STUDY REPORT FOR THE SUMMER 2004 BIOTURBATION MEASUREMENT PROGRAM ON THE PALOS VERDES SHELF

July 2005

Prepared for:

U.S. Army Corps of Engineers
Los Angeles District
915 Wilshire Boulevard
Los Angeles, CA 90017

U.S. Environmental Protection Agency
Region IX
Superfund Division (SFD-7-1)
75 Hawthorne Street
San Francisco, CA 94105

Prepared by:

Science Applications International Corporation
10260 Campus Point Drive
San Diego, CA 92121

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SAIC Report Number 679

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1.0 INTRODUCTION

Overview

The U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) approved an Investigation Work Plan (IWP) in July 2004 (SAIC 2004a) that detailed a field investigation and analyses to characterize large bioturbating infaunal organisms (BIO) and evaluate sediment mixing/ bioturbation rates on the Palos Verdes (PV) Shelf (Task 4). The IWP was developed to address questions pertaining to potential effects of bioturbation on cap integrity that were deemed high priority for the Remedial Investigation/Feasibility Study (RI/FS). Answers to these questions will benefit both the feasibility study and the engineering design of a cap intended to isolate contaminated sediments across broad areas of the PV Shelf, if capping is selected by EPA as the solution for this Superfund site. The information presented in the IWP is consistent with the preliminary technical approach for the 2004 multidisciplinary survey program, as described in the Preliminary Sampling Plan (PSP; SAIC 2004a).

The key question for this study element, as identified in the Data Quality Objectives (DQO) matrix table for the PV Shelf RI/FS, is:

Question FS-7: Will a cap be recontaminated by Effluent-Affected (EA) sediment from uncapped areas (deep regions)? From beneath the cap, due to bioturbators?

A task-level restatement of this question is: Do deep-burrowing bioturbators occur in substantial numbers and sizes/weights to contribute substantially to mixing and disturbance of sediments within the potential capping area on the PV Shelf?

In order to address this question concerning the effects of bioturbators, a baseline field study was conducted in two phases in July and August 2004. Sediment cores were collected for evaluation of BIO and sediment mixing/bioturbation rates. Specifically, triplicate samples were targeted at 19 coring stations for large BIO, and twelve and four dating stations for thorium-234 and lead-210, respectively.

This study report, prepared by Science Applications International Corporation (SAIC) and Oregon State University (OSU), describes the study background; methods; results; discussion, including fulfillment of DQOs; and summary and conclusions for the investigation.

Background

EPA is evaluating alternatives for remediation of effluent-affected (EA) sediments on the PV Shelf off the coast of Los Angeles, CA. One remediation alternative under consideration is in-situ capping, which involves placement of a cap of clean material over the EA sediment, thereby isolating the contaminated material. EPA is collaborating with the USACE to conduct field studies related to the evaluation of capping and other alternatives.

EPA conducted a pilot capping project in 2000 to demonstrate whether a cap could be placed on the PV Shelf in accordance with a design described by Palermo (2000). This project was primarily an engineering test to assess cap-placement feasibility using a variety of material types and placement techniques at sites that have different water depths and bottom slopes. Independent of the information that resulted from this pilot capping study, other questions that were not addressed as part of the demonstration study concerned the feasibility and effectiveness of capping on the shelf.

A USACE (1999) study on "Options for In Situ Capping of Palos Verdes Shelf Contaminated Sediments" concluded: "a cap thickness component for bioturbation of 30 cm should accommodate most concerns related to bioturbation effects on cap integrity for areas selected for isolation by the cap." This conclusion was based in large part on "extensive monitoring of benthos in the PV Shelf area by the Los Angeles County Sanitation Districts (LACSD)" and recommendations by benthic ecologists familiar with the program and environmental conditions off Palos Verdes. Subsequently, however, data from a March 2002 survey of the Palos Verdes pilot cap showed the existence of a surface contamination layer that may have been due in part to bioturbation (SAIC 2003).

Disturbance by large BIO may represent an important but poorly understood mechanism for mixing EA sediments into the cap layer. Existing data on the occurrence and abundance of large BIO, such as those collected historically by LACSD using Van Veen grabs, was inadequate to characterize the abundance of these species because LACSD sampling focuses on relatively shallow sediment depths (such as 15-20 cm, depending on Van Veen penetration at various stations) and data analysis focuses on benthic community characteristics. While these data provide important information on sites with relatively higher biological activity (e.g., associated with higher abundance and biomass) and the occurrence of species that represent BIO, the data do not permit evaluation of biological activity at deeper vertical depths, including abundance of BIO that may represent a particular consideration for capping effectiveness.

During technical meetings in 2004 of the EPA-sponsored, interagency PV Shelf project team, it was determined that additional field measurements, data analyses, and modeling efforts were needed to support EPA's ongoing review and interpretation of the results from the Pilot Cap Monitoring Program, as well as to provide key input during preparation of the RI/FS. A key objective was to investigate whether a cap could be recontaminated by EA sediment from uncapped areas, such as by resuspension and transport, or from beneath the cap, such as due to BIO. A consideration related to potential effects from BIO was whether they occur in substantial-enough numbers and sizes/weights to contribute substantially to mixing and disturbance of sediments within the potential capping area. DQOs to focus these efforts were developed and technical experts assembled in discipline-specific meetings to prioritize significant data gaps. As a result of these planning activities, the following studies were identified as high-priority:

- Oceanographic Measurements Program: Physical oceanographic measurements on the PV Shelf and Upper Slope to assess sediment resuspension and transport;

- Geotechnical Survey: Field measurements to assess spatial variations in geotechnical properties of sediments (primarily at the surface) on the PV Shelf;

- *Bioturbation Assessment: Field measurements to determine the density, size, and biomass (weight) of large burrowing organisms capable of mixing and redistributing cap material and EA sediments on the PV Shelf, and collections of sediment cores to evaluate sediment mixing rates and bioturbation*; and

- Sediment Resuspension Investigation: Field measurements on the existing pilot cap to assess the degree of EA-material resuspension that occurred during cap placement operations.

The subject of this study report, bioturbation assessment, was addressed by July and August 2004 field surveys and subsequent analyses of large BIO and sediment mixing /bioturbation rates in the PV Shelf region (Section 2). The DQO process that guided the bioturbation assessment, as specified in the IWP, is presented in Table 1.1-1.

State the problem	EPA has insufficient data from the Pilot Cap Monitoring Program to evaluate whether bioturbation could compromise the integrity and long-term functionality of the cap. This issue relates to the design of a cap and analyses that will be needed to prepare the RI/FS.
Identify the decision to be made	Information on bioturbation and sediment mixing rates will be used to help decide what sediment resuspension and modeling approach to use and to decide the feasibility of alternatives presented in the RI/FS (e.g., whether it is feasible to cap contaminated sediments in-situ and whether this will achieve the desired isolation of contaminants).
Identify inputs to the decision	1) Large (>2 mm), deep-burrowing animals collected in cores at specific sampling locations will be counted, weighed, and measured to determine the abundance and distribution of animals with potentials for mixing cap materials and EA sediments; 2) Cores will be analyzed for short-life (thorium) and long-life (lead) isotopes to help determine sediment mixing rates. Both inputs will be used, in conjunction with information from concurrent investigations of sediment transport processes, for decisions concerning the long-term effectiveness of a cap.
Define boundaries of the study	The study region encompasses the portions of the PV Shelf that have been identified as the boundary for the full-scale cap. Temporal boundaries may be important for biological processes (e.g., seasonal variability) and will be determined based on the validity of using previous data sets for comparisons. A one-time survey effort is proposed for the current task.
Specify limits on decision errors	Professional judgment will be used in conjunction with standard data collection and sample processing methods to ensure data are of reasonable quality and representativeness for these assessments.
Develop a decision rule	The decision rule is: Will a cap be eroded/moved/compromised from below due to the activity of deep-dwelling, bioturbating organisms? Results from this investigation (abundance, size, and biomass of large organisms, and information on sediment mixing rates) will be evaluated in conjunction with numerical modeling of sediment transport to develop a decision rule regarding capping feasibility.
Optimize the design for obtaining the data	1) The field survey program will collect large, deep-burrowing organisms from multiple locations within the boundaries of the cap. 2) Only organisms larger than 2 mm will be retained and analyzed from the cores to minimize processing time and focus effort on those organisms most likely to affect sediment mixing. 3) Sediment cores for dating will be collected from a subset of the stations sampled for biota so that sediment mixing rate/bioturbation information can be evaluated with respect to the distribution of the organisms. 4) Sampling locations were designed to provide spatial coverage of the proposed cap area, and overlap with locations that will be sampled by the other, concurrent investigations.

Study Area Overview

The PV Shelf is located within the Southern California Bight, generally offshore from Point Fermin to the northwest side of the PV peninsula (Figure 1.1-1). This shelf area contains contaminated sediments that are present on the continental shelf and continental slope. The continental shelf in this region is narrow, with a width of 1.5 to 4 kilometers (km) and a bottom slope of 1 to 4 degrees. A shelf break occurs at water depths of 70 to 100 meters (m). The continental slope extends seaward from the shelf, with a width of approximately 3 km and a mean slope of 13 degrees (Lee 1994), to a depth of approximately 800 m.

In general, the subtidal benthic region of the PV Shelf is characterized by hard-bottom habitat from shore to at least 20-m water depth, and soft-bottom habitat over most of the remainder of the shelf and slope region to at least 600 m depth. The exception to this pattern is the hard-substrate, artificial-reef habitat represented by the wastewater outfall pipes that extend primarily over soft bottom to approximately 60-m depth (Figure 1.1-1), some scattered hard-bottom areas on the shelf, and more extensive hard-bottom areas along parts of the shelf break.

Soft-Bottom Subtidal Habitats

Soft-bottom habitats grading from sand to mud typify the majority of the sea bottom deeper than approximately 20 m off Palos Verdes. Key inhabitants include infaunal and epifaunal invertebrates, both of which live in close association with the sediments and typically are resident (especially infauna) in localized areas as adults. Numerous bottom-feeding fish also are characteristic of these habitats.

Infaunal Community - The infaunal community on the shelf and slope is dominated by deposit feeders, primarily polychaete worms and small bivalves, but includes the full range of feeding types, including particle/suspension feeders and predators, representing numerous phyla (LACSD 1995). This community represents an important food source for many fish species and other invertebrates.

Based on results from surveys conducted by LACSD (1995), the greatest number of individuals occurs in the outfall area (>10,000 individuals per square meter [individuals/m^2]), although the number of organisms is also high (>7,500 individuals/m^2) at locations off Point Vicente, Long Point, and Portuguese Bend at depths ranging from 30 to 152 m. Fewer individuals (<2,500 individuals/m^2) occur in the deeper (e.g., 305 m) areas of the slope. Biomass is enhanced near and offshore of the outfall as a result of discharges of organic material. In general, the number and diversity of taxa are highest on the shelf and lowest on the slope. Diversity is also lower northwest of the outfall, in the general area of highest chemical contamination, although temporal trends have shown an increase in diversity in this area. Key members of the infaunal community include several species of polychaetes belonging to the following genera: *Spiophanes*, *Paraprionospio, Prionospio, Mediomastus, Cossura, Exogone, Glycera, Capitella*, and *Dorvillea*; the brittlestar *Amphiodia*; amphipods such as *Heterophoxus*; and the bivalves *Tellina* and *Parvilucina*. Important deep-burrowing species include thalassinid shrimp (e.g., ghost shrimp) and hemichordates.

Epifaunal Invertebrate Community - Spatial patterns in the epifaunal community are primarily related to depth, sediment type, and effects from the wastewater discharge (Stull 1995). Analysis of southern California trawl data from 1971 to 1984 classified the Palos Verdes samples as having a unique low diversity assemblage. In the 1980s, this assemblage declined and was replaced by one that was more typical of shelf assemblages in other areas of the Southern California Bight (Stull 1995). The distribution and diversity of the epibenthic macroinvertebrates have increased since the 1970s. Some of the changes may be attributed to improved habitat quality, although other environmental variables such as El Niño events have had significant effects on these populations (Stull 1995). Key epifaunal community members include ophiuroids, sea pens (e.g., *Stylatula*), heart urchins (e.g., *Brissopsis* and *Brisaster*), other sea urchins (e.g., *Lytechinus* and *Allocentrotus*), and seastars (e.g., *Astropecten* and *Luidia*).

Figure 1.1-1. General Study Area Location.

2.0 METHODS

As discussed in the IWP, the BIO survey and analysis were designed to evaluate the presence of large burrowing bioturbators, including species occurrence, abundance, and sizes/weights (Section 2.1). Information on sediment mixing rates and bioturbation was obtained from radionuclide analyses of sediment cores (Section 2.2) to assess the likelihood/degree of biological contributions to mixing and disturbance of sediments within the potential capping area on the PV Shelf. The goal of these evaluations is to assess the likely contribution of biological mixing to contaminant distribution with depth and, specifically, the potential for upward migration of contaminants (in sediment and pore water) that could affect cap integrity and contaminant availability. Supporting information from other data sources, including sediment-profile imagery (SPI) and plan-view photographs collected during July 2004, LACSD infauna data from summer 2003, and a bioturbation literature search, provide an additional basis for comparison with results from the bioturbation assessment (Section 2.3).

2.1 BIO DATA

Field Survey

The BIO survey was mobilized by SAIC at the Southern California Marine Institute (SCMI; Terminal Island, CA) on July 26, 2004, with samples collected from July 27 through August 2 and demobilization on August 3. SCMI is located approximately 16 km from the capping area, providing an ideal location for the Pilot Capping Program marine survey activities due to its proximity to the area and the local infrastructure. Heavy equipment, principally a spade (box) corer (0.06 m^2; box size 30L x 20W x 60H cm) owned and operated by the U.S. Geological Survey (USGS), and a container van used for processing biological specimens, were craned aboard the survey vessel, the *M/V Michael Uhl*. The survey vessel is about 30 m long with a width (beam) of 7.2 m and includes a hydraulic A-frame and winch for corer operations.

Accurate, standardized navigation equipment and data acquisition/recording procedures were used throughout the surveys to ensure high accuracy and repeatability in collecting vessel position information. SAIC was responsible for installation, operation, and maintenance of a Differential Global Positioning System (DGPS) navigation system aboard the survey vessel. An industry standard software product, Hypack®, was used for vessel positioning. This system provided a simple user interface for entry of target station locations and survey lanes, as well as real-time display and data recording capabilities. A GPS receiver provided continuous vessel position data, and the DGPS receiver was used to acquire real-time DGPS corrections from U.S. Coast Guard beacons in San Diego and Point Conception. These receivers were interfaced to a personal computer with a 400 MHz processor for real-time display of vessel positions and data storage. The DGPS antenna was approximately 3 meters offset from the hydrowire block on the ship's A-frame to provide an accurate navigation fix for each sample collection. The positioning accuracy of the navigation system was determined to be better than $\pm$3 m during a fixed-point calibration conducted prior to an earlier field element.

The BIO survey involved collection of triplicate sediment cores at each of 19 stations (Figure 2.1-1). Cores collected during the survey are listed in Table 2.1-1. Detailed rationale for station placement is provided in the IWP, but generally represented a range of upcoast-downcoast and depth (onshore-offshore) locations that corresponded to the potential capping area on the PV Shelf. These stations were located along several of the same transects as historically sampled by LACSD for permit monitoring. This allowed some spatial comparisons of infaunal distribution and abundance in relatively

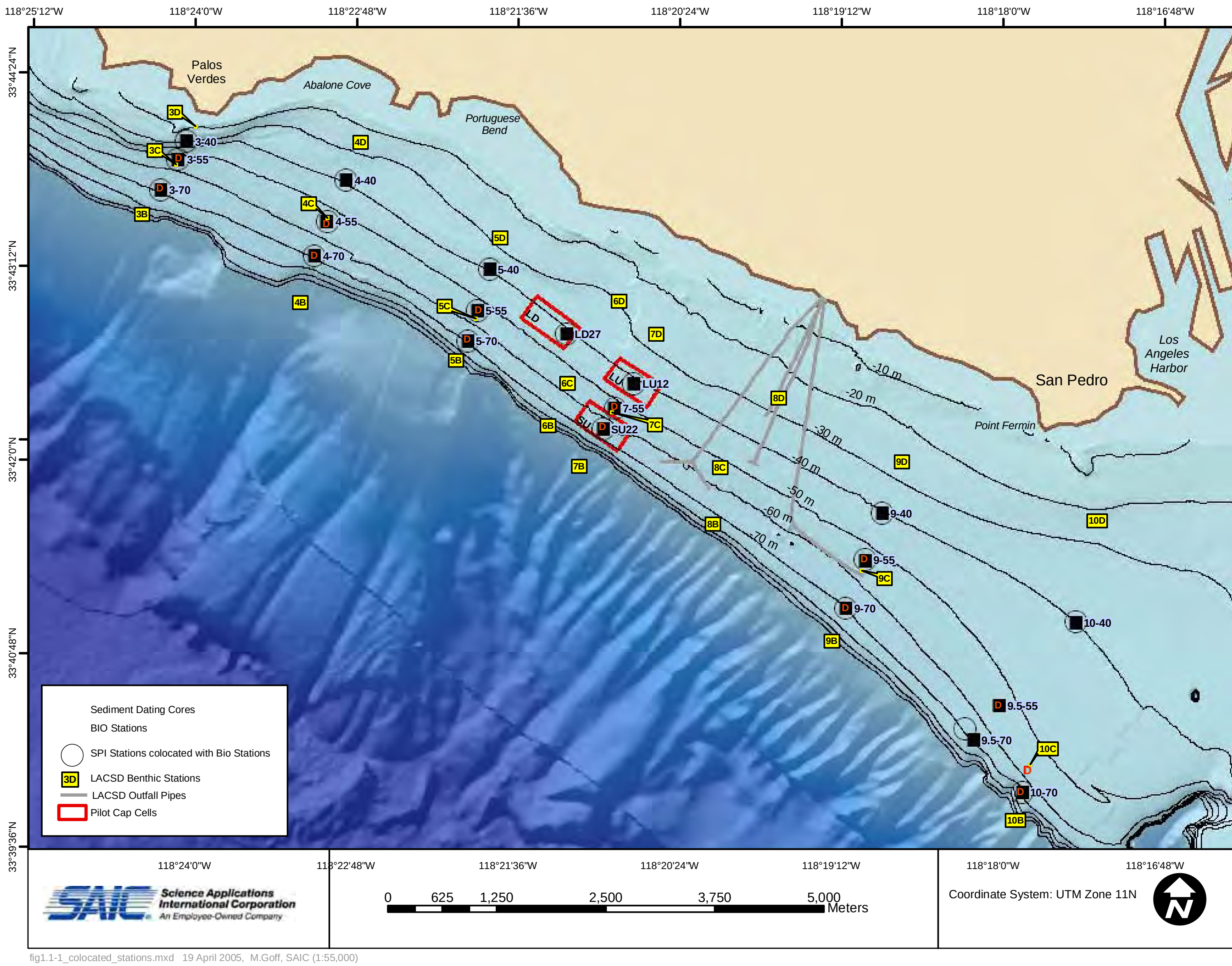


Figure 2.1-1. Station Locations for BIO, Vertical Mixing Rates/Bioturbation, SPI/Plan-View Photographs, and LACSD Data Collections on the Palos Verdes Shelf.

