this project, we defined subtidal as areas always covered by water (never exposed during low tide) and accessible by our boat (draft of 1.2 m). Samples were collected at four sites equally spaced along Transects 1, 2, 3, 7, 8 and 9 and at three sites along Transects 4, 5 and 6 for a total of 33 sites. Fewer sites were sampled at Transects 4, 5 and 6 because of the narrowness of South Basin. We used GPS to mark the location of each sample site.

The sample collection and analysis process is illustrated in Figure 2.2. Benthic samples were collected with a teflon-coated Van Veen grab sampler and sieved sequentially through 1.0 and 0.5 millimeter screens. All organisms collected on each of the screens were preserved immediately in 10 percent formalin in glass or plastic jars. The following information was recorded at each station: date, time, personnel, GPS coordinates, weather, depth, general substrate composition and characteristics, and number of samples collected.

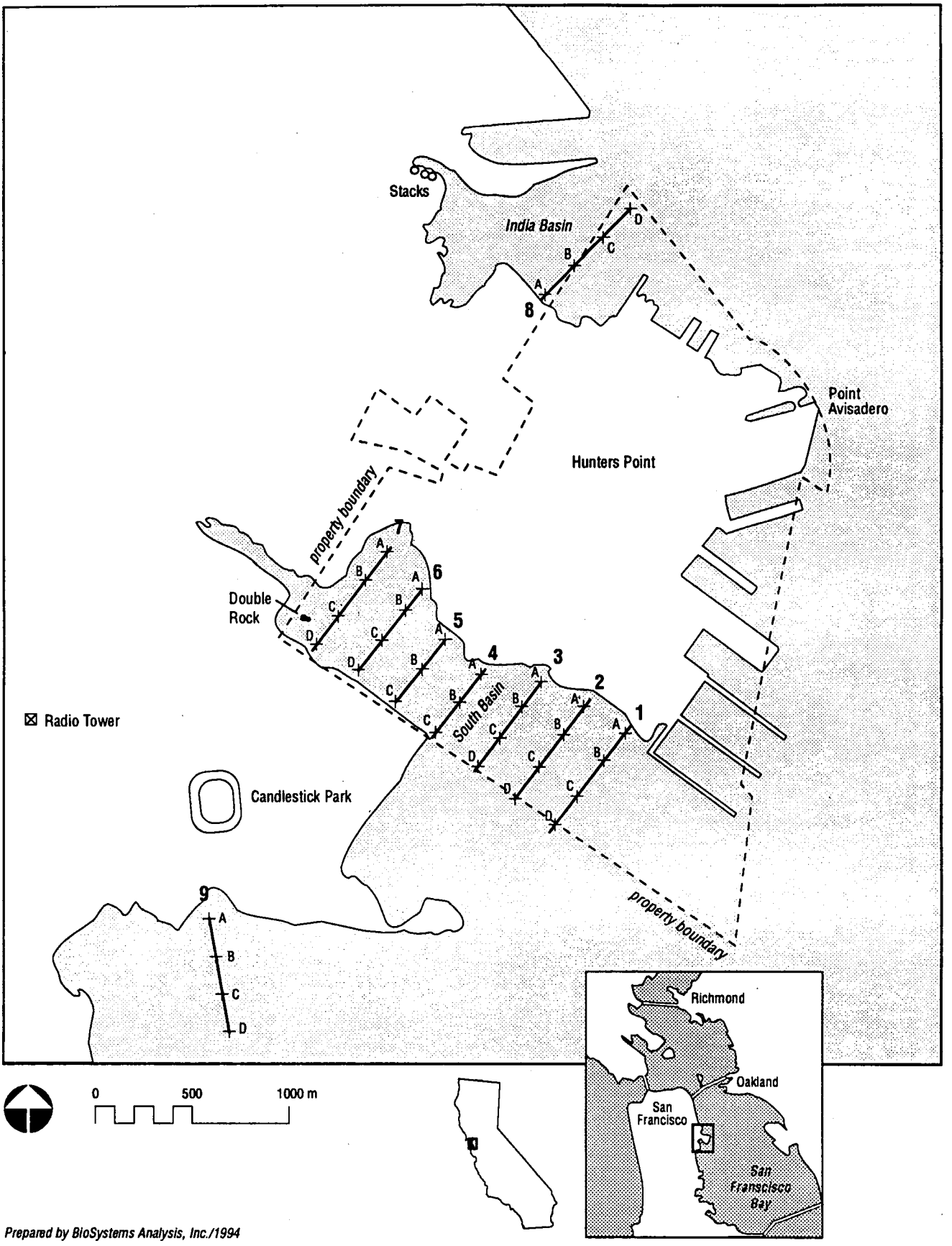

Figure 2.1 Location of subtidal benthic surveys conducted at Naval Station Treasure Island, Hunters Point Annex.