Table 2.1-1. Site Coordinates (UTM Zone 11N), Core Lengths, and Core Collection Dates from BIO Surveys, July/August 2004.

Date	Station	Easting Longitude	Northing Latitude	Overall Core length (cm)	Sample Processed
7/27/2004	5-55m-1	1966197.64	524037.80	42	x
7/27/2004	5-55m-2	1966203.37	524039.81	45	x
7/27/2004	5-55m-3	1966192.39	524038.00	43.5	x
7/27/2004	5-70m-1	1966097.78	523682.08	32-41	x
7/27/2004	5-70m-2	1966085.14	523690.08	42	x
7/27/2004	5-70m-3	1966089.44	523682.67	37	x
7/27/2004	5-40m-1	1966330.82	524508.20	45	x
7/27/2004	5-40m-2	1966330.35	524505.61	41	x
7/27/2004	5-40m-3	1966332.36	524505.98	42	x
7/28/2004	LU12-1	1967998.10	523208.17	26-29	x
7/28/2004	LU12-2	1968000.43	523211.86	34	x
7/28/2004	LU12-3	1968005.23	523214.80	47-52	x
7/28/2004	LU12-4	1968002.75	523211.30	32	x
7/28/2004	SU22-1	1967656.68	522689.66	47	x
7/28/2004	SU22-2	1967650.37	522695.04	34-38	x
7/28/2004	SU22-3	1967653.13	522690.78	54	x
7/28/2004	7-55m-1	1967786.38	522929.37	34-40	x
7/28/2004	7-55m-2	1967787.60	522922.89	33-35	x
7/28/2004	7-55m-3	1967784.52	522926.60	33-35	x
7/29/2004	LD27-1	1967220.13	523777.72	43-44	x
7/29/2004	LD27-2	1967220.11	523773.28	37-42	x
7/29/2004	LD27-3	1967222.44	523777.89	37	x
7/29/2004	4-40m-1	1964683.43	525514.68	44-49	x
7/29/2004	4-40m-2	1964685.42	525508.01	41-43	x
7/29/2004	4-40m-3	1964682.18	525511.17	40-42	x
7/29/2004	4-55m-1	1964467.06	525039.25	40-42	x
7/29/2004	4-55m-2	1964465.04	525037.97	37-39	x
7/29/2004	4-55m-3	1964467.83	525038.69	35-42	x
7/30/2004	9-70m-1	1970456.82	520662.03	32-36	x
7/30/2004	9-70m-2	1970457.44	520662.22	37-40	x
7/30/2004	9-70m-3	1970458.83	520661.84	36-39	x
7/30/2004	9-55m-1	1970675.10	521219.13	36-39	x
7/30/2004	9-55m-2	1970678.98	521224.10	34-36	x
7/30/2004	9-55m-3	1970674.76	521218.56	37-42	x
7/30/2004	9-40m-1	1970867.96	521757.44	32	x
7/30/2004	9-40m-2	1970865.95	521756.16	32-37	x
7/30/2004	9-40m-3	1970863.47	521754.50	31-36	x
7/31/2004	10-70m-1	1972494.01	518571.10	28	*
7/31/2004	10-70m-1b	1972492.63	518575.17	19-25	x
7/31/2004	10-70m-2	1972492.32	518572.58	26-32	x
7/31/2004	10-70m-3	1972488.45	518573.15	24-30	x

Table 2.1-1, continued.

Date	Station	Easting Longitude	Northing Latitude	Overall Core length (cm)	Sample Processed
7/31/2004	9.5-70m-1	1971930.02	519168.46	24-31	**a**
7/31/2004	9.5-70m-2	1971931.87	519169.01	18	**a**
7/31/2004	9.5-70m-2b	1971931.87	519166.61	17-21	**a**
7/31/2004	9.5-55m-1	1972223.82	519564.89	12-18	*****
7/31/2004	9.5-55m-1b	1972224.58	519562.48	9-20	**x**
7/31/2004	9.5-55m-2b	1972228.30	519566.35	17-21	**x**
7/31/2004	9.5-55m-3	1972224.89	519563.41	20-25	**x**
7/31/2004	10-40m-1	1973093.74	520524.45	36	**x**
8/1/2004	3-70m-1	1962553.33	525386.37	41-45	**x**
8/1/2004	3-70m-2	1962546.23	525386.77	35-41	**x**
8/1/2004	3-70m-3	1962548.70	525386.76	40	**x**
8/1/2004	3-55m-1	1962754.46	525733.88	45	**x**
8/1/2004	3-55m-2	1962754.17	525738.31	41	**x**
8/1/2004	3-55m-3	1962749.35	525731.86	39-42	**x**
8/1/2004	3-40m-new-1	1962801.09	525921.71	44-51	**b**
8/1/2004	3-40m-new-2	1962802.92	525917.27	36-41	**b**
8/1/2004	3-40m-new-3	1962800.15	525918.57	39-42	**b**
8/2/2004	10-40m-2	1973085.09	520526.51	34-38	**x**
8/2/2004	10-40m-3	1973086.47	520522.07	31-35	**x**
8/2/2004	4-70m-1	1964323.73	524646.01	31-45	**x**
8/2/2004	4-70m-2	1964322.67	524651.37	38-43	**x**
8/2/2004	4-70m-3	1964323.31	524655.62	36-40	**x**
8/2/2004	9.5-70m-3	1971935.45	519174.92	15-21	**x**

*** IWP criterion not met (>30 cm core); sample not processed.**
a Additional station added to try to meet IWP criterion (>30 cm core)
b Station moved from original location due to shallow water depth

near-surface layers (LACSD) and large BIO collected at 15-cm intervals to the full depth of the core for the present study.

Full-length cores (i.e., IWP criterion of $\geq$ 30 cm) were collected at all but two stations. At Stations 10-70 and 9.5-55, corer penetration was limited due to compacted mud and shell hash, as discussed in the August 2004 "Field Report for the 2004 Multidisciplinary Studies for the Palos Verdes Cap Monitoring Program: Task 4 Bioturbation Study". An alternate station to 10-70 (9.5-70) was established during the survey, but the bottom conditions were similarly compacted and also resulted in less than full-length cores. In total, 64 drops were completed and 62 cores were processed, compared to 57 cores targeted in the IWP. Of these processed cores, 6 were < 30 cm.

BIO cores were processed onboard the survey vessel. Core processing was initiated by longitudinal splitting of the core into 15-cm intervals using a specially designed, stainless steel divider as detailed in the IWP. Core intervals from top to bottom of each core were designated as interval 1 (0 to 15 cm), interval 2 (>15 to 30 cm), interval 3 (>30 to 45 cm), and interval 4 (>45 to 60 cm). Continued processing consisted of visual descriptions and photographs of each interval surface and the full length of the core; screening each interval through a 2-mm sieve; and subsequent sorting, identification, and length/weight measurements for all BIO. Digital calipers were used to measure each organism (or organism fragment) and a spring scale accurate to 0.1 g was used to weigh each organism or fragment, as specified in the IWP. Some specimens were weighed at SCMI using an Ohaus SP-402 digital scale, since boat movement prevented use of this instrument at sea due to its high accuracy (0.01 g) and consequent sensitivity to motion. A total of 297 organisms (including fragments) were processed, with approximately half retained in a voucher collection for subsequent verification or identification. Manuscript names (e.g., "red nemertean") were assigned to organisms that could not be identified to species during the survey. Specimens for the voucher collection were relaxed in a solution of magnesium sulfate ($MgSO_4$) and then fixed with 10% buffered formalin. Samples were subsequently transferred to ethanol for long-term preservation. Sample jars containing organisms were shipped under chain-of-custody to MEC Weston Solutions (MEC; Carlsbad, CA). Voucher organisms were identified or verified to the lowest taxonomic level by SAIC and MEC biologists, and the manuscript names were then updated in a project database by SAIC. The SAIC Quality Assurance Officer checked all data (100%) for accuracy, and any mistakes (e.g., spelling or data entry errors) were corrected for the final database.

Analysis and QA

Data collected included three replicate core samples per interval. Means for each interval were calculated and standardized to 0.1 m^2, corresponding to the core size used by LACSD and standardizations used for many benthic studies to facilitate comparisons

Sufficient numbers of BIO did not occur in the samples (Appendix A) to justify use of statistical methods such as ANOVA and multiple range tests (SNK) for evaluations of differences among stations. Instead, means were used as the basis for among-station comparisons, primarily using GIS plots to evaluate spatial patterns. Some statistical correlations were performed using DeltaGraph software (version 5.6) and a simple linear curve fit was used to determine the correlation coefficient (r^2) value.

2.2 SEDIMENT MIXING/BIOTURBATION RATES

Field Survey

Sediment cores for evaluation of vertical mixing/bioturbation rates were collected during field surveys conducted by SAIC and OSU in July 2004 (Figure 2.1-1 and Table 2.1-2). The surveys were mobilized

Table 2.1-2. Site Coordinates (UTM Zone 11N) and Core Collection Dates from Sediment Mixing Rates/Bioturbation Surveys, July 2004.

Date	Station	Easting Longitude	Northing Latitude	Core Type *
7/23/2004	D_NW7G	1962331.79	525652.34	pb-210
7/15/2004	10-55_E	1972581.67	518853.00	th-234
7/15/2004	10-55_F	1972577.43	518851.20	th-234
7/15/2004	9-55-d3_C	1970676.99	521216.24	th-234
7/14/2004	9-55m_d3-A	1970677.82	521215.49	th-234
7/14/2004	9-55m_d3-B	1970675.15	521212.22	th-234
7/19/2004	L3_NW17F	1962556.93	525388.15	th-234
7/23/2004	L3_NW17Z	1962560.52	525377.41	th-234
7/19/2004	L3_NW6B	1962754.16	525735.93	th-234
7/23/2004	L3_NW6Z	1962758.10	525741.30	th-234
7/21/2004	L4_NW_35_B	1964334.52	524633.42	th-234
7/23/2004	L4_NW22A	1964469.19	525037.92	th-234
7/23/2004	L4_NW22B	1964468.29	525043.69	th-234
7/23/2004	L4_NW22C	1964473.24	525055.62	th-234
7/23/2004	L4_NW35Z	1964345.83	524639.20	th-234
7/21/2004	L5_NW_49_B	1966101.63	523685.06	th-234
7/24/2004	L5_NW45-F	1966198.88	524028.16	th-234
7/24/2004	L5_NW45-G	1966203.51	524039.83	th-234
7/24/2004	L5_NW45-H	1966203.96	524028.49	th-234
7/24/2004	L5_NW49-C	1966099.69	523691.89	th-234
7/21/2004	L7_OUT_13_A	1967793.15	522937.32	th-234
7/24/2004	L7_OUT14-B	1967659.27	522702.90	th-234
7/24/2004	L7_OUT14-C	1967659.28	522697.14	th-234
7/20/2004	L_9_OUT_46-C	1970465.26	520663.69	th-234
7/24/2004	L9_OUT46-D	1970466.58	520657.91	th-234
7/26/2004	L9.5_55-F	1972230.43	519553.64	th-234
7/26/2004	L9.5_55-H	1972230.93	519568.13	th-234
7/25/2004	L10_SE47-G	1972495.84	518564.29	th-234
7/24/2004	NW53-A	1967443.61	523398.07	th-234

* pb = Lead; th = Thorium

and demobilized at SCMI, with sample collections ranging from July 14 through 26. The survey vessel *R/V Vantuna* was operated by SCMI. The vessel is 20 m in length and equipped with an A-frame and winch. Navigational positions of the survey stations were documented as described in Section 2.1 for the BIO survey.

Sediment samples were collected using a hydraulically damped piston core that is effective for collecting undisturbed cores down to 75 cm in a variety of sediment types. The corer is comprised of a 10.8-cm internal diameter by 95-cm long polycarbonate barrel, an 800-lb lead weight stand, and an aluminum support frame. The corer was winched through the water column at a controlled descent until bottom contact was evident by slack in the winch wire. Upon contact with the seafloor the weight-stand pushed the core barrel into the bed and simultaneously pulled a piston that forced water through a small valve. By regulating the valve opening the descent rate of the core barrel was controlled, thereby reducing the bow wave effect and minimizing disturbance of the surficial sediment layers. Its slow descent rate (typically around 4 cm/s), enabled the corer to collect an undisturbed sample with an intact sediment-water interface and sediment-free overlying water column.

Sediment subcores were vertically sectioned at different intervals consistent with the IWP sampling objectives. At four stations designated as "detailed" sampling stations (4-55, 5-55, 9-55, and 10-55), cores for thorium-234 analysis were sectioned at 1-cm intervals to a depth of 5 cm, and then at 2-cm intervals to a depth of 11 cm. Cores for thorium-234 at all other stations, designated as "comparison" stations, were sub-sampled at 0-1 cm and 1-5 cm intervals. The four detailed stations were at a near-outfall depth (55 m), while bracketing the outfall region (Transects 4, 5, 9, and 10) and covering a reasonable range of upcoast-downcoast locations within the potential capping area. The eight comparison stations covered the remaining 55-m and 70-m transect stations. Cores for lead-210 were sampled at the same detailed stations as for thorium-234, thereby providing direct comparability and likewise covering a range of upcoast-downcoast locations, including downcoast erosional areas (Transects 9 and 10) and contrasting upcoast depositional areas. For all cores, an outer ring of approximately 0.5 cm thickness was removed and discarded to minimize potential contamination from the vertical displacement of particles by the leading edge of the core tube. Samples were stored in whirl-pack bags and refrigerated during return to the OSU laboratory for analysis.

Analysis and QA

Several steps were performed in the laboratory prior to sample counting for thorium-234 and lead-210. These steps included determinations of sample dry weight and thickness and processing for uniform sample geometry. Samples were dried in an oven at 60° C for 24 to 60 hours, depending on the sample volume and moisture content, and then ground to a uniform consistency using a mortar and pestle. The purpose was to minimize systematic differences in the sample characteristics due to down-core variations in sediment conditions (e.g., porosity or grain size). Sediments were then transferred to pre-weighed plastic jars and weighed on a Mettler AE240 analytical balance. Sample weight was kept constant, at approximately 30 grams. The sample height was established by gently shaking the sample so that the surface was approximately level, and the height was measured using calipers at four equally spaced sites on the jar perimeter. Sample height, as discussed below, was important for a self-absorption correction step.

Samples were counted for gamma particle activity using two identical Canberra Instruments Model GL2020RS LEGe (low-energy germanium) detectors. The detectors were 20-mm thick, with active diameters of 50.5 mm, and each was equipped with 0.5 mm beryllium windows placed 5 mm from the detector. Individual samples were counted for 24 to 48 hours over 2048 channels. The channels were linearly calibrated to energy using NIST-certified reference materials of known isotopic composition. The calibration procedure was repeated periodically in the analysis sequence. Proprietary software associated with Canberra detectors allowed the analyst to specify regions of interest in the gamma-ray energy spectrum (e.g., the 63.3 keV peak for thorium-234). A region of interest was defined around each isotope peak, including the peak and four channels on each side of the peak. These eight peaks were used to determine the background gamma-ray activity at the peak's energy. Net counts per minute were the sum of all counts in the region of interest, minus the average of the eight channels used for background determination, multiplied by the number of channels in the peak. Activities and error estimates were calculated from the raw counts. The procedure for determining the self-absorption correction was based on Cutshall et al. (1983). Self-absorption is the attenuation of gamma radiation emitted by a sample due to the absorption of radiation by the sample itself.

Values for excess thorium-234 and lead-210 were determined by correcting the final counts for the amount of radioactive decay that occurred between the time the sample was collected and the analysis date. This correction was based on the procedure used by Gilmore and Hemingway (1995). In the case of thorium-234, which decays rapidly (24.1-day half life), this correction can be substantial.

Estimates of particle mixing rates within the sediment column were based on variations in the activity of excess thorium-234 with depth below the sediment-water interface. This activity can be affected by three processes: bioturbation, sedimentation, and radioactive decay. In general, the time rate-of-change for activity of a particular radionuclide is assumed to be at a steady state, representing a balance between the three processes. Under these conditions, the vertical activity profile of a short-lived radionuclide (e.g., thorium-234) is controlled by a balance between bioturbation and radioactive decay because the sedimentation rate is considered too small to affect the activity profile. Therefore, bioturbation rates ($D_{b;}$ cm^2/yr) are determined by regressing depth (cm), the independent variable, against the natural log of the activity (A; dimensionless), which is the dependent variable. The regression equation used to calculate biodiffusivity is: ln A = ln A_o - [(lambda/ D_b) exp0.5] z, where A_o is the excess activity at the sediment surface, lambda is the decay rate (1/yr), and z is depth (cm). The slope of the regression is [(lambda/D_b) exp0.5], with units of [(1/yr/cm^2/yr) exp0.5], which simplifies to 1/cm. This approach was used to calculate biodiffusivity values for the "detailed" station cores. For the comparison station cores, biodiffusivity rates were estimated from activity values for two core strata (0 to 1 cm and 1 to 5 cm), using the a priori assumption that the excess thorium-234 activity decreased exponentially in the upper few centimeters of the sediment column and was the result of bioturbation and radioactive decay processes only, and the supply of thorium-234 to the sediment surface and mixing rates were constant (Aller et al. 1980; Wheatcroft and Martin 1996).

For longer-lived radionuclides, such as lead-210 (22.3-year half life), the sedimentation rate cannot be considered negligible. Consequently, either the sedimentation or mixing rate must be known in order to calculate the other. The mixing rate can be estimated from thorium-234 activities; however, this requires an assumption that the mixing rate is constant over time. Alternately, when the bioturbation rate is considered negligible, such as at depths of several tens of centimeters in the sediment column, then the activity profile is expected to reflect the sedimentation rate and radioactive decay, and the sedimentation rate can be determined from the slope of the line for the relationship between activity and depth in the sediment core.

Theoretical mixing rates and detection limits with sediment depth indicate that thorium-234 can extend downward several tens of centimeters when mixing rates are high (R. Wheatcroft, OSU, personal communication). However, since mixing rates are generally low in shelf environments compared to decay rates for thorium-234, detection of this radionuclide extends only to about 10 cm, even though mixing occurs to at least the depth of deep-burrowing species. Notwithstanding, the mixing curves that can be calculated based on thorium-234 data in the top 10 cm will reflect conditions throughout the mixed layer, that is, as influenced by physical and biological processes over the sediment column. The relatively short decay time for thorium-234 is in sharp contrast to very long degradation time for DDT, such that even slow mixing rates as mediated by burrowing organisms can serve to mobilize EA sediments upwards towards the sediment surface.

2.3 OTHER DATA SOURCES

2.3.1 SPI and Plan-View Data

Field Survey

Approximately 170 SPI/Plan-View stations were occupied during the survey conducted in July 2004. Of these stations, 19 corresponded to BIO stations and served as an additional data source for evaluating biological conditions, such as community types and evidence of bioturbation, and physical conditions, such as grain size (Figure 2.1-1 and Table 2.1-3). Survey data were collected from the *R/V Vantuna* as described in Section 2.2, with navigational positions documented as described in Section 2.1.

Remote Ecological Monitoring of the Seafloor (REMOTS®) with a digital Sediment-Profile Imagery (SPI) camera is a benthic sampling technique that provides digital photographs of a cross-section of surface and near-surface sediments. The REMOTS® hardware consists of a Benthos Model 3731 sediment-profile camera designed to obtain undisturbed, vertical, cross-section photographs (in-situ profiles) of the upper 15 to 20 cm of the seafloor, depending on penetration. The REMOTS® frame was attached to a hydrowire and lowered and retrieved using a winch on the survey vessel. The digital sediment-profile camera system allowed nearly real-time review of the image quality and results. The high-resolution digital images were integrated directly into the computer-aided digital analysis system.

Analysis and QA

The SPI images captured sedimentary and biological conditions at the sediment-water interface to camera penetration depths ranging between 0 and 20 cm. Plan-view images provided documentation of the sediment surface (approximately 0.3 m^2). Two representative sediment-profile images and one representative plan-view image were selected for processing and analysis from the three replicates collected at each sampling station. All of the sediment-profile and plan-view image data were retained in pre-formatted spreadsheets and incorporated into the project GIS and data management system. The following sub-sections provide a synopsis of the more detailed methods included in the report for the geotechnical study task (SAIC 2005).

The sediment-profile images were processed using an in-house computer-based image processing system (Visual Basic customized interface, with information stored in a Microsoft Access database) to consistently characterize the images and to catalogue all relevant quantitative and qualitative results. Computer-aided analysis of each SPI image yields a suite of standard measured parameters, including sediment grain size major mode, camera prism penetration depth (an indirect measure of sediment bearing capacity/density), depth of the apparent redox potential discontinuity (RPD; a measure of sediment aeration), infaunal successional stage, and Organism-Sediment Index (OSI; a summary parameter reflecting overall benthic habitat quality). OSI values can range from −10 (azoic with low sediment-dissolved-oxygen and/or presence of methane gas in the sediment) to +11 (healthy, aerobic environment with deep RPD depths and advanced successional stages). These values are calculated using data assigned for the apparent RPD depth, successional status, and indicators of methane or low oxygen.

Plan-view images were analyzed to document general bottom conditions, substrate type, presence of epifauna and infauna, burrows, and bedforms. All SPI and plan-view data received 100% QA review.

Table 2.1-3. Site Coordinates (UTM Zone 11N) and Collection Dates from SPI/Plan-View Surveys, July 2004.

Date	Station-Replicate	Easting Longitude	Northing Latitude
7/9/2004	3-40m-A	1962841.89	525939.26
7/9/2004	3-40m-B	1962843.67	525939.07
7/9/2004	3-55m-A	1962752.67	525736.13
7/9/2004	3-55m-B	1962754.17	525734.63
7/9/2004	3-70m-A	1962550.28	525383.81
7/9/2004	3-70m-C	1962553.76	525383.78
7/9/2004	4-40m-A	1964684.13	525510.60
7/9/2004	4-40m-B	1964686.66	525510.40
7/9/2004	4-55m-A	1964467.62	525037.76
7/9/2004	4-55m-B	1964467.46	525038.04
7/9/2004	4-70m-A	1964327.30	524643.57
7/9/2004	4-70m-B	1964329.10	524643.45
7/9/2004	5-40m-A	1966328.60	524509.43
7/9/2004	5-40m-B	1966328.70	524510.22
7/9/2004	5-55m-A	1966196.25	524033.88
7/9/2004	5-55m-B	1966196.22	524035.28
7/9/2004	5-70m-A	1966087.59	523687.45
7/9/2004	5-70m-B	1966089.88	523687.05
7/10/2004	LD27-A	1967219.65	523775.01
7/10/2004	LD27-B	1967220.15	523775.84
7/10/2004	LU12-A	1968001.01	523216.23
7/10/2004	LU12-C	1968004.42	523217.26
7/10/2004	7-55m-A	1967782.97	522925.60
7/10/2004	7-55m-B	1967784.60	522923.99
7/10/2004	SU22-A	1967650.90	522689.97
7/10/2004	SU22-C	1967653.69	522692.50
7/10/2004	9-40m-A	1970863.00	521757.70
7/10/2004	9-40m-C	1970870.26	521757.06
7/10/2004	9-55m-A	1970674.02	521219.63
7/10/2004	9-55m-B	1970674.93	521219.39
7/10/2004	9-70m-A	1970458.48	520662.95
7/10/2004	9-70m-B	1970459.80	520663.07
7/11/2004	10-40m-B	1973091.33	520529.69
7/11/2004	10-40m-C	1973097.71	520524.21
7/11/2004	10-55m-A	1972573.87	518854.32
7/11/2004	10-55m-B	1972570.93	518855.51
7/11/2004	10-70m-A	1972494.65	518574.51
7/11/2004	10-70m-C	1972497.82	518574.46

2.3.2 LACSD Data

Infauna data on total abundance and biomass for the combined invertebrate community were obtained from LACSD for the most recently completed sampling year (2003). LACSD samples were sieved through 1-mm screens, compared to 2-mm screens used for the present study. These differences were related to standard, permit-specified monitoring methods for LACSD compared to the method used for focused collections of large BIO, respectively. Data units are per 0.1 m^2, corresponding to the size of the Van Veen sampler used for the LACSD monitoring program. These data serve as a general basis of comparison with the large BIO data, particularly interval 1 (0-15 cm core depth) as this roughly approximates core sampling depths for the Van Veen sampler. The LACSD data were collected from stations located at three bottom depths (30, 60, and 152 m) along eight onshore-offshore transects and are useful to indicate spatial patterns of abundance and biomass along the PV Shelf (Figure 2.1-1). The BIO data were collected along six of these transects, but at depths corresponding more closely to the range of potential capping depths (40, 55, and 70 m). LACSD data used for the comparison consisted of summer 2003 results from single samples at each station, summed across taxonomic groups to generate total abundance and biomass values. These values were plotted using GIS to evaluate spatial patterns. Biomass for small organisms (weight <0.1g) was assigned a value of 0.05 grams for computational purposes.

2.3.3 Bioturbation Literature Search

Literature searches to identify data on bioturbation rates by infaunal organisms were conducted on the Internet and through the Scripps Institution of Oceanography Library electronic database systems (Aquatic Biology, Aquaculture & Fisheries Resources, ABAFR; BIOSIS; and Marine, Oceanographic & Freshwater Resources, MOFR). Key words, such as bioturbation, sediment reworking, bioturbation rate, burrowing rate, and burrow depth, were used to search the electronic databases. Once a reference with the keywords was identified, abstracts were downloaded and assessed for relevant information, and full references obtained as appropriate.

3.0 RESULTS

Results are presented for large BIO (Section 3.1), including a community overview (Section 3.1.1) and key species (Section 3.1.2); SPI and plan-view photographs (Section 3.2); and sediment mixing rates/bioturbation (Section 3.3).

3.1 LARGE BIO

3.1.1 Community Overview

Number of Taxa
Overall, 40 taxa of BIO were collected, dominated by polychaetous annelids (20 taxa), then decreasing sharply to 5 and 6 taxa, respectively, for nemertean worms and arthropods (crustaceans), and 1 to 3 taxa for the remaining phyla (Table 3.1-1). The mean number of taxa by phylum and core depth interval was low, ranging from about 1 to 5 for annelids, but less than 2 for other phyla (Table 3.1-2). As summarized in Figure 3.1-1, the distribution of mean number of taxa was generally higher northwest of the outfall, especially along Transects 3 and 4. Values for the highest mean number of taxa ranged from about 3 to 5. There were no consistent onshore-offshore trends over the relatively narrow depth range (40-70 m) for the study (Figure 3.1-1).

Abundance
Overall, 297 BIO specimens (including fragments) were collected (Appendix A, Table A-1). Mean abundance by phylum and core depth interval was low, ranging from about 1 to 13 for annelids, but less than 4 for other phyla (Table 3.1-3). Mean abundance was generally higher northwest of the outfalls, particularly along Transects 3 and 4, but also including interval 2 for Station 10-70 (Figure 3.1-2).

Organism Size
Data on the size of BIO are summarized in Appendix A, Table A-1. Length data proved to provide limited useful information other than to confirm selection of appropriate large BIO. Computation of an overall mean size of large BIO was not possible due to standard differences in size measurements for different types of organisms, such as total length of polychaetes versus shell height for bivalves, and because organisms often were collected as fragments. Species-specific data on size are presented in Section 3.1-2 and summarized in Table A-1 for the predominant taxa, *Neotrypaea californiensis* (formerly *Callianassa californiensis*) and *Marphysa disjuncta*.

Biomass
Mean biomass data for BIO indicated that the highest values (e.g., about 5 to 11 g) were predominantly associated with core intervals 1 and 2 (0-15 cm and >15-30 cm, respectively), with the exception of one 40-m station (5-40) where interval 3 (>30 cm) was substantially higher (e.g., 1-2 orders of magnitude; Figure 3.1-3). Figure 3.1-4, showing mean abundance versus mean biomass, further emphasizes this difference between intervals. Interval 3 had low biomass at most stations, despite abundance values that were comparable to intervals 1 and 2 (Figure 3.1-2).

Spatial patterns for BIO indicated a general trend of higher biomass northwest of the outfall, compared to the southeast (Figure 3.1-3). With the exception of Station LU12, interval 2 (10.8 g), within the LU capping cell, the other five stations nearest the outfall (closest transects northwest and southeast) exhibited the lowest biomass (0 to 2.1 g). Overall, the main contributors to biomass for intervals 1 and 2 were annelids (particularly *Glycera* and *Marphysa* due to relatively high abundance of low biomass individuals), arthropods (the ghost shrimp *Neotrypaea*), and echiurans (*Listriolobus*) (Tables 3.1-4 and A-1). The relatively high value for interval 3 at Station 5-40 was due to *Neotrypaea* and the molluscan

Table 3.1-1. BIO Taxa by Phylum, July/August 2004, Including Number of Individuals per Interval and Percent Frequency of Occurrence.

	Phylum								Total Number			Percent Frequency of Occurrence		
Species/Family	Annelida	Arthropoda	Cnidaria	Echino-dermata	Echiura	Mollusca	Nemertea	Sipuncula	Interval 1	Interval 2	Interval 3	Interval 1	Interval 2	Interval 3
Arctonoe pulchra	X								1			0.6	0.0	0.0
Athenaria			X						2			1.2	0.0	0.0
Cerebratulus californiensis							X		1	1	1	0.6	0.6	0.6
Chirodota sp.				X					2			1.2	0.0	0.0
Drilonereis falcata	X								2	2		1.2	1.2	0.0
Eranno lagunae	X								3			1.8	0.0	0.0
Gari furcata						X			1			0.6	0.0	0.0
Glycera americana	X								8	6	1	4.7	3.5	0.6
Glycera capitata	X								3	1		1.8	0.6	0.0
Glycinde armigera	X								1			0.6	0.0	0.0
Goniada brunnea	X								3			1.8	0.0	0.0
Gymnonereis crosslandi	X								9	8		5.3	4.7	0.0
Harmothoe lunulata	X								1			0.6	0.0	0.0
Henricia				X					1			0.6	0.0	0.0
Lineidae							X		2			1.2	0.0	0.0
Listriolobus pelodes					X				15			8.8	0.0	0.0
Lumbrineridae	X								1			0.6	0.0	0.0
Lumbrineris limicola	X								1			0.6	0.0	0.0
Lumbrineris sp.	X								1			0.6	0.0	0.0
Marphysa disjuncta	X								68	45	3	39.8	26.3	1.8
Nemertea unidentified							X		4	2		2.3	1.2	0.0
Neotrypaea californiensis		X							11	12	2	6.4	7.0	1.2
Nephtys sp.	X								1			0.6	0.0	0.0
Nereis procera	X								4	12		2.3	7.0	0.0
Notomastus lineatus	X								1			0.6	0.0	0.0
Pennatulacea			X						1	1		0.6	0.6	0.0
Pinnixa occidentalis		X							5	4	1	2.9	2.3	0.6
Polychaete - errant	X								3	1		1.8	0.6	0.0
Polychaete - Nereid	X								1			0.6	0.0	0.0
Schmittius politus		X							1			0.6	0.0	0.0
Shrimp - unidentified		X							1			0.6	0.0	0.0

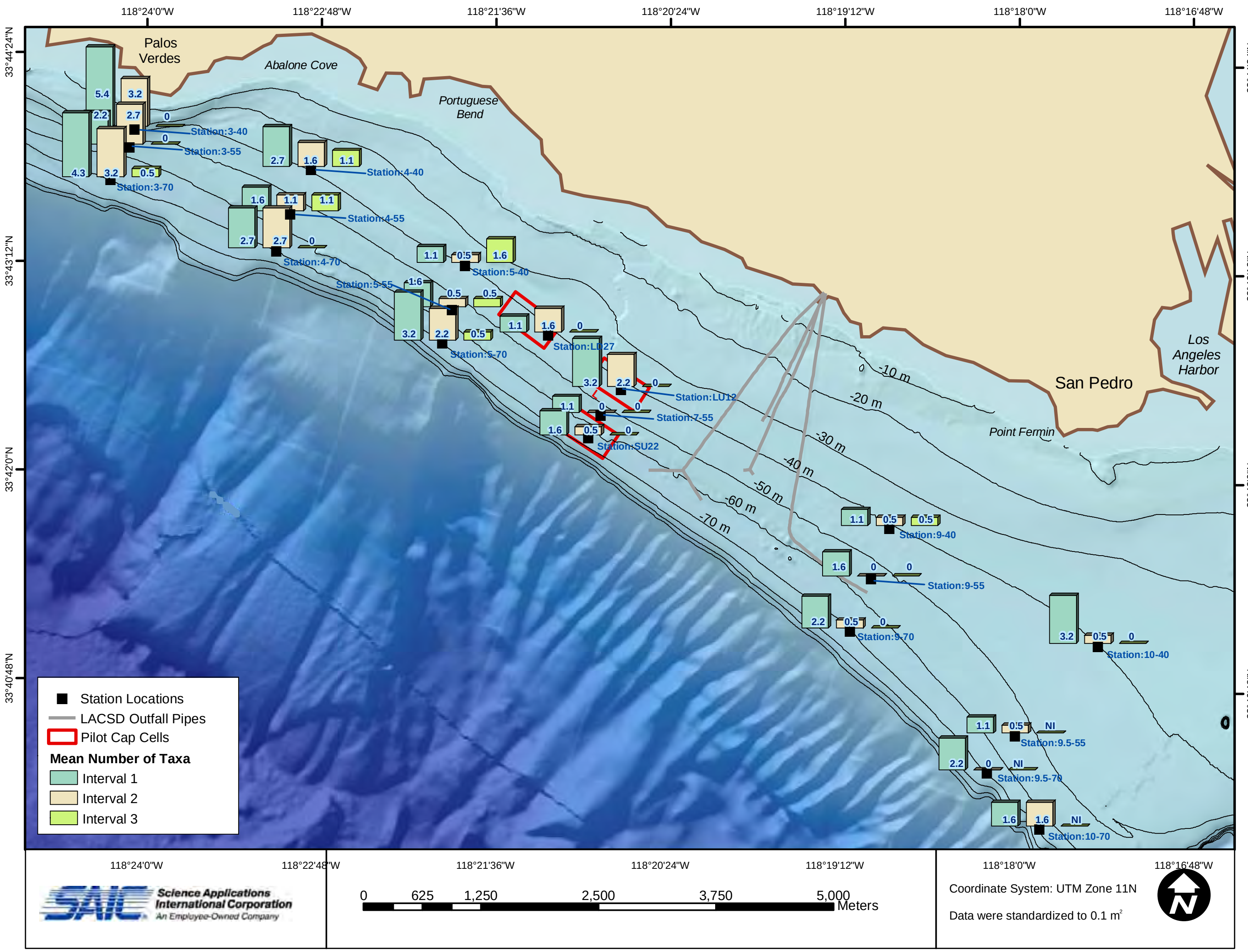
	Phylum								Total Number			Percent Frequency of Occurrence		
Species/Family	Annelida	Arthropoda	Cnidaria	Echino-dermata	Echiura	Mollusca	Nemertea	Sipuncula	Interval 1	Interval 2	Interval 3	Interval 1	Interval 2	Interval 3
Sicyonia ingentis		X							1			0.6	0.0	0.0
Sinum scopulosum						X			1		2	0.6	0.0	1.2
Sthenelais verruculosa	X								1			0.6	0.0	0.0
Sthenelanella uniformis	X								1	6		0.6	3.5	0.0
Stylatula elongata			X						3	3	2	1.8	1.8	1.2
Thysanocardia nigra								X	3	4		1.8	2.3	0.0
Tubulanus cingulatus							X		1			0.6	0.0	0.0
Tubulanus polymorphus							X		1			0.6	0.0	0.0

Table 3.1-2. Mean Number of Taxa by Station, Core Depth Interval, and Taxonomic Group, July/August 2004. Data were standardized to 0.1 m^2. ND = No data.

Station	Interval	Annelida	Arthropoda	Cnidaria	Echinodermata	Echiura	Mollusca	Nemertea	Sipuncula
3-40	1	3.76	1.61	0.00	0.00	0.00	0.54	1.61	0.00
	2	3.76	1.08	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-55	1	2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.54
	2	5.38	1.08	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-70	1	5.38	0.00	1.61	0.00	0.54	0.00	0.00	0.00
	2	4.30	0.00	0.00	0.00	0.00	0.00	0.00	0.54
	3	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-40	1	1.61	1.08	0.00	0.00	1.08	0.00	0.00	0.00
	2	1.08	0.54	0.00	0.00	0.54	0.00	0.00	0.00
	3	0.54	0.54	0.00	0.00	0.00	0.00	0.00	0.00
4-55	1	1.61	1.08	0.00	0.00	0.00	0.00	0.00	0.00
	2	1.08	0.54	0.00	0.00	0.00	0.00	0.00	0.00
	3	1.08	0.00	0.54	0.00	0.00	0.00	0.00	0.00
4-70	1	1.08	0.00	0.54	0.00	1.08	0.00	0.00	0.54
	2	2.69	0.00	1.08	0.00	0.00	0.00	0.54	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-40	1	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	1.08	0.00	0.00	0.00	0.54	0.00	0.00
5-55	1	0.00	0.00	0.54	0.00	1.08	0.00	0.54	0.00
	2	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00
5-70	1	1.61	0.00	0.00	0.00	0.54	0.00	1.08	0.00
	2	1.08	0.54	0.00	0.00	0.00	0.00	0.54	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00
LD27	1	0.00	0.54	0.00	0.00	1.08	0.00	0.00	0.00
	2	1.61	0.54	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LU12	1	2.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	1.08	1.08	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.1-2, continued.