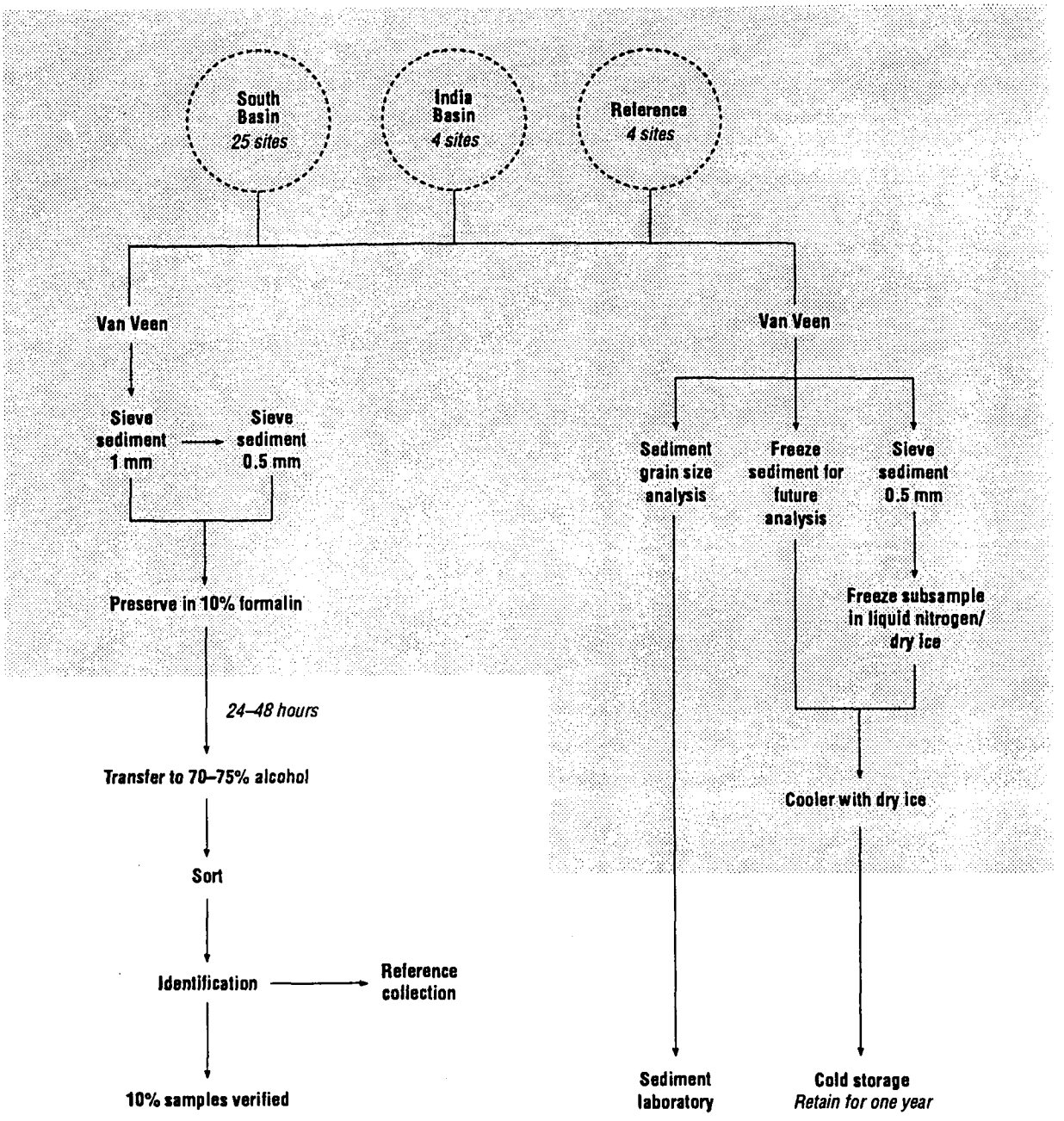

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Figure 2.2 Summary of subtidal benthic sampling and analysis procedures.

Sediment and organisms were also collected at each site using a teflon-coated Van Veen grab sampler for sediment grain size analysis, sediment chemistry, and future chemical/histopathological analysis. Approximately 1 gallon (3,800 ml) of sediment was collected and retained in a plastic container for sediment grain size analysis using the American Society for Testing and Materials' (1993) "Standard Test Method for Particle-Size Analysis of Soils." The color of each sediment sample was noted as well as any unusual odor.

For sediment chemistry analysis, we collected approximately 32 ounces (950 ml) of sediment samples in clean glass jars and froze them in our laboratory (0±5° F). These will be retained for one year from the date of collection. Although this procedure was stipulated in the work plan, standard scientific procedures specify time units for storing water samples for most chemical constituents, including volatile organic compounds and heavy metals. Samples can rarely be stored for more than one year, and, for some analyses, samples can only be held for 14 days.

The remaining sample was used for collecting and preserving biota for future chemical analyses. Approximately 3 gallons (11.3 liters) (equivalent to the volume of a Ponar sampler) was sieved through a 0.5 millimeter screen. Organisms remaining on the screen were collected into small plastic containers and flash-frozen using liquid nitrogen or dry ice, depending on the size of the organism. The samples were then placed on dry ice and transferred to cold storage (0±5° F) in the laboratory. Frozen samples will be securely retained for one year from date of collection.

In the laboratory, benthic samples collected for the biota analysis were transferred to 70-75 percent ethanol within 24 to 48 hours of collection and sorted into appropriate categories by laboratory technicians. A taxonomist counted all specimens and identified them to species in each portion (0.5 mm and 1.0 mm) of the samples. Separate data sheets were prepared for each site.

2.2 Data Entry and Analytical Methods

All field and laboratory data forms were copied and retained at two locations for safety. Data from all other forms were entered into a database computer program for further analysis of species composition and abundance. Once data was entered into the database program, a hard copy was printed and checked for errors. Data entry was verified and corrected prior to analysis.

All data were backed up automatically on BioSystems' client/server computer network system (Novell Netware 3.11). All files stored on the network were automatically duplicated on tape every night using the grandfather/father/son rotation method that rotates 10 tapes over a 12 week period. This method provided a high degree of data redundancy and security.

The mean and standard error (SE) of the number of organisms from the subtidal benthic community at each of the nine transects were calculated for all species combined. Separate analyses were completed for each portion of the samples (0.5 and 1.0 mm). Student-Newman-Keuls (SNK), Duncan,

and Scheffe multiple comparison methods (Snedecor and Cochran 1980) were used to determine the differences in abundance estimates.

We used the Margalef (1958) index, R1, and the Menhinick (1964) index, R2, to measure species richness for each of the nine transects. The R1 index can be calculated as follows:

$$R1 = \frac{S-1}{\ln(n)} \tag{1}$$

where S is the number of species in a community (i.e., sample); n is the number of individuals observed in a sample.

The R2 index is:

$$R2 = \frac{S}{\sqrt{n}} . \tag{2}$$

Diversity indices incorporate both species richness and evenness into a single value (Ludwig and Reynolds 1988). We applied two of the most commonly used diversity indices, N1 and N2, presented by Hill (1973) in this study. The N1 index measures the number of abundant species in the sample which can be expressed as:

$$N1 = e^{H'} \tag{3}$$

where H′ is the Shannon index (Shannon and Weaver 1949). The value of H′ can be estimated from a sample as:

$$\hat{H} = -\sum_{i=1}^{S} [(\frac{n_i}{n})\ln(\frac{n_i}{n})] \tag{4}$$

where n_i is the number of individuals belonging to the *i*th of S species in the sample; n is the total number of individuals in the sample.