Station	Interval	Annelida	Arthropoda	Cnidaria	Echinodermata	Echiura	Mollusca	Nemertea	Sipuncula
7-55	1	0.54	0.00	0.00	0.00	0.54	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SU22	1	1.61	0.54	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9-40	1	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00
9-55	1	1.08	0.00	0.00	0.00	0.54	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9-70	1	1.61	1.08	0.00	0.00	0.54	0.00	0.00	0.00
	2	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10-40	1	2.15	0.54	0.00	0.00	0.00	0.54	0.00	0.00
	2	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.5-55	1	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.54
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.5-70	1	0.00	0.00	0.54	1.08	0.00	0.00	0.54	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10-70	1	2.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.54	0.00	0.54	0.00	0.00	0.00	0.00	1.08
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



taxa#_nocaption.mxd 29June 2005, M.Goff, SAIC (1:50,000)

Figure 3.1-1. Mean Number of BIO Taxa by Core Depth Interval, July/August 2004. Data were standardized to 0.1 m^2. NI = no interval collected.

Table 3.1-3. Mean Abundance by Station, Core Depth Interval, and Taxonomic Group, July/August 2004. Data were standardized to 0.1 m^2. ND = No data.

Station	Interval	Annelida	Arthropoda	Cnidaria	Echinodermata	Echiura	Mollusca	Nemertea	Sipuncula
3-40	1	5.91	3.76	0.00	0.00	0.00	0.54	2.69	0.00
	2	6.99	2.69	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-55	1	9.14	0.00	0.00	0.00	0.00	0.00	0.00	0.54
	2	13.44	1.08	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-70	1	11.83	0.00	1.61	0.00	0.54	0.00	0.00	0.00
	2	8.06	0.00	0.00	0.00	0.00	0.00	0.00	0.54
	3	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-40	1	2.69	1.08	0.00	0.00	1.08	0.00	0.00	0.00
	2	2.15	0.54	0.00	0.00	0.54	0.00	0.00	0.00
	3	0.54	0.54	0.00	0.00	0.00	0.00	0.00	0.00
4-55	1	3.23	1.08	0.00	0.00	0.00	0.00	0.00	0.00
	2	1.61	0.54	0.00	0.00	0.00	0.00	0.00	0.00
	3	2.15	0.00	0.54	0.00	0.00	0.00	0.00	0.00
4-70	1	3.23	0.00	0.54	0.00	1.61	0.00	0.00	0.54
	2	5.38	0.00	1.08	0.00	0.00	0.00	0.54	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-40	1	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	1.08	0.00	0.00	0.00	0.54	0.00	0.00
5-55	1	0.00	0.00	0.54	0.00	1.08	0.00	0.54	0.00
	2	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00
5-70	1	2.15	0.00	0.00	0.00	0.54	0.00	1.08	0.00
	2	1.08	1.08	0.00	0.00	0.00	0.00	0.54	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00
LD27	1	0.00	0.54	0.00	0.00	1.61	0.00	0.00	0.00
	2	2.15	0.54	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LU12	1	2.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	1.08	1.08	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.1-3, continued.

Station	Interval	Annelida	Arthropoda	Cnidaria	Echinodermata	Echiura	Mollusca	Nemertea	Sipuncula
7-55	1	1.08	0.00	0.00	0.00	0.54	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SU22	1	1.61	0.54	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9-40	1	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00
9-55	1	2.69	0.00	0.00	0.00	0.54	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9-70	1	5.38	1.61	0.00	0.00	0.54	0.00	0.00	0.00
	2	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10-40	1	2.69	0.54	0.00	0.00	0.00	0.54	0.00	0.00
	2	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.5-55	1	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.54
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	ND	ND	ND	ND	ND	ND	ND	ND
9.5-70	1	0.00	0.00	0.54	1.61	0.00	0.00	0.54	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54
	3	ND	ND	ND	ND	ND	ND	ND	ND
10-70	1	3.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	1.61	0.00	0.54	0.00	0.00	0.00	0.00	1.08
	3	ND	ND	ND	ND	ND	ND	ND	ND

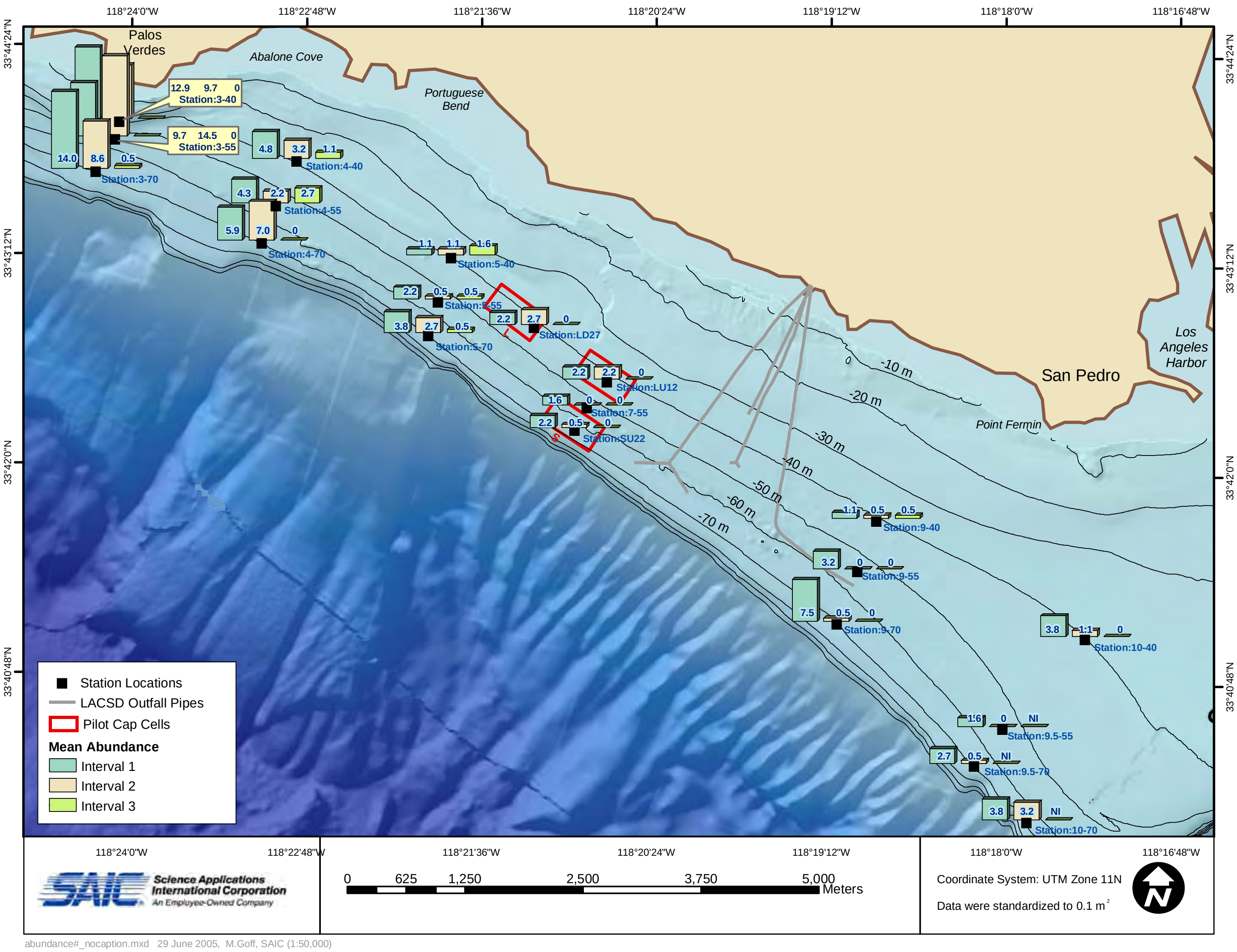


Figure 3.1-2. Mean Abundance of BIO by Core Depth Interval, July/August 2004. Data were standardized to 0.1 m^2. NI = no interval collected.

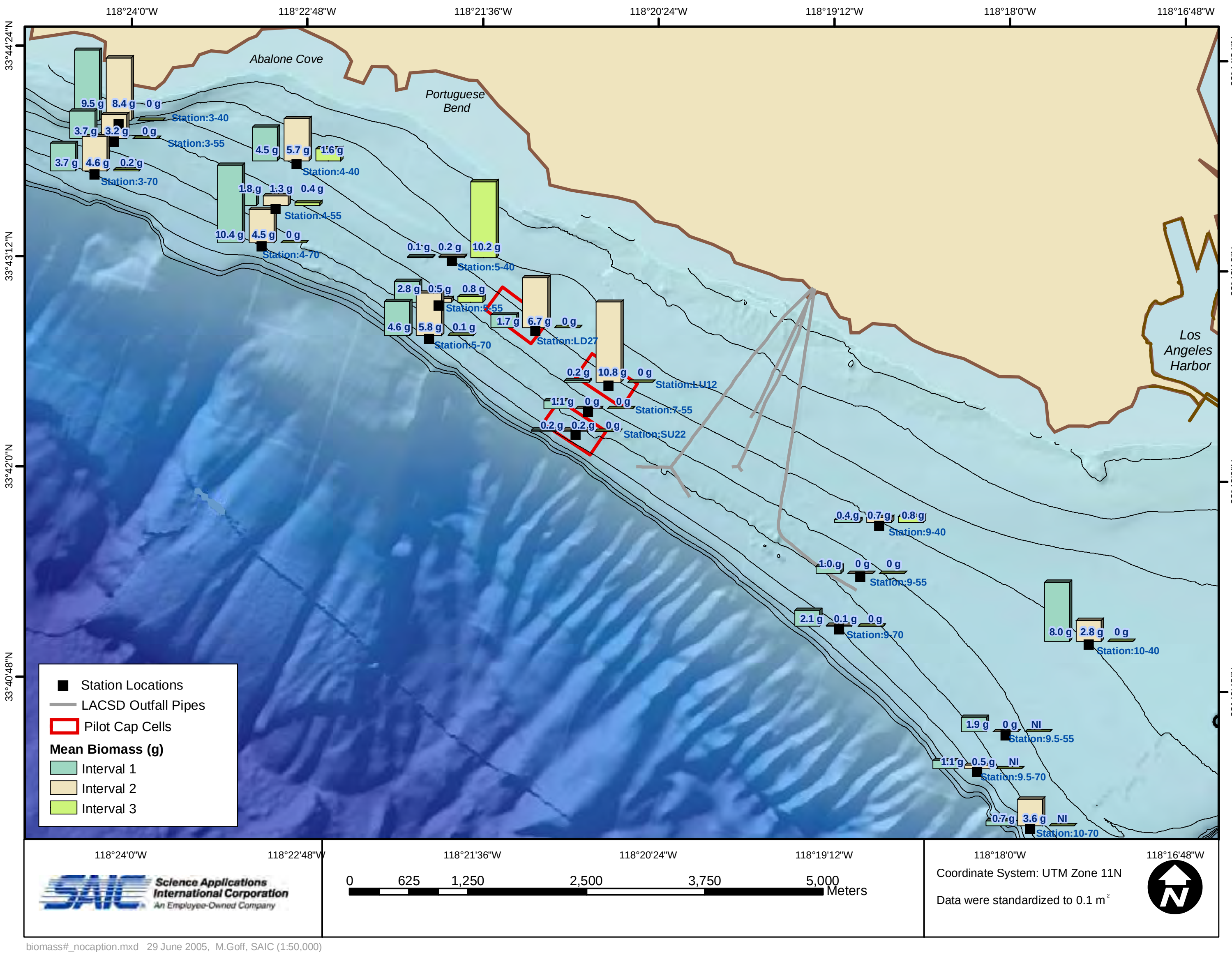


Figure 3.1-3. Mean Biomass (g) of BIO by Core Depth Interval, July/August 2004. Data were standardized to 0.1 m^2. NI = no interval collected.

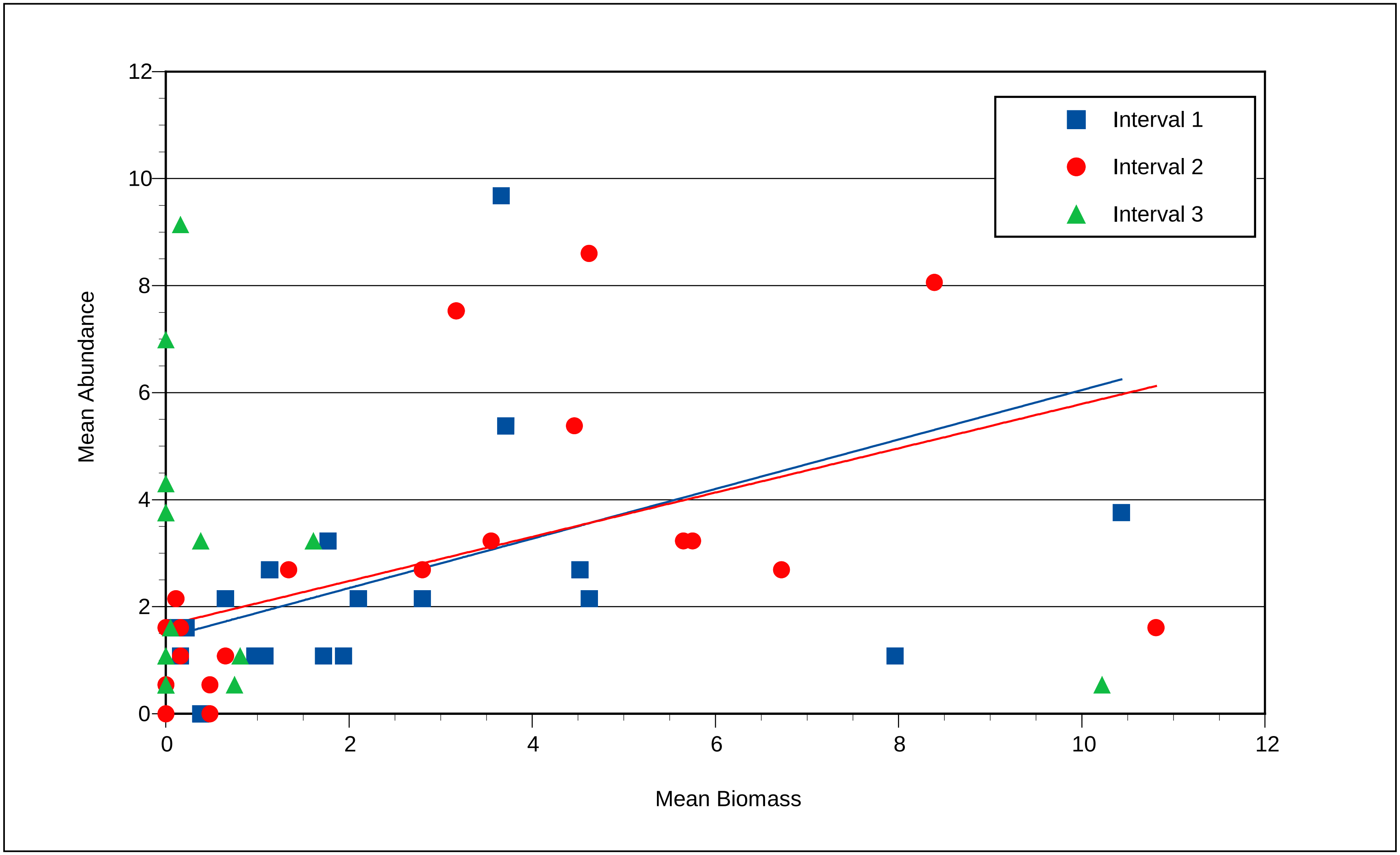


Figure 3.1-4. Relationship Between Mean Abundance and Biomass (g) by Station and Core Depth Interval, July/August 2004. Intervals 1, 2, and 3 are distinguished by red, green, and blue line colors, respectively. Data were standardized to 0.1 m^2.

Table 3.1-4. Mean Biomass (g) by Station, Core Depth Interval, and Taxonomic Group, July/August 2004. Data were standardized to 0.1 m^2 and then normalized by core interval volume. ND = No data.

Station	Interval	Annelida	Arthropoda	Cnidaria	Echinodermata	Echiura	Mollusca	Nemertea	Sipuncula
3-40	1	1.99	6.99	0.00	0.00	0.00	0.05	0.43	0.00
	2	2.15	6.24	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-55	1	3.49	0.00	0.00	0.00	0.00	0.00	0.00	0.16
	2	2.26	0.91	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-70	1	3.28	0.00	0.32	0.00	0.11	0.00	0.00	0.00
	2	4.30	0.00	0.00	0.00	0.00	0.00	0.00	0.32
	3	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4-40	1	0.54	0.11	0.00	0.00	3.87	0.00	0.00	0.00
	2	0.81	0.54	0.00	0.00	4.30	0.00	0.00	0.00
	3	0.19	1.71	0.00	0.00	0.00	0.00	0.00	0.00
4-55	1	1.67	0.11	0.00	0.00	0.00	0.00	0.00	0.00
	2	1.29	0.05	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.53	0.00	0.09	0.00	0.00	0.00	0.00	0.00
4-70	1	1.72	0.00	1.13	0.00	6.99	0.00	0.00	0.59
	2	3.06	0.00	1.34	0.00	0.00	0.00	0.05	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-40	1	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	8.56	0.00	0.00	0.00	3.49	0.00	0.00
5-55	1	0.00	0.00	0.38	0.00	2.37	0.00	0.05	0.00
	2	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00
5-70	1	0.22	0.00	0.00	0.00	0.54	0.00	3.87	0.00
	2	5.54	0.11	0.00	0.00	0.00	0.00	0.11	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00
LD27	1	0.00	0.38	0.00	0.00	1.34	0.00	0.00	0.00
	2	0.16	6.56	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LU12	1	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	2.85	8.61	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.1-4, continued.

Station	Interval	Annelida	Arthropoda	Cnidaria	Echinodermata	Echiura	Mollusca	Nemertea	Sipuncula
7-55	1	0.97	0.00	0.00	0.00	0.11	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SU22	1	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9-40	1	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.00
9-55	1	0.91	0.00	0.00	0.00	0.05	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9-70	1	1.18	0.16	0.00	0.00	0.75	0.00	0.00	0.00
	2	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10-40	1	4.57	1.83	0.00	0.00	0.00	1.56	0.00	0.00
	2	2.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.5-55	1	0.75	0.00	0.00	0.00	0.00	0.00	0.00	1.18
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	ND	ND	ND	ND	ND	ND	ND	ND
9.5-70	1	0.00	0.00	0.16	0.86	0.00	0.00	0.11	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16
	3	ND	ND	ND	ND	ND	ND	ND	ND
10-70	1	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.38	0.00	0.22	0.00	0.00	0.00	0.00	2.96
	3	ND	ND	ND	ND	ND	ND	ND	ND

gastropod *Sinum*. Information on key species contributions to biomass is described in the following section.

3.1.2 Key Species

Key taxa from the BIO survey, based on frequency of occurrence across intervals 1 to 3, abundance, and biomass were the ghost shrimp, *Neotrypaea*, and the polychaete worm, *Marphysa* (Tables 3.1-1 and A-1). Other taxa of note included the polychaetes *Glycera americana* and *G. capitata*, *Gymnonereis crosslandi*, and *Nereis procera*; the echiuran *Listriolobus pelodes*; and the crab *Pinnixa occidentalis*, commonly co-occurring in the same samples as *Neotrypaea*. It is notable that the frequency of occurrence of these species was substantially higher, depending on the station, in both intervals 1 and 2 or in interval 1 alone.

Mean abundance data for ghost shrimp indicated that all the specimens were collected northwest of the outfalls, predominately at Stations 3-40, 3-55, 4-40, and 5-40, with an overall maximum of four at one station (Figure 3.1-5). No individuals were collected at any of the 70-m stations. Mean abundance data for *Marphysa* indicated a broader distribution, but similar predominance northwest of the outfalls, along Transects 3 and 4 (Figure 3.1-6). Station 9-70 also had relatively high abundance. The highest values for *Marphysa* ranged from about 5 to 8. Mean biomass data for ghost shrimp and *Marphysa* indicated a predictably similar distribution as observed for abundance: higher values were from stations northwest of the outfalls, but notably for *Neotrypaea* at Station 5-40 (interval 3) and near the center of capping cell Stations LD27 and LU12 (interval 2) (Figures 3.1-7 and 3.1-8).

Plots of mean abundance versus mean biomass for *Neotrypaea* and *Marphysa* indicated some key differences in the distributional characteristics of these species between the core intervals (Figures 3.1-9 and 3.1-10, respectively). *Neotrypaea* was mostly characterized by similar mean biomass, independent of depth interval and abundance. *Marphysa* showed a comparable pattern (i.e., non-linear) for interval 3, but a weak linear relationship for interval 2 ($r^2 = 0.48$) and a strong relationship for interval 1 ($r^2 = 0.84$). A similar pattern was noted for mean abundance versus mean length for the two species (Figures 3.1-11 and 3.1-12, respectively), although the linear relationship for *Marphysa* was even stronger than noted for biomass ($r^2 = 0.61$ for interval 2 and 0.90 for interval 1). These patterns indicate that *Neotrypaea* was mainly characterized by individuals of a similar range in size and weight over all three core depth intervals. *Marphysa* was characterized by a similar size and weight of smaller individuals in the lower interval (> 30 cm), but a much broader range in the top two intervals ($\leq$ 30 cm). Patterns were not evident for other taxa due to the relatively few individuals that were present in the samples.

3.2 SPI AND PLAN-VIEW

Sediment-Profile Imagery

Analysis of the SPI images from the BIO stations (Figure 2.1-1) indicated that surface sediments at a majority of the stations were predominantly fine-grained, tan and gray sandy silt, with major modes of > 4 phi and 4 to 3 phi (Table B-1 and Figure B-1 series in Appendix B). The only exception was Station 3-40, which was characterized by sandier sediments (3 to 2 phi). The most common benthic habitat at these stations was classified as unconsolidated silty sediment (code UN.SI), followed by fine sand mixed with silt (code UN.SS), and less commonly fine sand (code SA.F). This latter habitat was noted at Stations 3-40 and 10-55, located in the northwest and southeast ends of the study area, respectively. In general, mean camera penetration measurements indicated the lowest values (most compacted) at the Transect 10 stations (southeast survey area), and at Station LU12 within the LU capping cell (Table B-1).

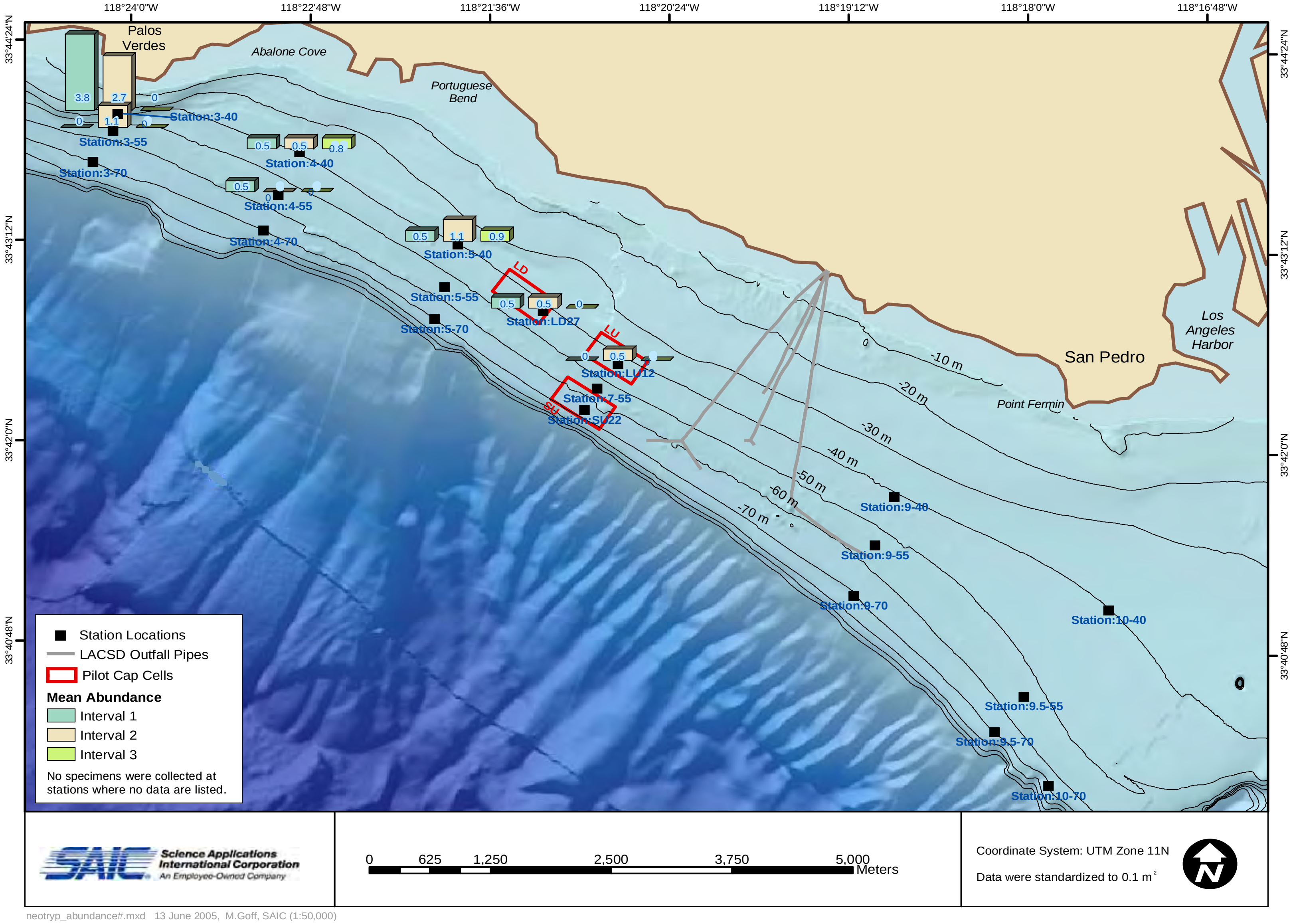


Figure 3.1-5. Mean Abundance ("head" count) of the Ghost Shrimp, *Neotrypaea*, by Core Depth Interval, July/August 2004. Data were standardized to 0.1 m^2.

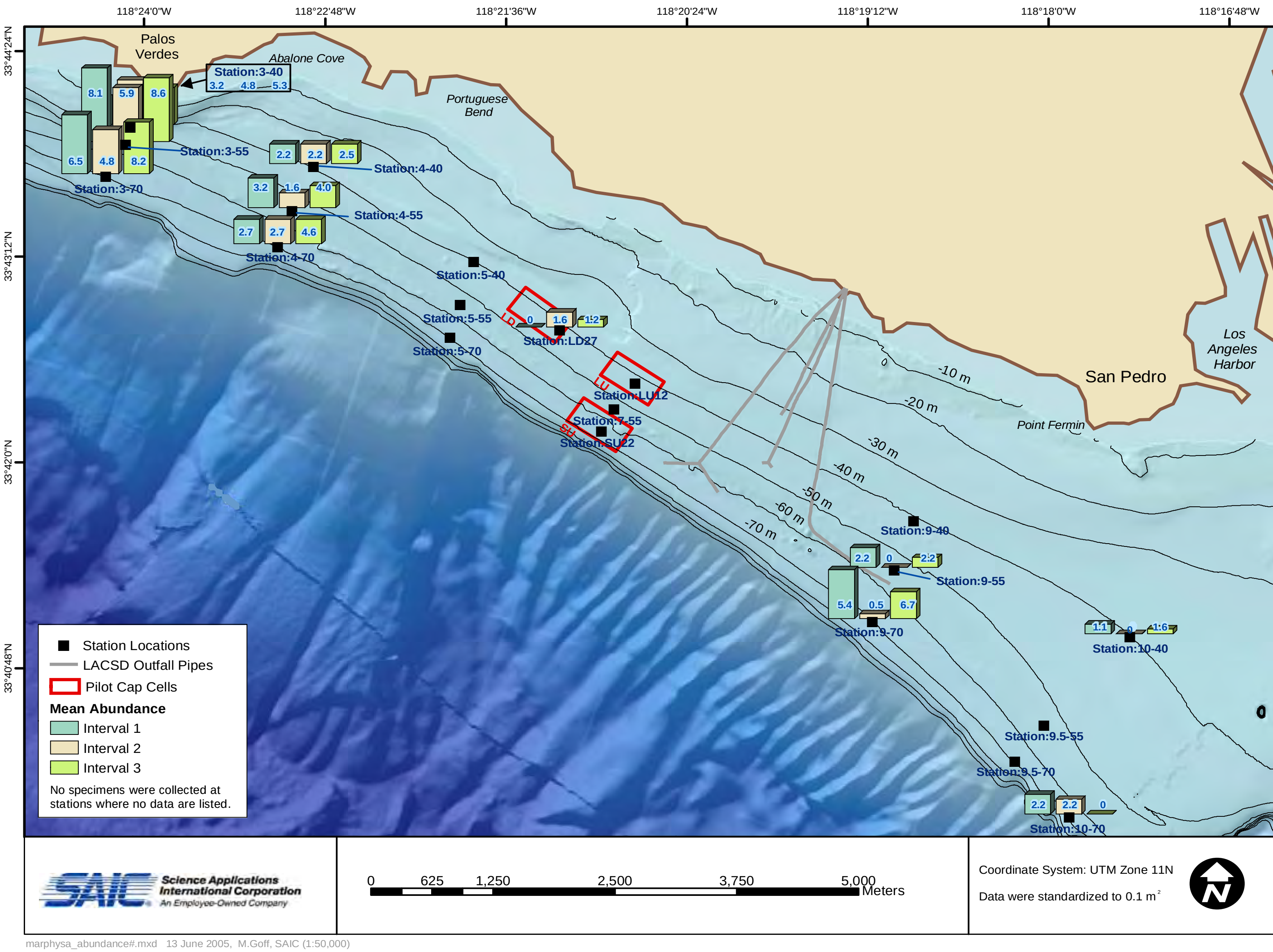


Figure 3.1-6. Mean Abundance ("head" count) of the Polychaete, *Marphysa*, by Core Depth Interval, July/August 2004. Data were standardized to 0.1 m^2.

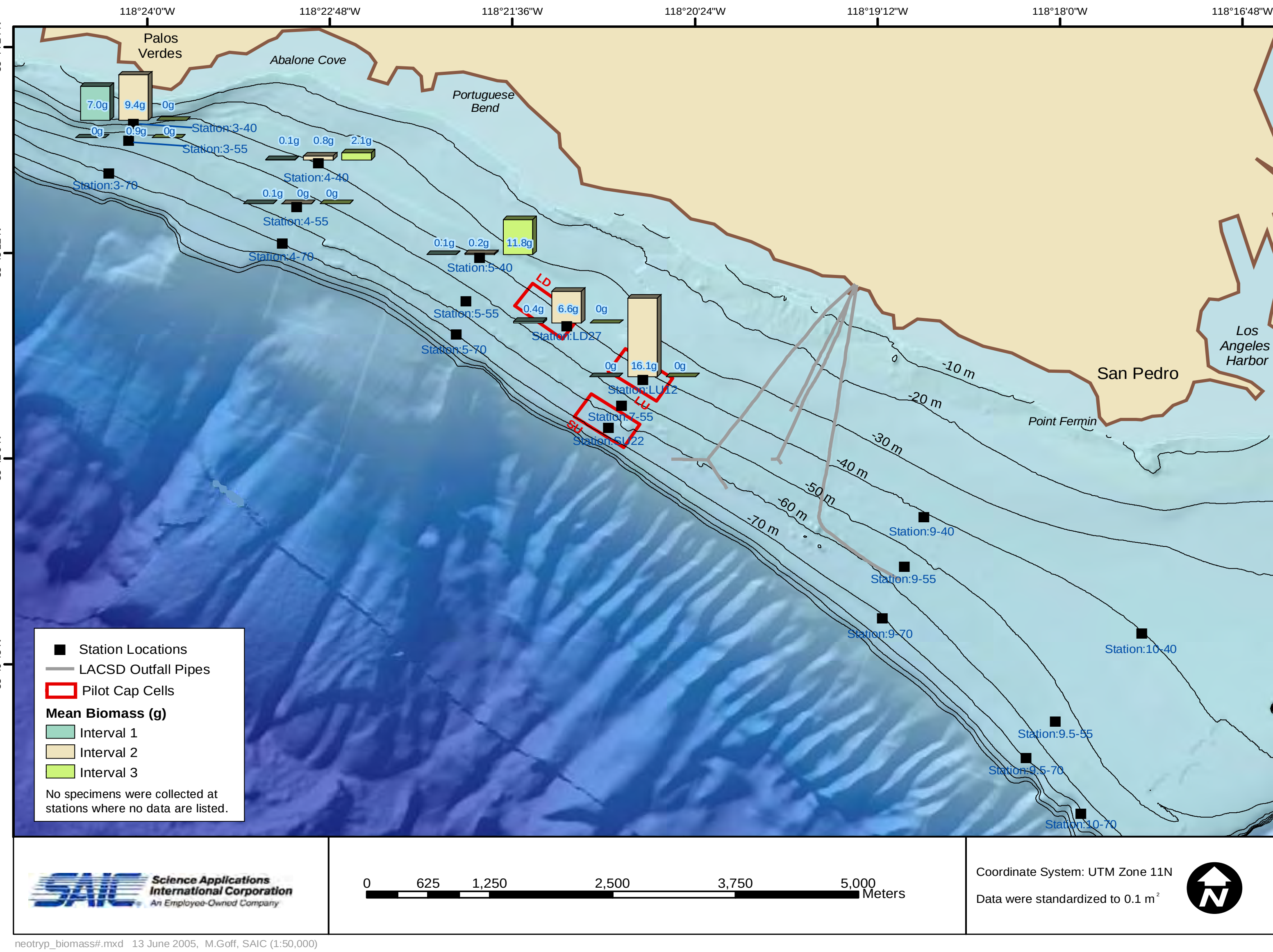


Figure 3.1-7. Mean Biomass (g; all specimens combined) of the Ghost Shrimp, *Neotrypaea*, by Core Depth Interval, July/August 2004. Data were standardized to 0.1 m^2.

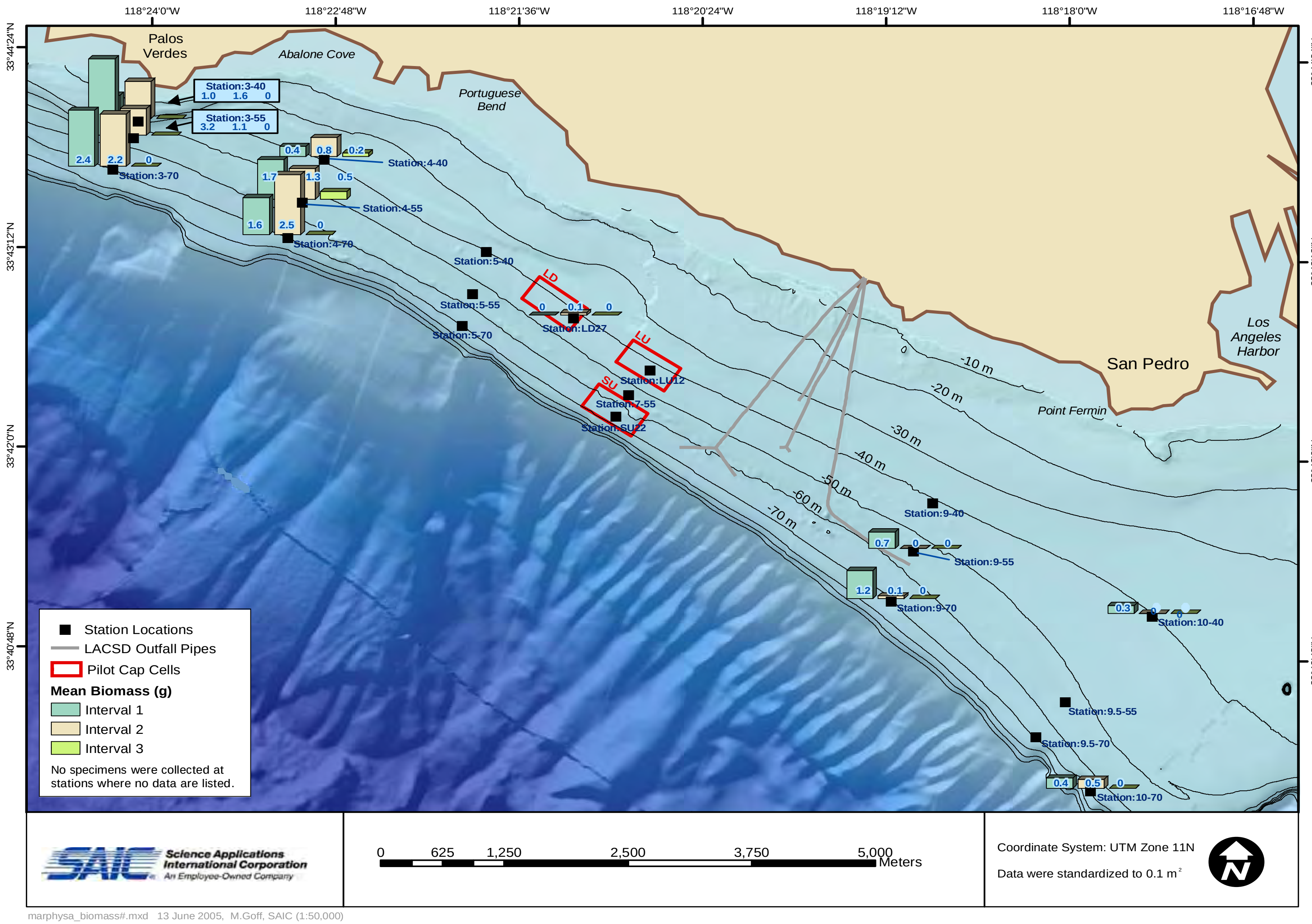


Figure 3.1-8. Mean Biomass (g; all specimens combined) of the Polychaete, *Marphysa*, by Core Depth Interval, July/August 2004. Data were standardized to 0.1 m^2.