The N2 index measures the number of very abundant species which can be formulated as:

$$N2 = \frac{1}{\lambda} \tag{5}$$

where λ is the Simpson's index (Simpson 1949). The unbiased estimator for λ is:

$$\hat{\lambda} = \sum_{i=1}^{S} \frac{n_i(n_i-1)}{n(n-1)} \quad . \tag{6}$$

Then, we used a modified Hill's ratio (Hill 1973, Alatalo 1981), E5, to quantify the evenness component of diversity. The E5 is:

$$E5 = \frac{(1/\lambda)-1}{e^{H'}-1} = \frac{N2-1}{N1-1} \quad . \tag{7}$$

Since the SNK is one of the most powerful multiple comparison methods (Snedecor and Cochran 1980), we used this method to compare each of the above indices among the nine transects.

2.3 Quality Assurance/Quality Control (QA/QC)

2.3.1 Field Equipment

Prior to sampling, all equipment was visually inspected, cleaned and tested to ensure proper performance. For all sampling equipment, we used a checklist of components to be inspected, cleaned and tested. Data sheets documenting these inspections were completed prior to use at each station and retained by BioSystems. Any problems or repairs to the equipment during the surveys were documented.

2.3.2 Sample Tracking

Each sample collected in the field was assigned a unique and permanent number, which was recorded on a sampling log sheet. All sample containers were labelled with sample number, date and time, location of collection, and personnel. For each sample, a chain of custody/sample tracking form was maintained that included the following information: sample number, sampling date, community type sampled, container type and size, and chain of custody information. In addition, this form was used to record any event relating to the sample (e.g., transfer to ethanol or sorting).

If a sample was split during sorting, resulting split samples were labeled with the original sample number and a prefix to designate it as a sorted sample. Since sorted samples from the same sampling location were physically kept together, tracking of sorted samples was maintained on the original chain of custody/sample tracking form.

The chain of custody/sample tracking forms were maintained in a binder in a secure central location and were available for review by the project manager at any time.

2.3.3 Verification of Identification

To verify species identifications, three samples (including both the 1.0 mm and 0.5 mm portions) were randomly selected and sent to a second taxonomist who recorded the findings on a separate data sheet. The identifications were compared and any discrepancy in species composition or abundance was investigated and corrected. We resorted the 0.5 mm and 1.0 mm portions of three samples to verify that we had not missed significant numbers of organisms during processing.

3.0 Results

3.1 Site Description

The physical characteristics of substrate samples collected at subtidal benthic sites are summarized in Table 3.1. Seventy-nine percent (26 of 33) of the samples consisted of at least 60 percent aerobic mud. Sand was the primary component on 12 percent (4 of 33) of the samples and anaerobic mud made up at least 60 percent in 9 percent (3 of 33) of the samples. All stations on Transect 7 contained anaerobic mud. The predominant color of the samples was black, grey, or a mixture of the two. We observed oil in nine of the samples and smelled hydrogen sulfide in three samples during collection. During analyses in the laboratory, a petroleum odor was detected in 16 samples; the smell was very strong in four of these. The date, time, depth and location of each of the sampling sites are summarized in Table 3.2.

Table 3.1 Physical characteristics of substrate at subtidal benthic sampling sites at Naval Station Treasure Island, Hunters Point Annex.

	Percentage of:						Petroleum Odor		
Station/ Site	Anaerobic Mud	Aerobic Mud	Sand	Gravel	Substrate Color	Visible Oil	Slight	Strong	Notes
1A		30	70		grey		X		
1B		70	30		grey/brown				
1C	10	90			grey/brown				
1D	10	90			grey/brown				
2A		10	90		brown	X		X	
2B		90	10		grey/brown				
2C		95	5		grey/brown				
2D		95	5		grey/brown		X		
3A		80	20		grey/black	X	X		
3B		90	10		grey				
3C		95	5		grey	X	X		
3D		95	5		grey				
4A	20		80		black			X	strong hydrogen sulfide odor
4B	95		5		grey/black			X	slight hydrogen sulfide odor
4C		70	30		grey/black		X		
5A		70	30		black/grey	X	X		
5B		95	5		black/grey				
5C		70	30		black/grey	X	X		
6A		95	5		grey	X	X		
6B		95	5		grey/black				
6C		90	10		black/grey				
7A	30	60	10		black	X		X	
7B	35	65			black				
7C	35	65			black		X		
7D	95		5		black			X	hydrogen sulfide odor
8A	30	70			grey/brown		X		
8B		80	20		black/grey				
8C	60	40			grey	X			
8D		49	50	1	grey				
9A		90	10		grey/black	X	X		
9B		95	5		grey				
9C		95	5		grey				
9D		95	5		grey				

Table 3.2 Collection date, time, depth and location of samples collected from the subtidal benthic community at nine transects at Naval Station Treasure Island, Hunters Point Annex.

Sample	Date	Time	Depth (m)	Location	
1A	11/19/93	08:49	1.7	N: 37° 42′ 58″	W: 122°22′ 00″
1B	11/17/93	10:06	3.4	N: 37° 42′ 54″	W: 122° 22′ 04″
1C	11/17/93	10:35	4.0	N: 37° 42′ 50″	W: 122° 22′ 09″
1D	11/17/93	11:05	4.2	N: 37° 42′ 46″	W: 122° 22′ 13″
2A	11/17/93	11:35	2.2	N: 37° 43′ 00″	W: 122° 22′ 02″
2B	11/17/93	11:49	4.5	N: 37° 42′ 56″	W: 122° 22′ 08″
2C	11/17/93	12:11	4.5	N: 37° 42′ 52″	W: 122° 22′ 11″
2D	11/17/93	12:29	4.8	N: 37° 42′ 48″	W: 122° 22′ 17″
3A	11/18/93	09:25	2.1	N: 37° 43′ 03″	W: 122° 22′ 13″
3B	11/18/93	09:34	2.4	N: 37° 42′ 59″	W: 122° 22′ 17″
3C	11/18/93	09:55	2.4	N: 37° 42′56″	W: 122° 22′ 20″
3D	11/18/93	10:05	2.4	N: 37° 42′ 52″	W: 122° 22′ 25″
4A	11/18/93	11:38	2.0	N: 37° 43′ 06″	W: 122° 22′ 27″
4B	11/18/93	11:56	2.6	N: 37° 43′ 03″	W: 122° 22′ 29″
4C	11/18/93	12:07	2.3	N: 37° 42′ 58″	W: 122° 22′ 33″
5A	11/18/93	13:35	2.1	N: 37° 43′ 10″	W: 122° 22′ 30″
5B	11/18/93	13:53	2.8	N: 37° 43′ 09″	W: 122° 22′ 37″
5C	11/18/93	14:09	2.1	N: 37° 43′ 03″	W: 122° 22′ 41″
6A	11/18/93	12:34	1.8	N: 37° 43′ 16″	W: 122° 22′ 34″
6B	11/18/93	12:49	2.4	N: 37° 43′ 11″	W: 122° 22′ 42″
6C	11/18/93	13:07	2.0	N: 37° 43′ 08″	W: 122° 22′ 48″
7A	11/17/93	14:07	2.4	N: 37° 43′ 23″	W: 122° 22′ 38″
7B	11/17/93	14:27	2.7	N: 37° 43′ 21″	W: 122° 22′ 42″
7C	11/17/93	14:46	2.8	N: 37° 43′ 16″	W: 122° 22′ 47″
7D	11/17/93	15:06	2.4	N: 37° 43′ 11″	W: 122° 22′ 54″
8A	11/19/93	08:10	2.1	N: 37° 43′ 58″	W: 122° 22′ 08″
8B	11/19/93	08:17	2.1	N: 37° 44′ 02″	W: 122° 22′ 03″
8C	11/16/93	10:10	4.5	N: 37° 44′ 06.2″	W: 122° 21′ 57.5″
8D	11/19/93	08:25	8.8	N: 37° 44′ 11.1″	W: 122° 21′ 51″
9A	11/18/93	07:45	1.5	N: 37° 42′ 33″	W: 122° 23′ 09″
9B	11/18/93	08:11	2.2	N: 37° 42′ 27″	W: 122° 23′ 09″
9C	11/18/93	08:25	2.2	N: 37° 42′ 22″	W: 122° 23′ 08″
9D	11/18/93	08:44	2.3	N: 37° 42′ 16″	W: 122° 23′ 07″

Particle size distribution for individual sample sites is shown in Table 3.3. The total dry weight of the samples ranged from 0.5 to 1.6 kg and the mean of all samples was approximately 1 kg. In 91 percent (30 of 33) of the samples, the predominant particle size was less than 0.075 mm in diameter. Seventeen samples contained shell fragments, pieces of wood, gravel, or a combination of these materials.

Table 3.3 Particle size distribution (by percent) of substrate samples collected at the 33 subtidal benthic sites at Naval Station Treasure Island, Hunters Point Annex.

Range of Particle Sizes (mm)	Site Number																
	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D	4A	4B	4C	5A	5B
>38.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38.1-19.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0[a]	0.0	0.0	0.0	0.0
19.05-9.5	0.2[a]	0.0	0.0	0.0	0.9[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5[a]	0.0	0.2[a]	0.7[c]	0.0
9.5-4.75	0.5[a]	0.0	0.0	0.0	5.8[b]	0.0	0.0	0.0	0.1[a]	0.0	0.0	0.0	6.9[a]	0.0	0.4[a]	0.4	0.0
4.75-2.0	1.7[a]	0.0	0.0	0.0	7.5[b]	0.0	0.0	0.0	0.3	0.0	0.0	0.0[a]	10.7[a]	0.0	0.8[a]	1.1	0.1[a]
2.0-1.18	3.4[a]	0.0	0.0	0.2	5.8[b]	0.1	0.0	0.1	0.7	0.1	0.1	0.1	7.3[a]	0.1	0.5	0.8	0.0
1.18-0.6	6.0[b]	0.1	0.1	0.2	6.4[b]	0.1	0.1	0.3	0.6	0.3	0.2	0.1	7.9	0.2	0.8	1.1	0.1
0.6-0.3	11.2[c]	0.1	0.1	0.2	11.7	0.1	0.1	0.2	0.5	0.2	0.1	0.4	7.8	0.1	9.	2.4	0.1
0.3-0.15	32.0	0.1	0.1	0.4	27.0	0.2	0.1	0.2	2.2	0.2	0.1	0.1	11.1	0.2	43.3	11.9	0.1
0.15-0.075	9.1	1.0	0.9	3.3	10.0	0.5	0.4	0.7	12.5	0.2	0.2	0.2	7.4	0.2	5.9	20.4	0.3
<0.075	36.0	98.7	98.8	95.7	25.0	99.1	99.4	98.6	83.0	99.1	99.1	99.2	36.3	99.2	38.6	61.2	99.4
Sample weight (kg)	0.9	0.5	0.7	0.5	0.7	0.8	0.6	0.7	0.9	0.7	0.8	0.8	1.2	0.8	1.3	0.9	0.6

Range of Particle Sizes (mm)	Site Number															
	5C	6A	6B	6C	7A	7B	7C	7D	8A	8B	8C	8D	9A	9B	9C	9D
>38.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38.1-19.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.05-9.5	0.4[a]	0.0	0.0	1.1[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.5-4.75	0.9[a]	0.2[a]	0.0	2.0[f]	0.5[g]	0.0	0.0	0.0	0.0	0.0	0.0	0.1[a]	0.1[a]	0.0[a]	0.0	0.0
4.75-2.0	1.7	0.6[b]	0.1	2.5[b]	1.2[f]	0.1	0.3	0.2	0.1	0.1[a]	0.0	0.4[e]	0.3[b]	0.1[c]	0.0[a]	0.0
2.0-1.18	1.1	0.7[c]	0.1	1.2	0.7	0.1	0.3	0.2	0.1	0.0[c]	0.1	0.8[c]	0.3[c]	0.1	0.1	0.2
1.18-0.6	1.1	0.9[d]	0.1	1.0	0.7	0.1	0.2	0.1	0.1	0.1	0.1	4.4[d]	0.4[d]	0.4	0.2	0.3
0.6-0.3	1.4	1.0	0.1	1.0	0.7	0.1	0.3	0.2	0.1	0.0	0.1	42.2	0.5	0.3	0.1	0.2
0.3-0.15	16.6	3.8	0.1	5.3	1.6	0.4	0.5	0.5	0.6	0.3	0.9	11.3	1.4	0.3	0.1	0.3
0.15-0.075	13.2	14.0	0.2	8.5	2.8	0.5	0.7	1.7	4.6	3.0	14.5	7.5	9.3	0.4	0.6	1.4
<0.075	63.7	78.9	99.3	77.6	91.9	98.6	97.8	97.1	94.5	96.5	84.3	33.5	87.6	98.5	98.8	97.7
Sample weight (kg)	1.1	1.0	0.6	0.9	1.0	0.8	0.9	0.8	1.1	0.9	0.9	1.6	0.9	0.8	0.8	0.7

[a] -All shells
[b] - 75% shells
[c] - 50% shells
[d] - 25% shells
[e] - Shells and gravel
[f] - Mostly shells
[g] - Mostly wood pieces
[h] - 50% wood and shells

3.2 Species Composition and Abundance

3.2.1 0.5 mm Size-fraction Samples

For the 0.5 mm portion of the samples from the subtidal benthic community, the species composition and number of organisms collected at each site (A-D) along Transects 1-9 are summarized in Table 3.4. A total of 8,854 organisms, representing 6 phyla and 49 species, were identified from the 33 sampling sites. The number of species collected from the sites varied from 10-21, while the number of organisms varied from 38-1345.