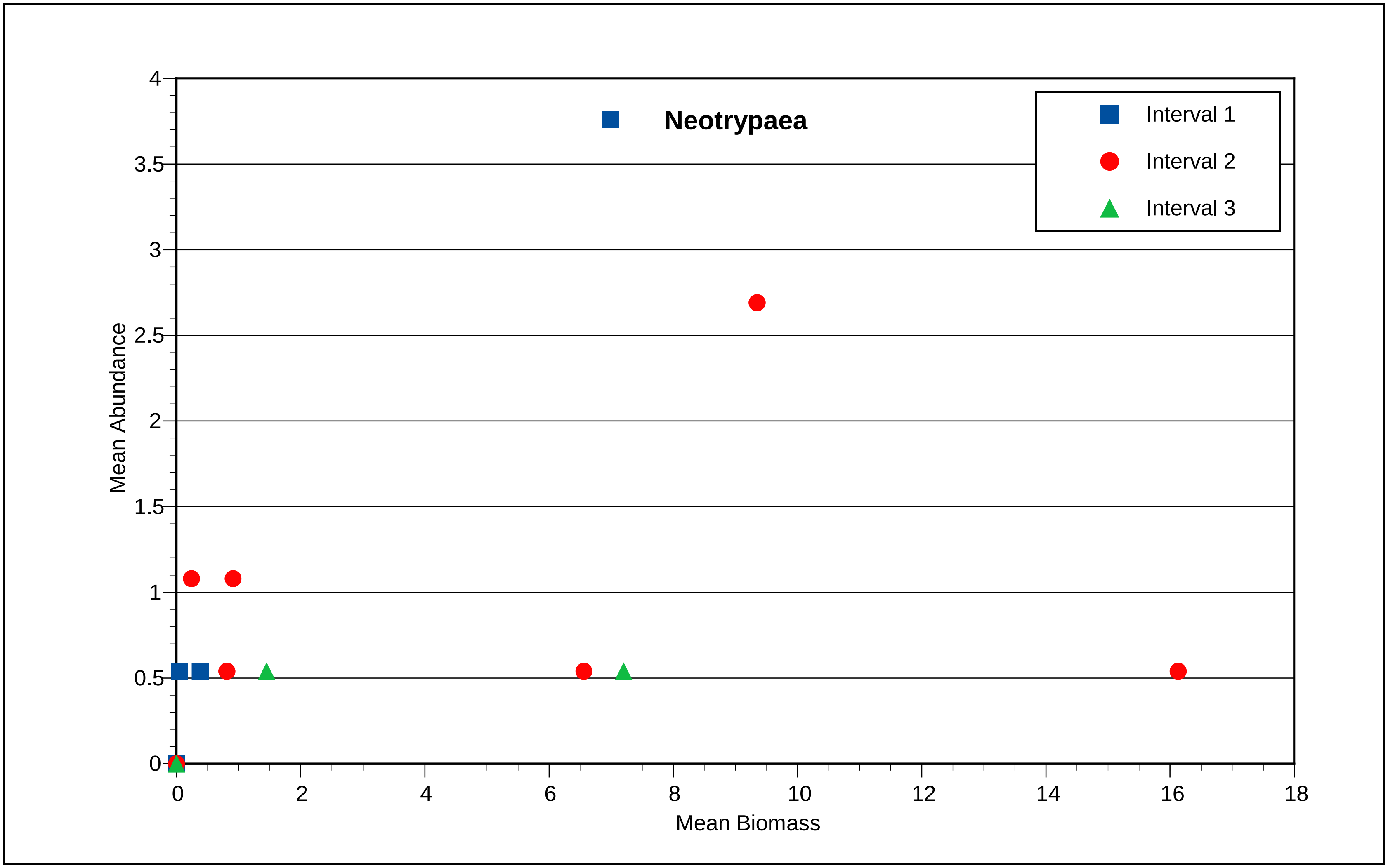


Figure 3.1-9. Mean Abundance versus Mean Biomass (g) of the Ghost Shrimp, *Neotrypaea*, by Core Depth Interval, July/August 2004. Data were standardized to 0.1 m^2.

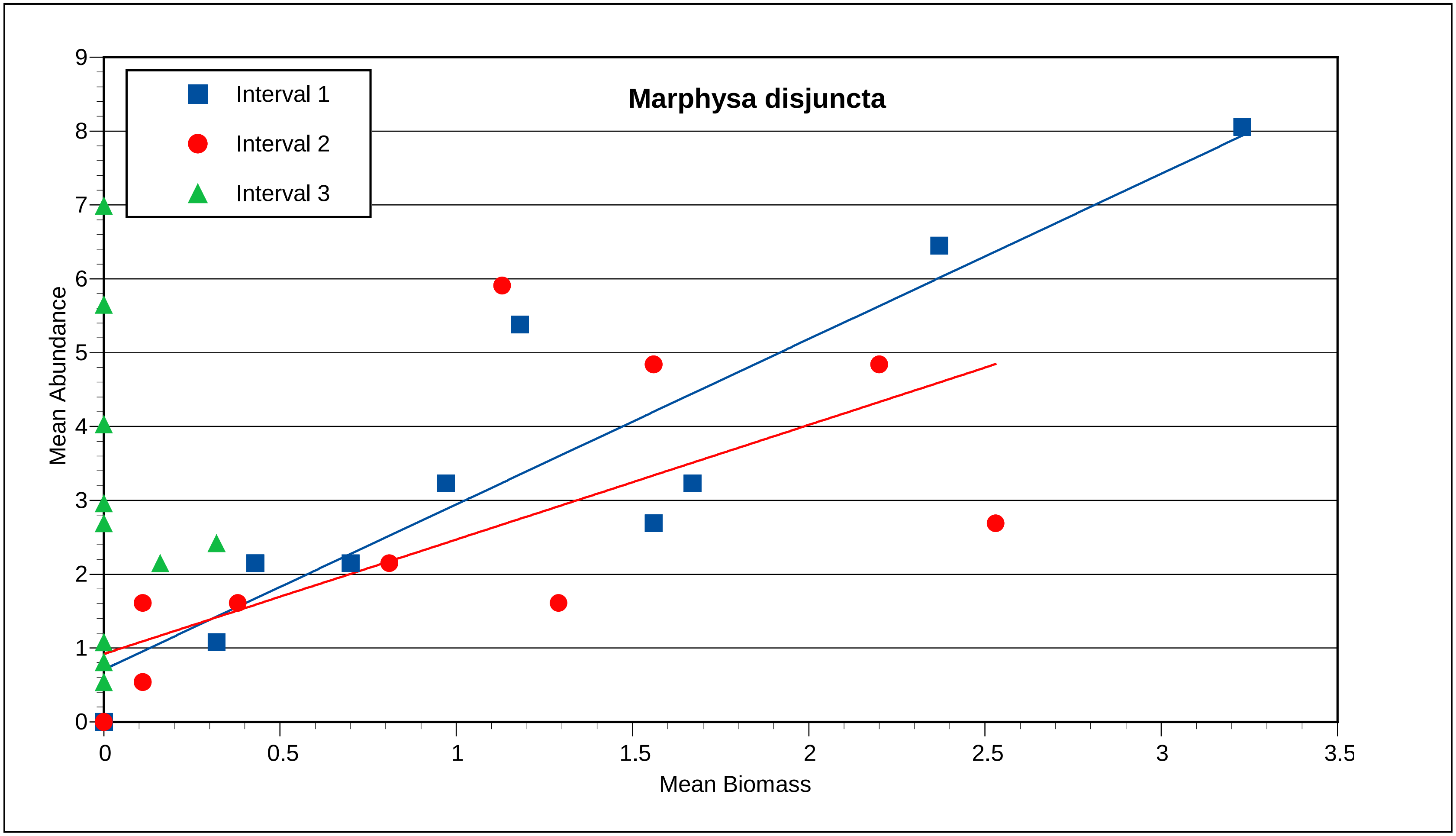


Figure 3.1-10. Mean Abundance versus Mean Biomass (g) of the Polychaete, *Marphysa*, by Core Depth Interval, July/August 2004. Data were standardized to 0.1 m^2.

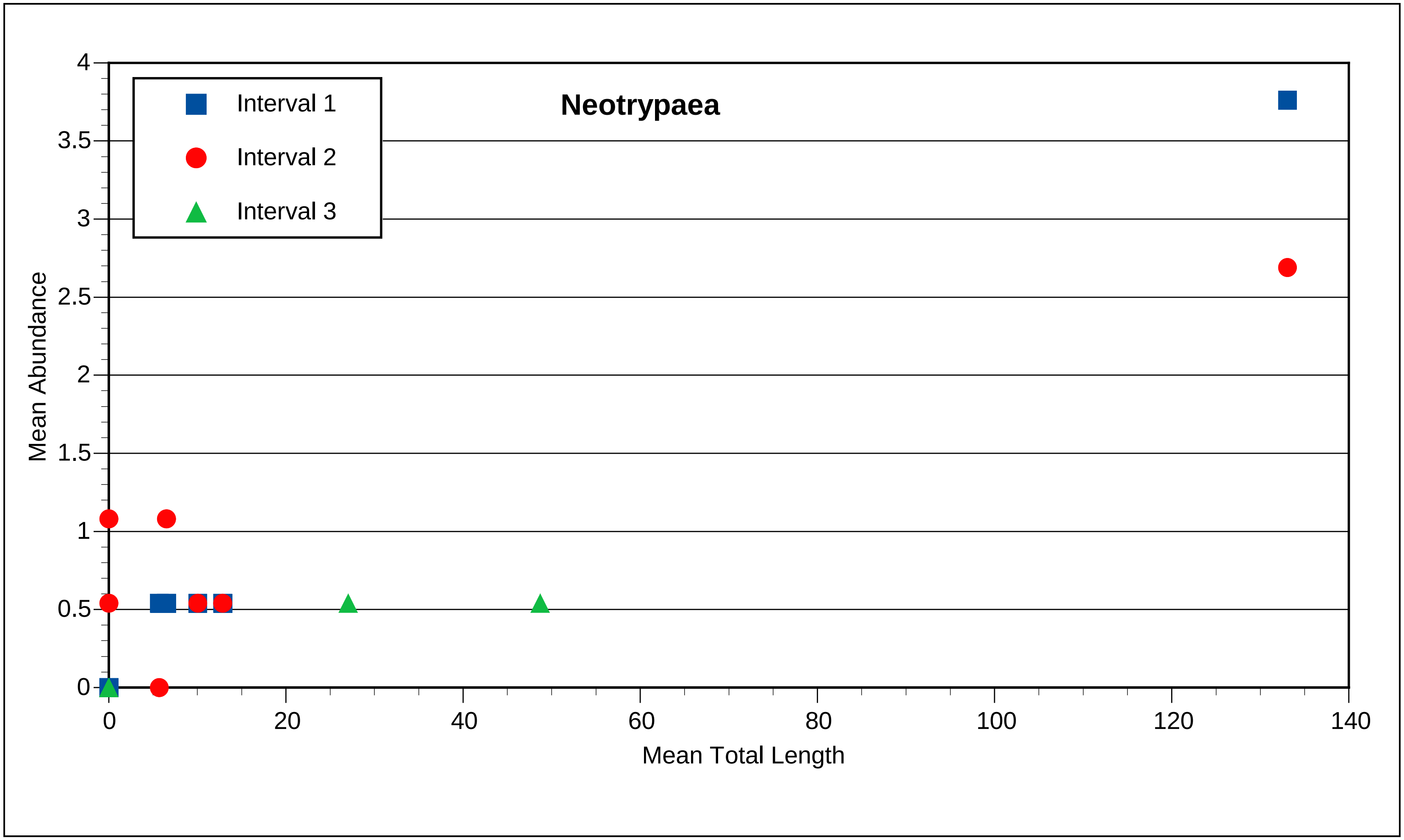


Figure 3.1-11. Mean Abundance versus Mean Total Length (mm; all specimens combined) of the Ghost Shrimp, *Neotrypaea*, by Core Depth Interval, July/August 2004. Data were standardized to 0.1 m^2.

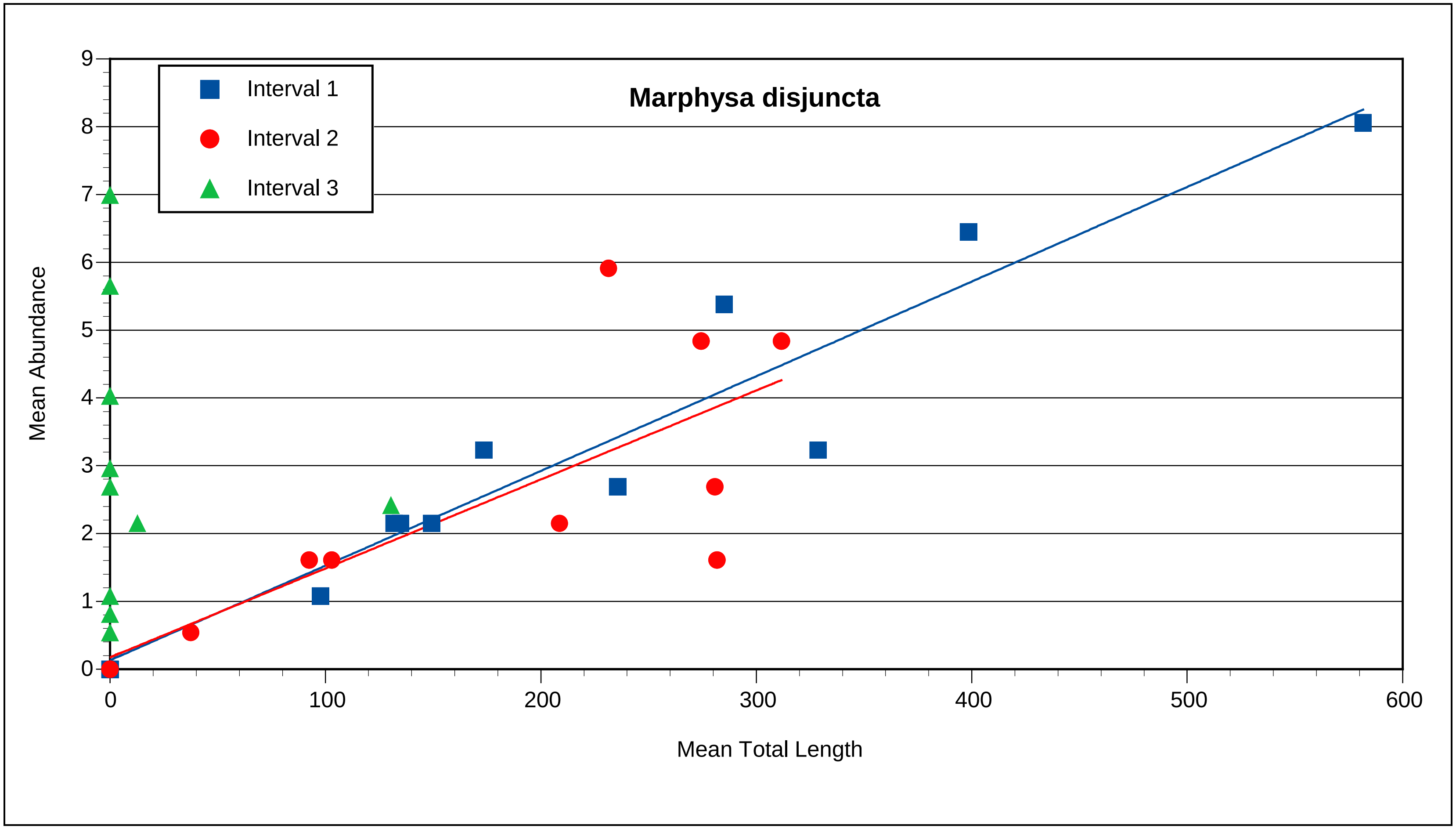


Figure 3.1-12. Mean Abundance versus Mean Total Length (mm; all specimens combined) of the Polychaete, *Marphysa*, by Core Depth Interval, July/August 2004. Data were standardized to 0.1 m^2**.**

Three parameters were used to assess overall benthic habitat quality within the survey area: RPD depth, infaunal successional status, and OSI, as described in Section 2.3.1. The RPD depth measured in each image provided an estimate of the apparent depth of oxygen penetration into the surface sediment. Mean RPD depths in the study area were moderately deep, with the majority of the stations characterized by values between approximately 2.0 and 4.0 cm (Table B-1 and Figure B-1 series). The only exception was a value of 1.28 cm at Station 9-40. None of the images showed any evidence of low dissolved oxygen conditions or methane gas entrained within the sediment.

Infaunal successional status indicated the presence of an advanced benthic community across most of the study area. Stage I polychaetes were observed at the sediment surface together with Stage III feeding voids at depth (Stage I on III successional status) at the majority of the stations (Table B-1 and Figure B-1 series). Exceptions included Stage I-only conditions at most of the same stations characterized by relatively compacted sediments and/or habitats types coded as fine sand (e.g., along Transect 10 and at Stations 3-40 and LU12), or low mean RPD (Station 9-40). Evidence of Stage III activity included active feeding voids produced by head-down, deposit-feeding infauna in the subsurface sediments, as well as errant polychaetes within the sediment matrix (Figure B-1 series). When present, Stage III organisms were accompanied by Stage I polychaetes at each BIO station. This relationship is typical of productive seafloor areas receiving relatively high inputs of organic matter, sufficient to maintain a diverse benthic population of both suspension- and deposit-feeders.

The successional stage results are consistent with high mean OSI values such as 9 to 11 (Table B-1) over the majority of the stations. Bioturbation by this community has served to irrigate and aerate the surface sediments, resulting in RPD depths that generally exceeded 2 cm across the survey area, with evidence of burrowing and feeding voids at least down to the approximately 10- to 20-cm SPI camera penetration depths achieved for the survey (Figure B-1 series). However, although the OSI provides a useful indicator of the relative benthic health of near-surface sediments across the PV Shelf, this index by itself cannot be used to make broader inferences about the longer-term sediment contamination concerns that presently exist. Lower OSI values (e.g., 3 to 6) were observed at stations that were characterized by relatively compacted sediments and/or fine sand habitats or low mean apparent RPD, along Transect 10 and at Stations 3-40 and LU12.

Plan-View Images

Based on the collective plan-view image results, and consistent with the SPI data, the study area was mostly composed of soft, fine-grained sediments consisting of a mixture of silts/clays and fine sand (Table B-2 and Figure B-1 series). Exceptions were medium-to-fine sand at Stations 3-40 and 9-55. Changes in surface topography were usually due to physical features such as shell material or bedforms (sand ripples). In the plan-view images, the majority of the BIO stations contained some shell material (e.g., shell hash). Bedforms (sand ripples) generally occur in high-energy environments and were only observed at two of the 40-m BIO stations (4-40 and 5-40; Table B-2).

The majority of the BIO stations (14 of 19) contained no to relatively few (0 to 10) burrows (Table B-2 and Figure B-1 series). The five stations with the highest number of burrows were located to the northwest of the LACSD outfalls at relatively deeper depths (Stations 3-70, 4-70, 5-55, 5-70, and 7-55), all characterized by SPI results as occurring in areas of unconsolidated silty sediment (Table B-1). Invertebrates observed in the plan-view images included tube worms, sea cucumbers, sea pens, seastars, and brittle stars (Table B-2 and Figure B-1 series).