The sampling design for this reconnaissance survey did not call for the collection of replicate samples at each site. Therefore, differences in abundance estimates between the 33 sampling sites could not be examined statistically. We plotted the number of organisms collected at each of the 33 sites in ascending order (Figure 3.1) to determine if we could detect general trends in abundances. These plots show that the three sites along Transect 6 ranked in the upper 25 percent of the 33 sites. Three of the four sites along Transect 7 ranked in the upper 40 percent of all sites. Conversely, the abundance of organisms at three of the four sites at both Transects 1 and 2 were much lower, ranking in the lower half of all sites.

The mean number of individuals per transect and associated standard error are presented in Table 3.5. The SNK, Duncan, and Scheffe methods all indicated mean abundances were not significantly different among the transects (Table 3.5). This is not surprising given the high variability observed among sites within a transect.

3.2.2 1.0 mm Size-fraction Samples

For the 1.0 mm portion of the samples from the subtidal benthic community, the species composition and number of organisms collected at each site along the transects are summarized in Table 3.6. A total of 4,176 organisms representing 9 phyla and 74 species were identified from the 33 sampling sites. The number of species collected from the sites varied from 7 at Site 3C to 33 at Site 8D. The number of organisms ranged from 19 at Site 3A to 1,257 at Site 8D.

We also plotted the number of organisms caught at each of the 33 sites in ascending order (Figure 3.2) to determine general trends in abundances. Two of the three sites along Transect 6 and three of the four sites along Transect 7 ranked in the upper third of all sites. Conversely, the abundance of organisms at all four sites along Transect 3 ranked in the lower 40 percent. Two of four sites along Transect 8 (8A and 8B) ranked in the lower 10 percent, while the greatest number of organisms were collected at site 8D.

Taxa	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D	4A	4B	4C	5A	5B	5C	6A	6B	6C	7A	7B	7C	7D	8A	8B	8C	8D	9A	9B	9C	9D	TOTAL
Phylum Porifera																																		
Phylum Cnidaria																																		
Anthozoa - unidentified																																		
Phylum Nemertea																																		
Nemertea - unidentified																																		
Phylum Nematoda																																		
Nematoda - unidentified	31				115				36	1	2	4	308			18		5	25	7	1	14		3			4	12	13					599
Phylum Annelida																																		
Class Oligochaeta																																		
Tubificidae	1	4	16	21		2	10	8	15	24	28	47	18	23	18	11	1	15	3	609	43	91	54	67	299	224	21	31		34	1	1	1	1,741
Class Polychaeta																																		
Family Polynoidae																																		
Harmothoe imbricata		1						1		3	3	2		4			1		1				1				1	3						21
Hesperanoe spp.																																		
Family Sigalionidae																																		
Pholoe glabra																												1						1
Family Phyllodocidae																																		
Eteone spp.																									1									1
Family Pilargidae																																		
Pilargidae - unidentified																												1						1
Family Syllidae																																		
Exogone lourei	3	3	1	2	17	4			2			1	5			11		11	37	80	13	20		2	11		1	2		1		3		230
Spaerosyllis californiensis									3			1	1						4					1		2	3	2	1	1		1		20
Pionosyllis gigantea																																		
Typosyllis Sp. A							5	1									1										2							9
Typosyllis nr. pulchra																																		
Typosyllis spp.		3	6	3		2		4	2	1					7			1		4						13	3			5	13	37	8	112
Syllidae - unidentified														1	3												1							5
Family Nereidae																																		
Nereis succinea					1																													1
Nereis latescens	1																																	1
Nereis spp.																																		
Platynereis bicanaliculata																																		
Family Glyceridae																																		
Glycera americana																																		
Family Goniadidae																																		
Glycinde polygnatha	3	11	9	13	2	12	11	15	4	17	5	4	1	3	1		1	4	1	4	8	5	32		1	4	1	1		6	16	19	9	223
Family Nephtyidae																																		
Nephtys caecoides		1	3					3		1	1																2	1						12
Nephtys cornuta franciscana								1								1												1						3
Family Dorvilleidae																																		
Dorvillea rudolphi								1					1										1							1				4
Family Orbiniidae																																		
Leitoscoloplos elongatus		4	1	5		3	2	5		2	7	14		2	2				98	6						4	4	2				2		163
Family Spionidae																																		
Streblospio benedicti																						1												1
Family Cirratulidae																																		
Cirriformia spirabrancha																																		
Family Opheliidae																																		
Armandia brevis																																		
Family Capitellidae																																		
Heteromastis filiformis				1		1	2	1			1	1							1															8
Heteromastus spp.																																2		2
Family Maldanidae																																		
Asychis elongata																																		
Family Sabellaridae																																		
Sabellaria cementarium																																		
Family Ampharetidae																																		
Schistocomus hiltoni																																		
Family Terebellidae																																		
Ameana occidentalis																																		
Family Sabellidae																																		
Euchone nr. limnicola												3								2			3											8
Sabellidae - unidentified		7	10	11		16	5	11		8	1	1							1			1		2				1	1	1	13	15	1	106
Phylum Phoronida																																		
Phoronida - unidentified															1																			1
Phylum Arthropoda																																		
Class Crustacea																																		
Subclass Cephalocarida																																		
Cephalocarida - unidentified																										1								1
Subclass Ostracoda																																		
Sarsiella zosteracola	18				15				7				33		33	16	2	116	12	28	22	31		5	6			11		6		2		363
Subclass Copepoda																																		
Order Harpacticoida																																		
Harpacticoida - unidentified																1				1								1						3
Subclass Cirripedia																																		
Balanus crenatus																																		
Subclass Malacostraca																																		
Order Cumacea																																		
Hemileucon hinumensis	6		1	9	1	3	4	13		37	130	109		9	43	12	15	76	99	99	172	478	1	94	180	71	31	46	4	35	37	14		1,829
Cumacea - unidentified																1												3						4
Order Tanaidacea																																		
Leptochelia dubia	36				14						3										1								20					74
Order Isopoda																																		
Paranthura elegans	48				17				1	2			5		2	2	1		11	1									2	9			1	102
Cirolana harfordi																																		
Order Amphipoda																																		
Ampelisca abdita	1	10	20	17		15	3	7		9	29	7		2	3		22	17	55	5	20	51	16	4	66	3	1		961	56	8	8	4	1,420
Ampithoe spp.													1					1							1									3
Corophium heteroceratum		29	71	33		34	35	11		13	33	10		17			10			24			6	1	2			10			33	40	10	422
Corophium insidiosum																		7		13					44									64
Corophium spp.		11	16	6		29	10	7		36	21	25	1	10	10	1	5	9	1	15	5	5	2		5	2		39	9	18	25	20	1	344
Grandierella japonica	30	1			3					2	3	1	1		12		5	21	89	13	25	30	4	2	45	2	1			34	1	1		326
Caprella sp. A																	1															1		2
Caprellidae - unidentified													1		1					1					1						1			5
Photis brevipes																																		
Photis spp.																													3					3
Amphipoda - unidentified													3	1											2					2	1			9
Order Decapoda																																		
Cancer gracilis																																		
Brachyura larva																																		
Phylum Mollusca																																		
Class Gastropoda																																		
Subclass Prosobranchia																																		
Crepidula spp.																																		
Subclass Opistobranchia																																		
Cephalaspidea - unidentified																																		
Class Bivalvia																																		
Subclass Pteriomorpha																																		
Musculista senhousia	1	13	16	21	10	8	2	17	31	16	12	22		11	21	2	9				1	1	4	1		10	3	1	254				1	488
Subclass Heterodonta																																		
Cryptomya califorica																																		
Gemma gemma																										3								3
Macoma balthica																																		
Macoma nasuta																																		
Macoma spp. (juv.)																													1					1
Mysella tumida																																1		1
Mysella sp. A																												5	5					10
Potamocorbula ameurensis																							4											4
Solen sicarius																																		
Tapes japonica		1	1	3	1		1	2	2						1								1			2			70		1		2	88
Theora lubrica				1								2				1											1	1						6
Bivalvia - unidentified					1											3																		4
Phylum Echinodermata																																		
Class Ophiuroidea																																		
Ophiuroidea - unidentified							1																						1					2
Amphipolis spp.																																		
Phylum Bryozoa																																		
Bryozoa - unidentified																																		
Number of organisms	179	99	171	146	197	129	91	108	103	172	279	254	379	83	158	80	74	283	438	912	311	728	129	182	664	341	80	175	1345	209	150	167	38	8,854
Number of species	12	14	13	14	12	12	13	17	10	15	15	17	13	11	15	13	13	12	15	17	11	12	13	11	14	13	16	21	14	14	12	16	10	450
Number of phyla	4	3	3	3	4	3	4	3	4	4	4	4	3	3	4	4	3	3	3	3	4	4	3	4	2	3	4	4	5	2	3	3	3	113

Table 3.4 Species composition and abundance for organisms from the subtidal benthic community (0.5 mm size-fraction) at nine transects at Naval Station Treasure Island, Hunters Point Annex.

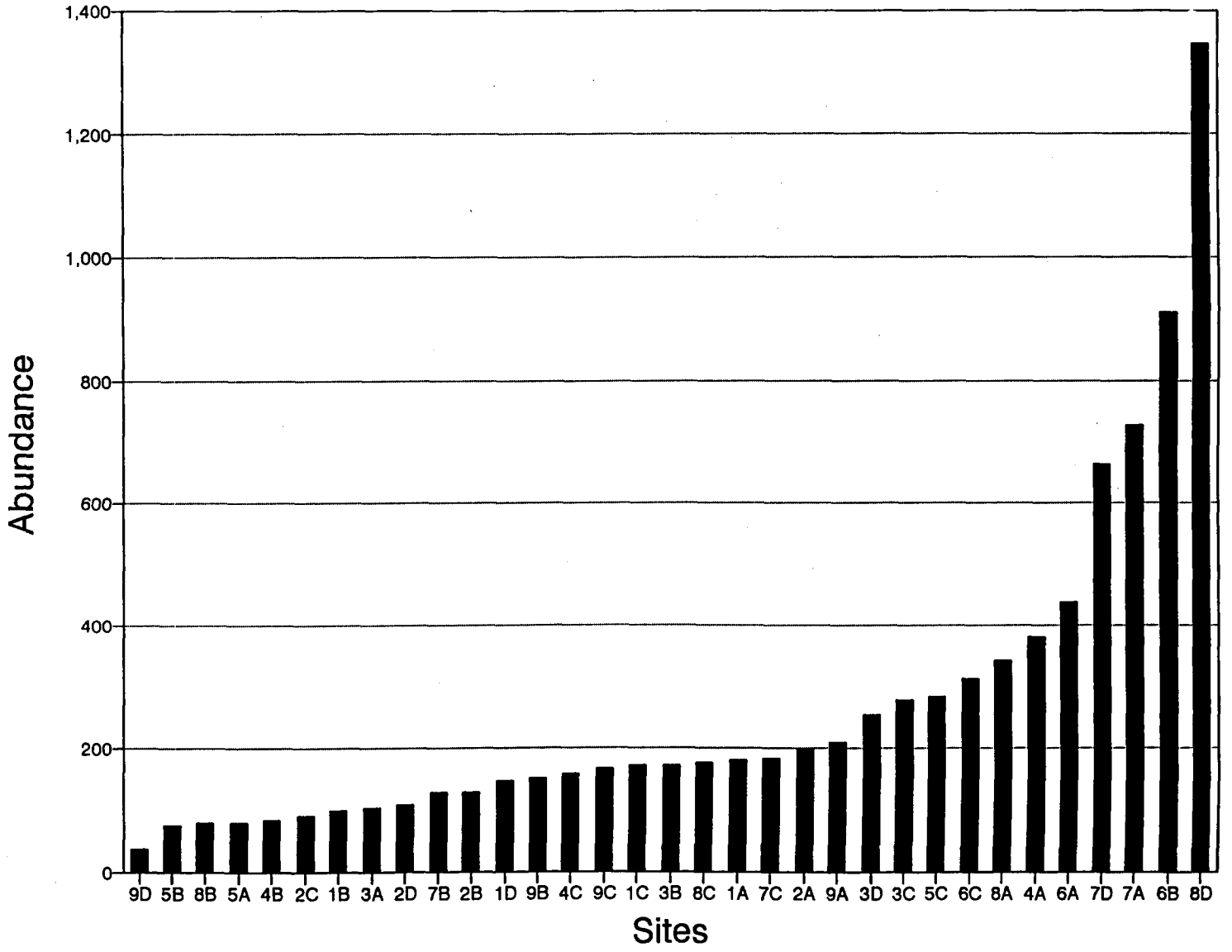

Figure 3.1 Abundance of organisms from the subtidal benthic community (0.5 mm size-fraction) at nine transects at Naval Station Treasure Island, Hunters