3.3 SEDIMENT MIXING AND BIOTURBATION RATES

Profiles of excess lead-210 were used to determine sediment accumulation rates at four stations (Figures 3.3-1 and 3.3-2). The profiles were characterized by regions of high and nearly constant activity underlain by regions of exponentially decreasing activity (Figure 3.3-1 and Table C-1 in Appendix C). The results provided a context for sediment mixing and bioturbation rate estimates using thorium-234, as presented below. The upper lead-210 profile region, which ranged in thickness from roughly 10 cm (9.5 55F) to > 50 cm (L5NW45C), probably reflected a combination of physical and biological mixing and non-steady fluxes of lead-210. Sediment accumulation rates ranged from 0.8 to 1.6 mm/yr in three of the four profiles. Sedimentation rates could not be determined from the L5NW45C profile because the down-core activity of lead-210 was nearly uniform; this was likely due to a non-steady flux of lead-210 (higher fluxes occurred during the 1960 to 1980 period due to the elevated mass flux from the JWPCP outfalls and the Portugese Bend landslide). These values were consistent with previous measurements of sedimentation rates on the Palos Verdes (Wheatcroft and Martin 1994) and Santa Monica margins (Alexander and Venherm 2003) using lead-210 geochronology. There was some indication that the sediment accumulation rate was relatively lower in the southeast portion of the study area (Figure 3.3-2), although this may have been a relative pattern that reflected the addition of outfall-derived solids to the northwest. These conclusions were somewhat limited because the profiles were based on a small number of data points.

Profiles of excess thorium-234 to evaluate sediment mixing/bioturbation rates were measured for 11 cores from six stations (Figures 3.3-2 and 3.3-3 and Table C-2). In general, surface activities ranged from 3 to12 disintegrations per minute per gram (dpm/g). Excess thorium-234 did not extend below 6 cm, and the log-linear plots of activity with depth yielded straight lines, indicative of biodiffusive mixing. Model fits permitted estimates of the vertical biodiffusivity, D_b, at most of the stations. These values ranged from 3 to 23 cm^2/yr (Figure 3.3-3), with an average mixing intensity of 13 ± 6 cm^2/yr (n=9). This value was low compared to a mean value of 37 ± 23 cm^2/yr (n=9) measured in 1992 and 1993 at LACSD stations 3C and 6C (Wheatcroft and Martin 1996).

Biodiffusivities also were estimated for an additional 15 cores from nine stations using the method of Aller et al. (1980) and employed by Wheatcroft and Martin (1996). This approach *assumes* biodiffusive mixing and uses the ratio of excess thorium-234 in the 0-1 and 0-5 cm depth intervals to estimate D_b (Table C-3). Using this approach, the biodiffusivity values ranged from 1 to 89 cm^2/yr, although most values were in the range of 5 to 25 cm^2/yr (Figure 3.3-2). Note in the figure that the thorium and lead data are distinguished using different color histogram bars and the data scales are different to better display this information. Values estimated for replicate cores varied considerably among the sampling locations. At some stations, biodiffusivity values differed by up to one order of magnitude. The agreement between replicate values using the gradient method (e.g., Station L4-NW22 -A and -B) typically was better than results from the comparison method (e.g., Station L3_NW8 -B and -Z). The highest mixing intensities were in the northwest portion of the study area, and there was a progressive decrease toward the outfall region (Figure 3.3-2). Comparisons of biodiffusivities estimated from the profile and "comparison" data sets yielded average biodiffusivities of 19 ± 21 cm^2/yr (n=24) for the present survey versus 31 ± 20 cm^2/yr (n=21) for the 1992/1993 results. Considering the large degree of variability, the present mixing intensity on the PV Shelf based on all thorium-234 data was roughly comparable to values measured a decade earlier.

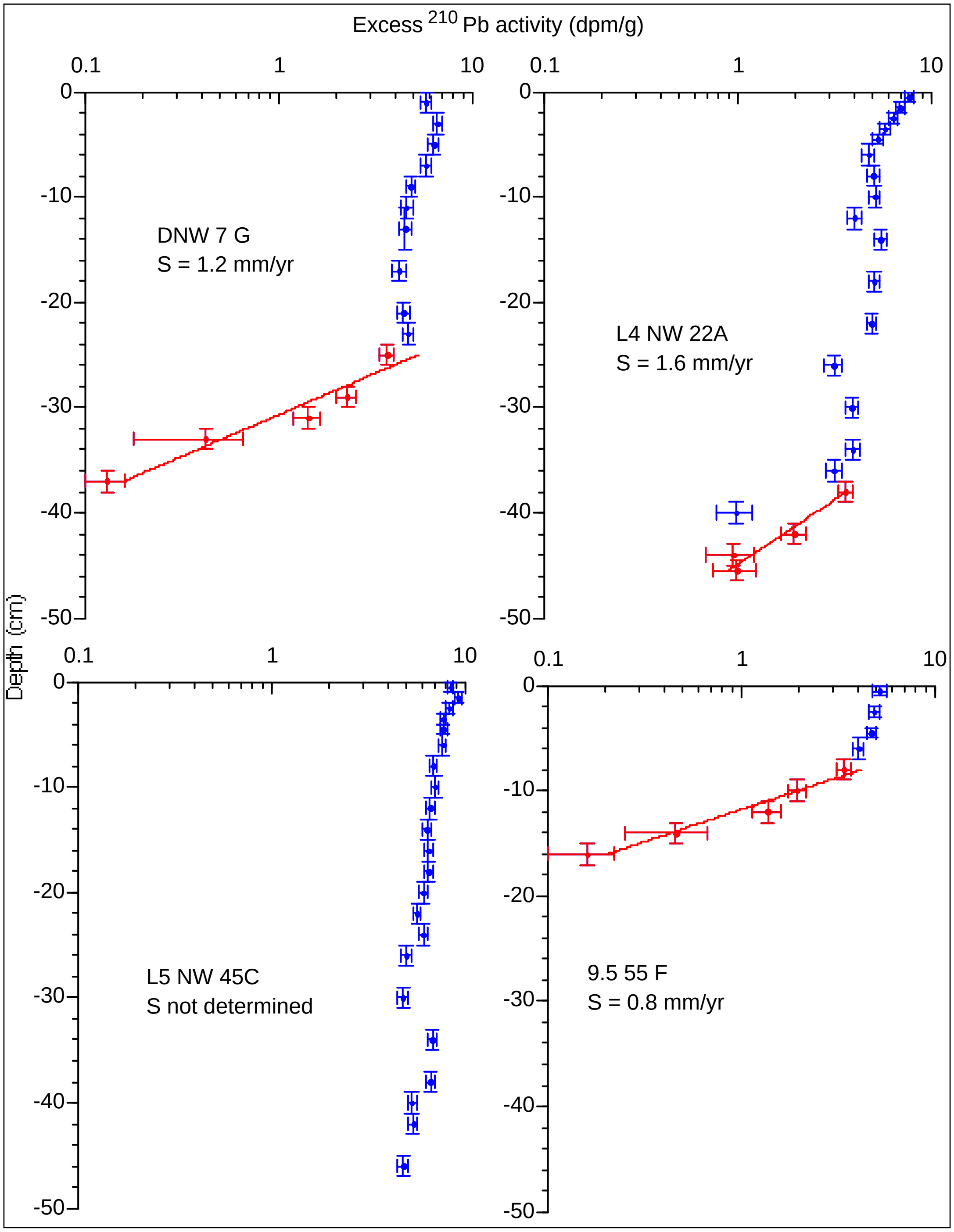
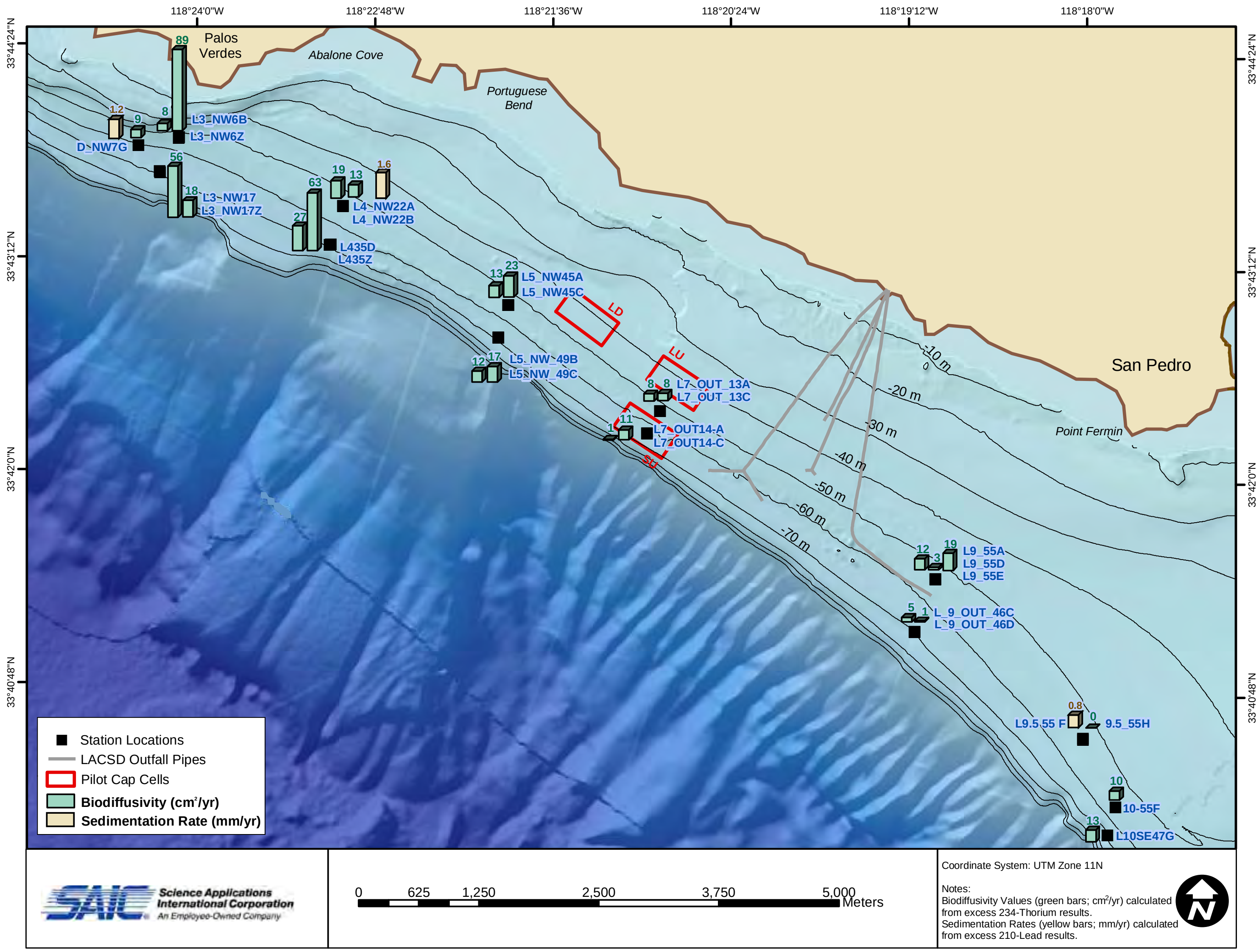


Figure 3.3-1. Excess Lead-210 (dpm/g) Versus Core Depth (cm) at Four Stations on the Palos Verdes Shelf. Least-squares fits were applied to the data points marked in red and the resultant sediment accumulation rates (mm/yr) are listed.



diffusivity#.mxd 7 April 2005, M.Goff, SAIC (1:55,000)

Figure 3.3-2. Biodiffusivity Values and Sedimentation Rates, July 2004

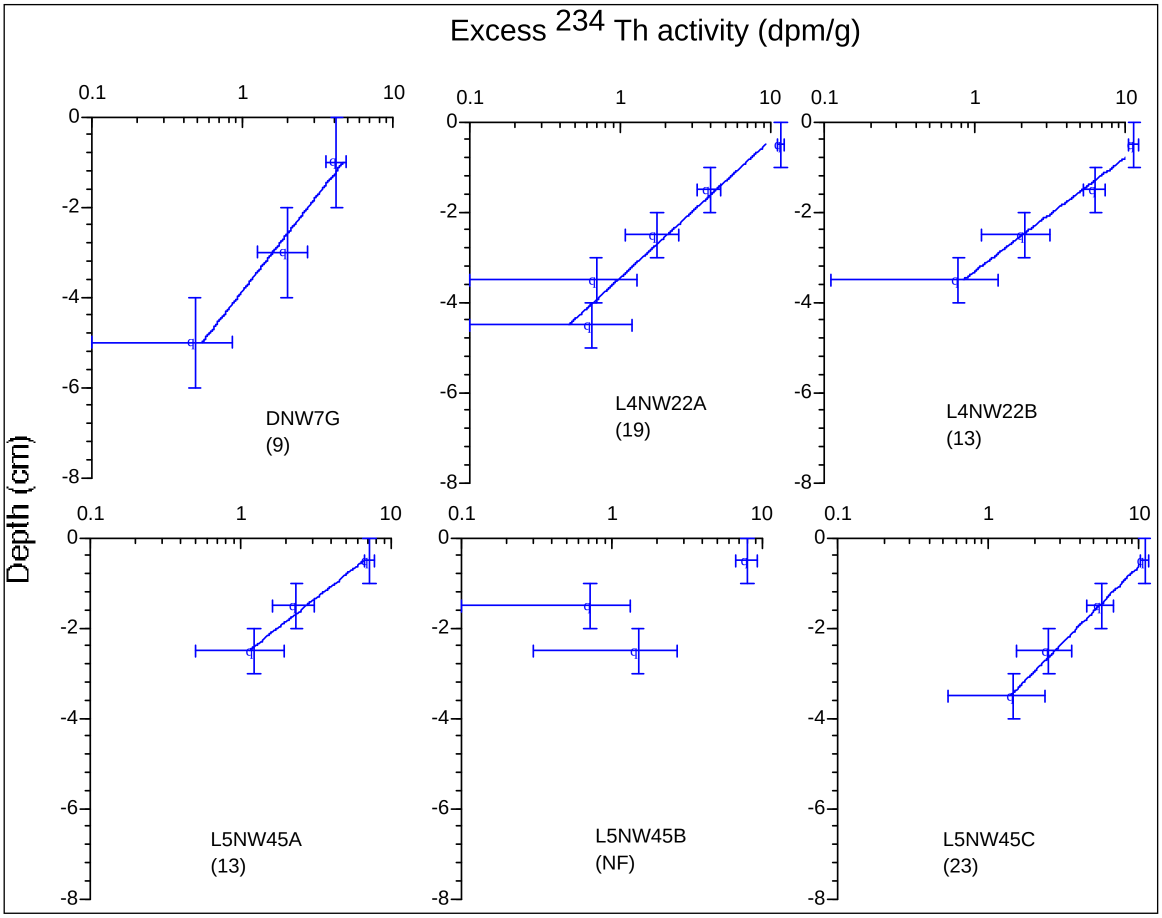


Figure 3.3-3. Profiles of Excess Thorium-234 Versus Depth for Replicate Stations in the Northern Portion of the Study Area. Lines are least-squares fits to the data, with the resultant biodiffusivity (in cm^2/yr) given in parentheses.
NF = not fit.

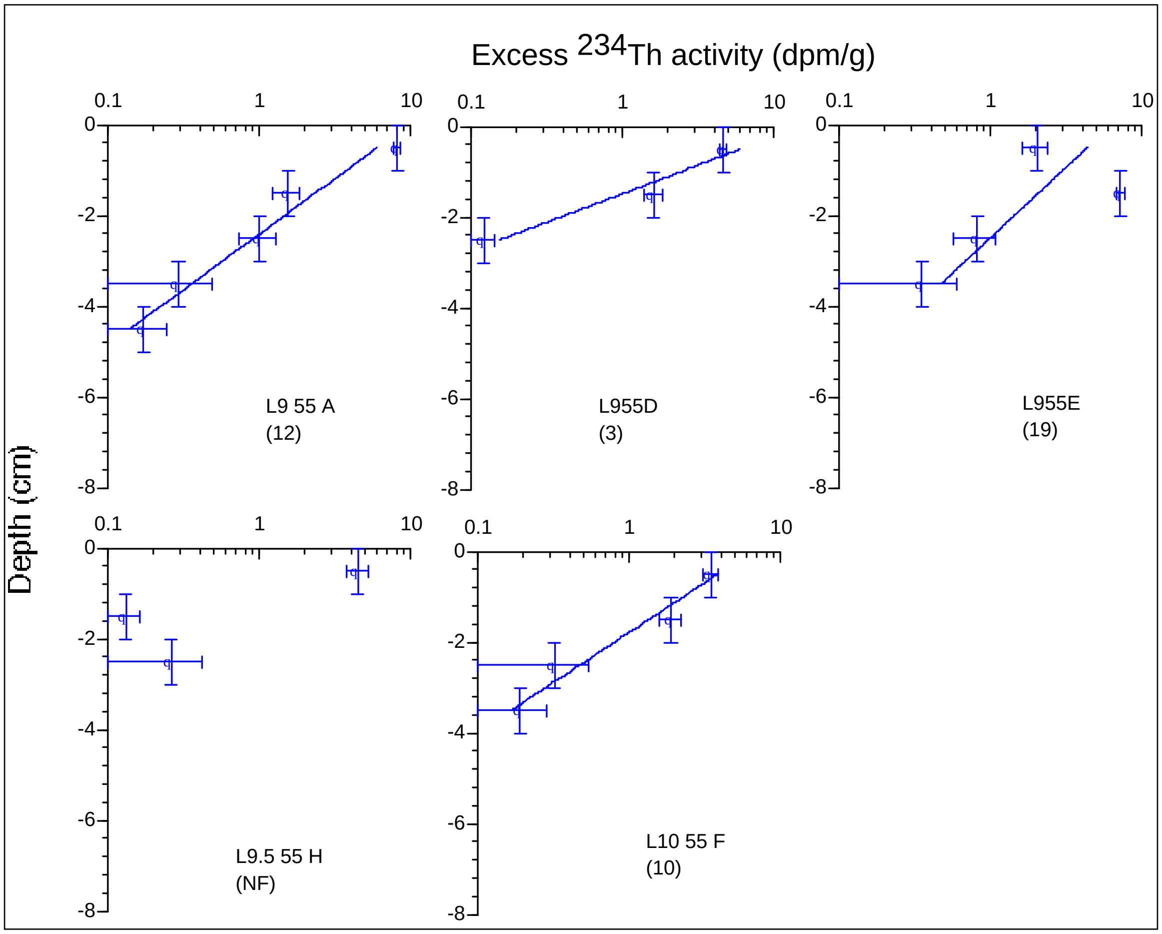


Figure 3.3-3(cont.). Profiles of Excess Thorium-234 Versus Depth for Replicate Stations in the Southern Portion of the Study Area. Lines are least-squares fits to the data, with the resultant biodiffusivity (in cm^2/yr) given in parentheses.
NF = not fit.