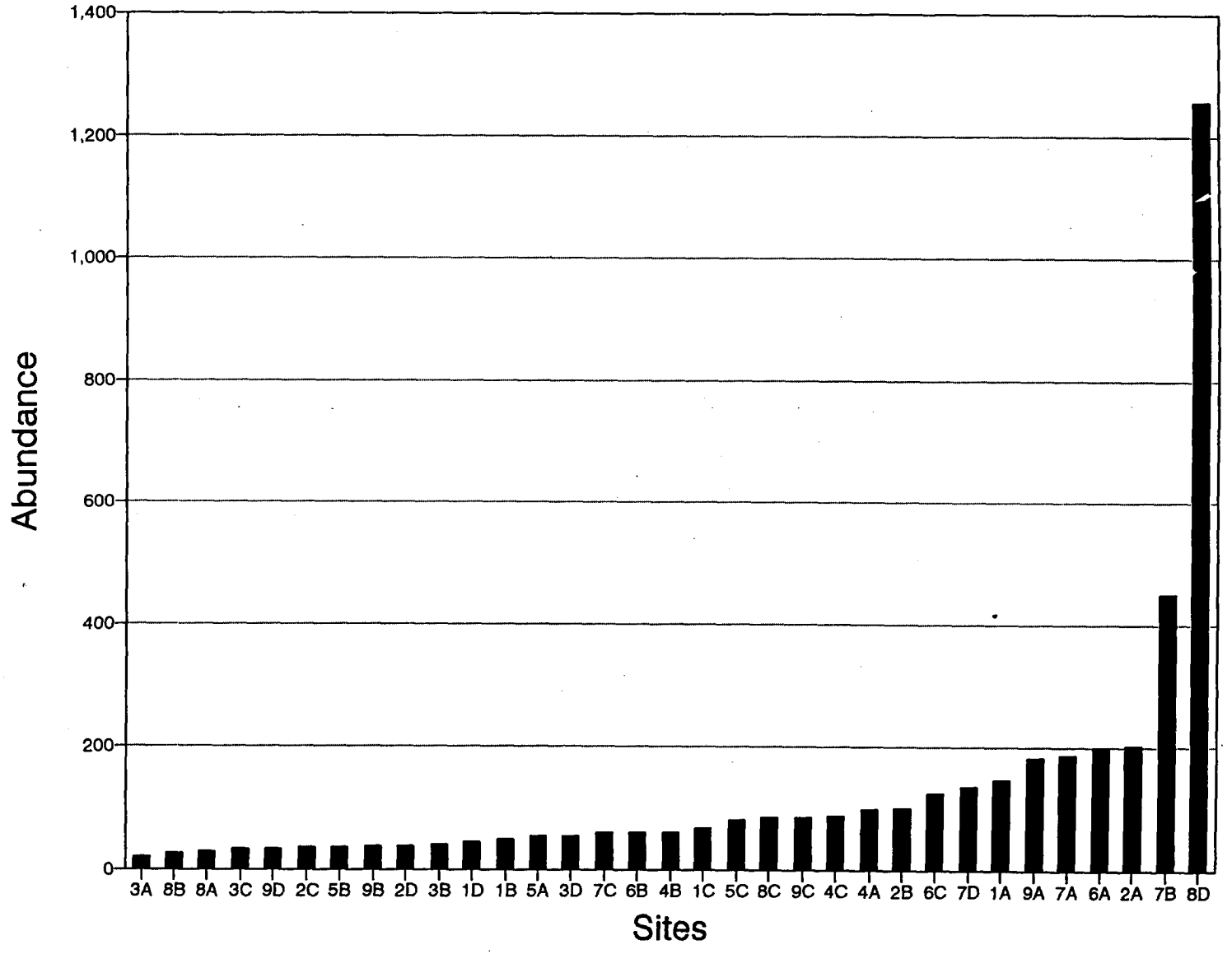

Figure 3.2 Abundance of organisms from the subtidal benthic community (1.0 mm size-fraction) at nine transects at Naval Station Treasure Island, Hunters

Table 3.5 Mean abundance of organisms from the subtidal benthic community (0.5 mm size-fraction) at nine transects at Naval Station Treasure Island, Hunters Point Annex. The results of the SNK, Duncan and Scheffe multiple comparison tests are also reported. The same letters between transects for each test indicate no significant difference at $P \geq 0.05$.

			Multiple Comparison Method		
Transect	Mean	Standard Error	SNK	Duncan	Scheffe
1	148.8	18.0	A	A	A
2	131.3	23.3	A	A	A
3	202.0	40.1	A	A	A
4	206.7	88.8	A	A	A
5	145.7	68.7	A	A	A
6	553.7	182.9	A	A	A
7	425.8	156.9	A	A	A
8	485.3	291.6	A	A	A
9	141.0	36.5	A	A	A

The mean number of individuals per transect and associated standard error are presented in Table 3.7. The SNK, Duncan, and Scheffe methods all indicated mean abundances were not significantly different among the transects.

3.3 Richness, Diversity, and Evenness Indices

3.3.1 0.5 mm Size-fraction Samples

For the 0.5 mm portion of the samples, Table 3.8 lists the mean and standard error of the richness, diversity, and evenness indices calculated from each transects. SNK tests indicated no significant differences among the transects for any of the indices (Table 3.8).

3.3.2 1.0 mm Size-fraction Samples

For the 1.0 mm portion of the samples, Table 3.9 lists the mean and standard error of the richness, diversity, and evenness indices calculated from each transects. SNK tests indicated no significant differences among the transects for any of the indices (Table 3.9).

Table 3.6 Composition and abundance of organisms from the subtidal benthic community (1.0 mm size-fraction) at nine transects at Naval Station Treasure Island, Hunters Point Annex

see file 3-6-TAB.wq1 for data, Tom did paste up for final presentation

Table 3.7 Mean abundance of organisms from the subtidal benthic community (1.0 mm size-fraction) at nine transects at Naval Station Treasure Island, Hunters Point Annex. The results of the SNK, Duncan and Scheffe multiple comparison tests are also reported. The same letters between transects for each test indicate no significant difference at $P \geq 0.05$.

			Multiple Comparison Method		
Transect	**Mean**	**Standard Error**	**SNK**	**Duncan**	**Scheffe**
1	75.5	24.0	A	A	A
2	93.3	39.2	A	A	A
3	35.8	7.1	A	A	A
4	81.7	11.3	A	A	A
5	55.3	12.8	A	A	A
6	127.7	40.7	A	A	A
7	208.3	85.1	A	A	A
8	348.5	303.1	A	A	A
9	84.3	34.9	A	A	A

3.4 Quality Control

Samples 1C, 7C and 8D were randomly selected for verification of species identification and abundance estimates. Currently, we have not completed our analysis of these samples. We will present results of this analysis in the final report. If significant discrepancies are found, we will reanalyze the data for the final report.

We have completed resorting of both the 0.5 and 1.0 millimeter portions of samples 1C, 7C and 8D. Overall, we missed approximately 4 percent (68 of 1,766) of the organisms in the 0.5 millimeter portion of the samples. In the 1.0 millimeter portion of the samples, we missed approximately 1 percent (19 of 1,382) of the organisms.

Table 3.8 Mean values of five richness, diversity, and evenness indices of organisms from the subtidal benthic (0.5 mm size-fraction) community at nine transects at Naval Station Treasure Island, Hunters Point Annex. The results of the SNK, Duncan and Scheffe multiple comparison tests are also reported. The same letters between transects for each test indicate no significant difference at $P \geq 0.05$.

	Margalef Index (R1)			Menhinick Index (R2)			Hill's Diversity No. 1 (N1)			Hill's Diversity No. 2 (N2)			Modified Hill's Ratio (E5)		
Transect	Mean	SE	SNK	Mean	SE	SNK	Mean	SE	SNK	Mean	SE	SNK	Mean	SE	SNK
1	2.5	0.2	A	1.1	0.1	A	8.0	0.8	A	6.4	0.8	A	0.8	0.0	A
2	2.6	0.3	A	1.2	0.2	A	7.9	1.6	A	6.4	1.8	A	0.7	0.1	A
3	2.5	0.2	A	1.0	0.1	A	6.8	0.8	A	4.9	0.8	A	0.7	0.1	A
4	2.4	0.2	A	1.0	0.2	A	5.9	1.9	A	4.8	1.6	A	0.7	0.1	A
5	2.5	0.3	A	1.2	0.3	A	7.0	0.7	A	5.7	0.9	A	0.8	0.1	A
6	2.1	0.2	A	0.6	0.0	A	5.1	1.0	A	3.7	1.2	A	0.6	0.1	A
7	2.0	0.2	A	0.7	0.2	A	4.3	0.5	A	3.0	0.4	A	0.6	0.0	A
8	2.8	0.5	A	1.1	0.3	A	5.4	1.5	A	3.7	1.1	A	0.6	0.0	A
9	2.5	0.2	A	1.2	0.2	A	7.4	0.4	A	6.3	0.2	A	0.8	0.0	A

Table 3.9 Mean values of five richness, diversity, and evenness indices of organisms from the subtidal benthic (1.0 mm size-fraction) community at nine transects at Naval Station Treasure Island, Hunters Point Annex. The results of the SNK, Duncan and Scheffe multiple comparison tests are also reported. The same letters between transects for each test indicate no significant difference at $P \geq 0.05$.

	Margalef Index (R1)			Menhinick Index (R2)			Hill's Diversity No. 1 (N1)			Hill's Diversity No. 2 (N2)			Modified Hill's Ratio (E5)		
Transect	Mean	SE	SNK	Mean	SE	SNK	Mean	SE	SNK	Mean	SE	SNK	Mean	SE	SNK
1	2.7	0.2	A	1.5	0.1	A	7.3	0.3	A	5.8	0.3	A	0.8	0.0	A
2	3.5	0.4	A	1.9	0.3	A	9.0	1.8	A	7.9	2.2	A	0.8	0.1	A
3	2.5	0.3	A	1.7	0.2	A	6.0	0.5	A	4.7	0.7	A	0.7	0.1	A
4	3.3	0.1	A	1.7	0.1	A	8.1	1.1	A	5.8	1.8	A	0.6	0.1	A
5	2.7	0.2	A	1.6	0.2	A	6.7	0.8	A	5.4	1.2	A	0.7	0.1	A
6	2.1	0.3	A	1.1	0.3	A	4.9	0.5	A	3.6	0.5	A	0.7	0.1	A
7	2.3	0.2	A	1.0	0.1	A	4.8	0.4	A	3.0	0.3	A	0.5	0.0	A
8	3.1	0.5	A	1.5	0.2	A	5.6	1.4	A	4.9	1.7	A	0.7	0.2	A
9	3.1	0.4	A	1.7	0.0	A	6.2	0.5	A	4.2	0.2	A	0.6	0.0	A

4.0 Conclusions

The aquatic investigations in this phase of the ecological risk assessment were designed as qualitative reconnaissance surveys to help focus future quantitative data collecting. The sampling design for this survey did not call for collection of replicate samples at each site. Therefore, difference in abundance estimates between the 33 sites could not be examined statistically. The study design also did not attempt to document seasonal or diel changes in species composition or abundance.

Our results for the 0.5 millimeter size-fraction suggest that the number of organisms at Transects 1 and 2 are depressed, relative to the other sampling transects. For the 1.0 millimeter size-fraction, the number of organisms along Transect 3 appears to be depressed. Along Transect 6 and 7 we collected relatively higher numbers of organisms in both the 0.5 and 1.0 mm size-fraction. There does not appear to be a relationship between species abundance and the presence of oil or petroleum odor at the sample sites for either size-fraction. Additional studies are needed to identify these relationships.

5.0 References

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