3.4 LACSD INFAUNAL DATA

LACSD total abundance and biomass data from summer 2003 are presented in Figures 3.4-1 and 3.4-2, respectively. Principle patterns include higher abundance at the shallow (30 m) and mid-depth (60 m) stations along most transects, and the highest values (e.g., over 1,000 individuals/0.1 m^2) near and immediately northwest and southeast of the outfalls. High abundance was also observed at Station 3D (30 m) located in the northwest part of the survey area. Similar patterns were observed for biomass, with the highest values ranging from about 15-43 g/0.1 m^2.

3.5 BIOTURBATION LITERATURE SEARCH

Results from the literature search are presented in Table A-2 of Appendix A. In general, the search determined that there was insufficient data, particularly for common BIO collected on the PV Shelf or for related taxa, to allow extrapolations of bioturbation rates. The most significant information related to burrow depths of ghost shrimp (e.g., up to 2-m depths for *Callianassa*; now *Neotrypaea*) and reworking rates of several hundred cubic centimeters/day for *Callianassa* and various polychaetes. These results provided additional documentation of bioturbation potential. However, even for the ghost shrimp quantitative information on specimen size (e.g., length or weight) was insufficiently presented to enable meaningful extrapolations to the 2004 BIO data.

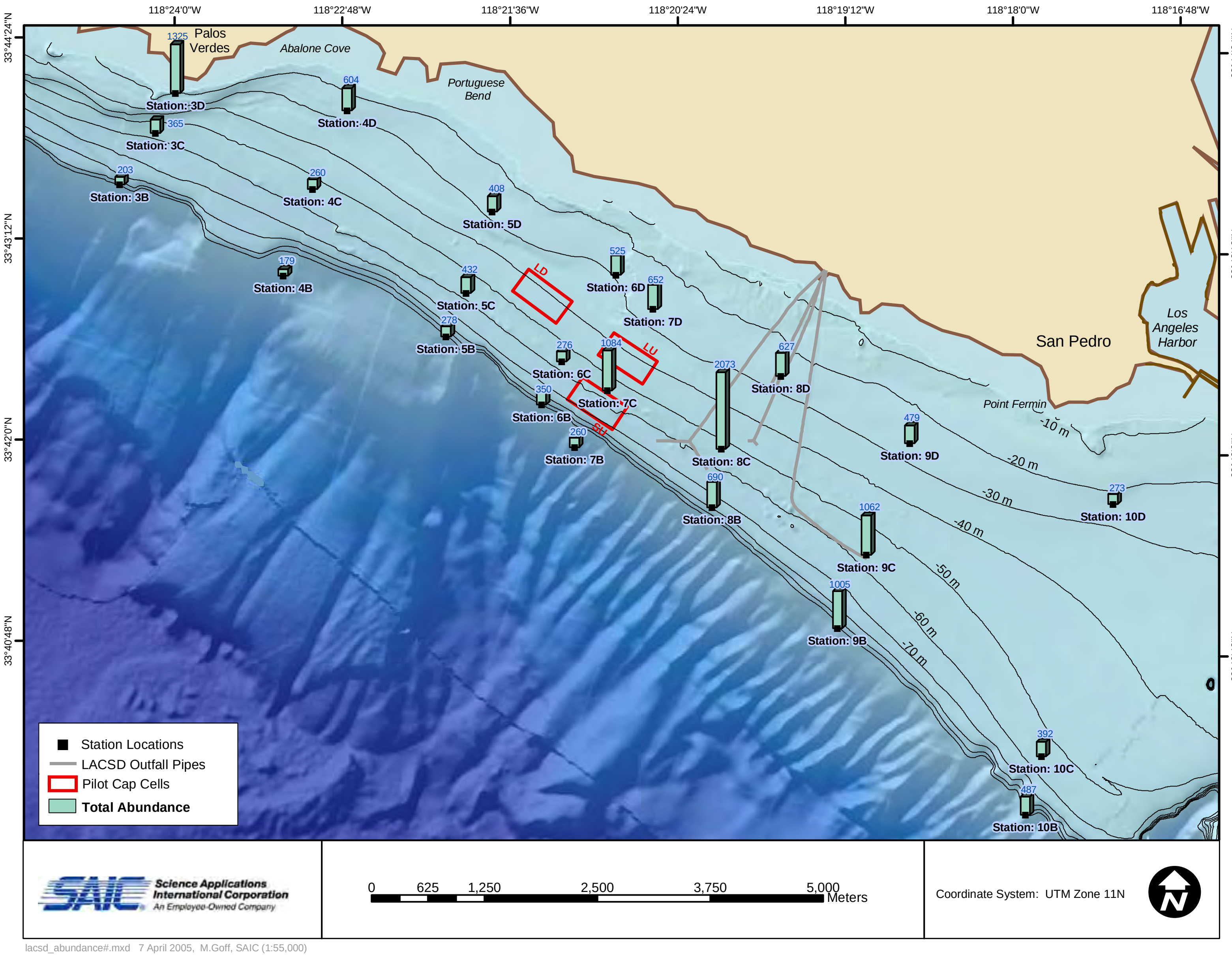


Figure 3.4-1. Total Infaunal Abundance by LACSD Station, per 0.1 m^2 Core, Summer 2004.

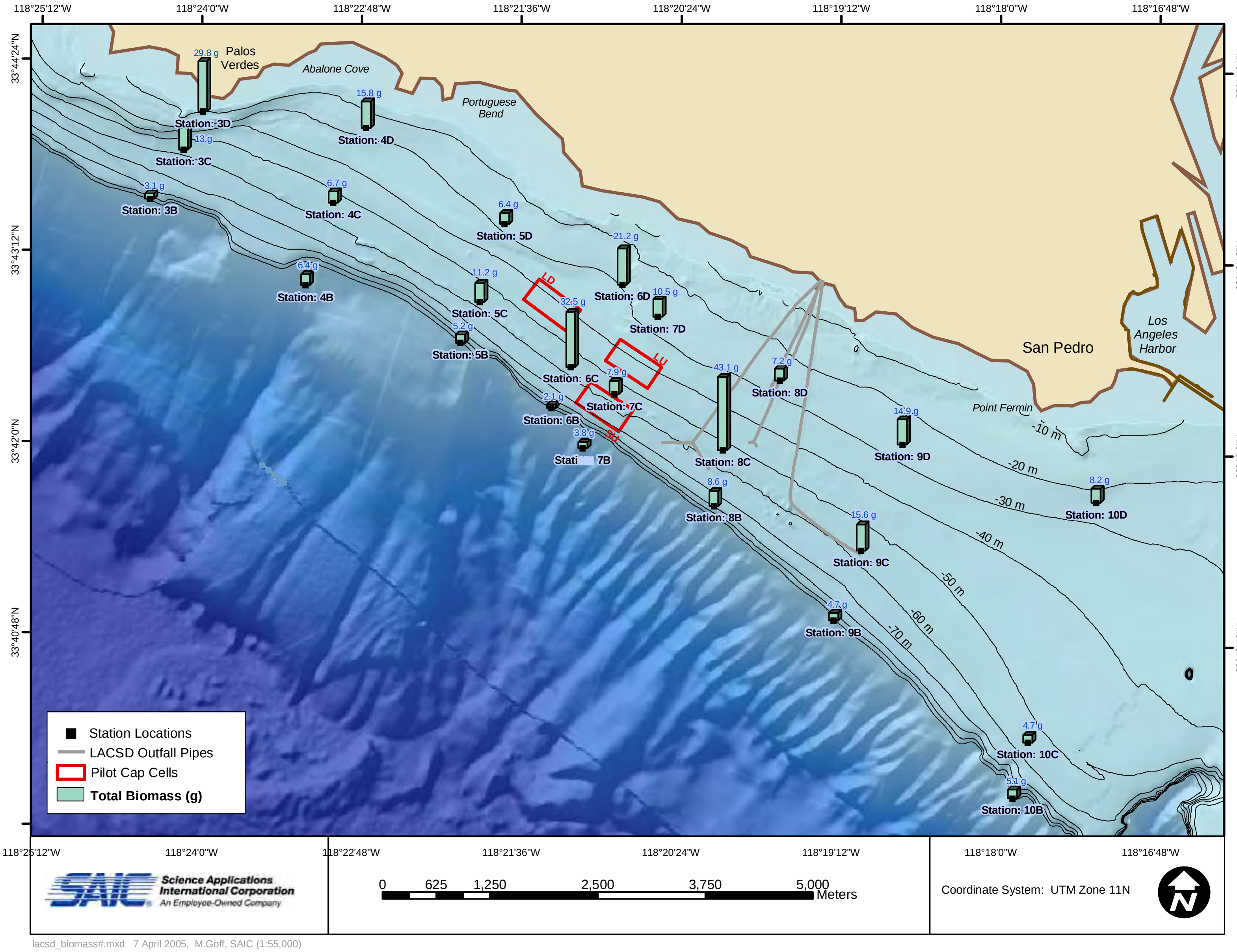


Figure 3.4-2. Total Infaunal Biomass (g) by LACSD Station, per 0.1 m^2 Core, Summer 2003.

4.0 DISCUSSION

The 2004 Bioturbation Assessment Study involved the collection, identification, and enumeration of BIO on the PV Shelf to characterize spatial patterns of potential sediment mixing due to bioturbation. A companion task measured short- and long-lived radionuclides (thorium-234 and lead-210) in a series of sediment cores to characterize biodiffusion and sedimentation rates, respectively. For these tasks, Tables 4.1-1 and 4.1-2 provide respective summaries, modified from the IWP to provide post-survey and analysis information on: (1) objectives completed in support of Question FS-7, (2) study optimization measures, and (3) how limits on decision errors were addressed for this study element. These data indicate that the IWP specifications were met or exceeded for the various elements. Results from this study were sufficient to characterize the types, abundance, and size of BIO, as well as rates of biodiffusive mixing throughout the PV Shelf area that will be considered for capping. Lead 210 data provided general information on sedimentation rates.

The movement, burrowing, tube-building, and deposit-feeding activities of organisms living in or on bottom sediments cause mixing of the seabed (Drake 1994). These activities can displace particles and any associated contaminants in vertical and horizontal directions, thereby altering sediment characteristics, such as texture, composition, and vertical structure within the sediment column. Time-averaged bioturbation typically is considered a diffusive process over a depth at which biological mixing occurs (Swift et al. 1996). Biodiffusion rates reflect the intensity of biological mixing and sedimentation rates. Mixing is most intense in upper sediment layers that are characterized by the highest abundance of infaunal organisms. Decreases in biodiffusion with depth reflect the relatively lower availability of labile organic matter in subsurface sediment layers. Clarke et al. (2001) describe this relationship as consisting of three zones: surficial bioturbation to about 10-cm below the sediment-water interface, comprising the highest mixing by infauna; mid-depth bioturbation from about 10 to 40 cm, with decreases in sediment reworking with depth; and deep bioturbation at depths below about 40 cm, as generally influenced by larger infauna such as ghost shrimp and some polychaetes.

Deep-burrowing organisms are also capable of advective transport of sediment particles between nonadjacent sediment strata or to the seafloor. An example of biologically mediated advective transport is represented by ingestion of subsurface sediment particles by head-down deposit feeders and defecation of fecal pellets at the sediment surface. This process is termed non-local mixing and generally causes unidirectional transport of particles and particle-associated contaminants. Although this process is considered potentially important, few data are available for representative species to characterize rates for advective transport of sediments caused by non-local mixing (Drake 1994).

In bottom sediments with vertical gradients in contaminant concentrations, biological mixing processes can result in a net transport of contaminants into shallower or deeper strata depending on the profile of the concentration gradient (Boudreau 1998). On the PV Shelf, peak EA concentrations occur at depths up to several tens of centimeters beneath the sediment-water interface. Consequently, advective mixing processes would tend to transport contaminants upwards, into shallower strata. The rate of this biological mixing has important implications for modeling the long-term fate of sediment contaminants, as well as predicting the effectiveness of a cap layer placed on top of existing EA sediments, specifically the key points considered by Question FS-7 in the DQO matrix table for the PV Shelf RI/FS: *Will a cap be recontaminated by EA sediment from uncapped areas (deep regions)? From beneath the cap, due to bioturbators?*

Table 4.1-1. Study Objectives and Approach for Box Coring and Infaunal Analyses.

Survey Objective	End Use of Data With Respect to Feasibility Study Qu. 7*	Survey Approach/Design Optimization	Limits on Decision Errors
To identify distribution, abundance, and size/weight of large BIO (>2mm) in the potential capping region.	The survey collected quantitative data on large BIO at 19 planned and 3 additional stations to assess occurrence and depth at each station and spatial variability (*A). Cores were subsampled at two to three 15-cm intervals, depending on overall core length to compare depth of occurrence to potential cap thickness. BIO size/abundance data were collected and analyzed from each station and a literature search was conducted on key ecological metrics including occurrence burrowing and sediment reworking rates. Radionuclide profiles in sediment were collected at planned stations to assess the likelihood that organisms could affect contaminant distribution with depth and the potential for upward migration of contaminants that could affect cap integrity and contaminant availability.	Sediment samples were collected using a deep penetrating box corer to ensure adequate sample depth (e.g., anticipated depth of occurrence of organisms). Transect and station locations were aligned with LACSD transects to allow comparisons of data. Cores were processed at 15-cm intervals to correlate results with other program data (e.g., SPI/Plan-View images and radionuclide profiles). Only deep-burrowing organisms retained on a 2-mm mesh screen were assessed to limit sample-processing time and focus on organisms with the greatest potential to substantively affect sediment mixing. A voucher collection was developed for each large BIO taxon.	Direct observations of box cores were used to confirm acceptable cores for analysis, including adequate sediment penetration, and undisturbed sediment in the corer. Within-station variability was assessed based on triplicate cores collected at each BIO station and evaluation of mean data for all key metrics. Standard summary statistics, such as mean taxa, abundance, and biomass, were utilized to evaluate spatial patterns, augmented by GIS plots. Correlation analyses and scatter plots were conducted where appropriate based on data sufficiency. More complex statistics were not warranted based on the low occurrence of BIO at most stations.

*** End Use of the Data:** To provide information pertaining to Feasibility Study Question 7: Will a cap be recontaminated by EA sediment from uncapped areas (deep regions) and/or from beneath the cap, due to bioturbators? Question FS-7 can be clarified as follows: Do deep-burrowing bioturbators occur in (A) substantial numbers and sizes/weights to (B) contribute substantially to mixing and disturbance of sediments within the potential capping area on the PV Shelf?

Table 4.1-2. Study Objectives and Approach for Sediment Dating Analyses.

Survey Objective	End Use of Data With Respect to Feasibility Study Qu. 7*	Survey Approach/Design Optimization	Limits on Decision Errors
Quantify radionuclide concentrations with depth for PV Shelf sediments to estimate the vertical mixing/ bioturbation rate potential that might be attributable to large BIO.	Profiles of thorium-234 and lead-210 in the sediment were collected to estimate the extent of vertical mixing (*B). Results were evaluated in conjunction with the large BIO data. This assisted in a comprehensive assessment of the effect of large BIO on cap stability/cap integrity, in answer to Question FS-7.	Field collections for radionuclide analysis were conducted using a gravity corer at a subset of the large BIO sampling stations: all 12 planned stations plus 1 extra for thorium-234, and all 4 planned stations for lead-210. Four of the thorium-234 stations were subjected to detailed subsampling, in accordance with the IWP. Less detailed subsampling, per the IWP, was conducted at the remaining, comparison stations. The four stations for detailed thorium-234 sampling also included single cores for lead-210, sampled to the full length of the core per the IWP.	Cores were visually assessed to determine that an undisturbed sediment profile with adequate penetration depth was collected. Station locations represented a reasonable subset of the large BIO sampling stations to include a representative range of depths, in water depths sufficient to preclude routine sediment reworking from physical processes (i.e., 55- and 70-m depth stations). The detailed thorium stations were evaluated using three replicate cores per station; duplicate cores were collected at the remaining stations. Results were used to develop vertical mixing profiles, as summarized using standard statistical summaries to compare variability. Quantitative evaluations were conducted to compare areas of relatively high and low potential bioturbation (based on the radionuclide data) with the occurrence of BIO.

*** End Use of the Data:** To provide information pertaining to Feasibility Study Question 7: Will a cap be recontaminated by EA sediment from uncapped areas (deep regions) and/or from beneath the cap, due to bioturbators? Question FS-7 can be clarified as follows: Do deep-burrowing bioturbators occur in (A) substantial numbers and sizes/weights to (B) contribute substantially to mixing and disturbance of sediments within the potential capping area on the PV Shelf?

Measurements of the vertical profiles of short-lived radionuclides, such as thorium-234 have been used to estimate biodiffusion rates on the PV Shelf (Wheatcroft and Martin 1996). Thorium-234 is strongly associated with particles, providing a tracer for sediment movement. It also decays at a constant, known rate, and the ratios between the individual elements in the decay series change with time. Consequently, vertical profiles of the ratios for specific decay elements in the sediment column, combined with information on sedimentation rates, can be used to determine rates of biodiffusion.

Based on the bioturbation assessment results presented in Section 3, the following sections address the occurrence of BIO in the PV Shelf study area, in terms of potential bioturbation (Section 4.1), and biodiffusion rates as indicators of actual mixing intensities across a depth-integrated biological community (Section 4.2).

4.1 BIOLOGICAL COMMUNITY PATTERNS

Evaluation of biological community and associated physical data from the BIO and SPI/Plan-View surveys conducted in 2004 indicated low numbers of taxa (highest means about 3 to 5/interval), low abundance (highest means about 5 to 9/interval), and low biomass (highest means about 5 to 11 g/interval), as summarized in Tables 3.1-1 through 3.1-4 and Figures 3.1-1 through 3.1-3. SPI data do, however, indicate that the biological community in the study region generally is characterized by advanced infaunal successional stages (i.e., Stage 1 on Stage III; Section 3.2) typical of productive seafloor areas receiving relatively high inputs of organic material. As a general basis for evaluation, mean abundance of BIO for interval 1 (0-15 cm) was very low (e.g., 1 to 9; Figure 3.1-2 and Table 3.1-3) compared to overall infaunal mean abundance values at comparable bottom depths for LACSD data (e.g., 260 to over 2,000; Figure 3.4-1). Consistent with the low abundance noted for the BIO community (interval 1 compared to LACSD data), mean biomass in interval 1 was also relatively low (e.g., 0.1 to 10 g; Figure 3.1-3 and Table 3.1-4) compared to LACSD values (7 to 13 g; Figure 3.4-2), as discussed in Section 4.2). The LACSD data represent collections of surface interval communities, so are most comparable to BIO sampling conducted for interval 1. Because the BIO study focused on collection of relatively large (> 2 mm diameter) errant animals, the large discrepancy in mean abundance values between this study and the LACSD data that included errant and sedentary taxa (> 1 mm diameter) underscores that surficial sediments of the PV Shelf area are dominated by small and/or sedentary invertebrates. These collective results suggest, in general, that substantial populations of large, errant invertebrates do not occur in near-surface sediments in the survey area. When vertical sediment distribution is considered, even fewer BIO occur at mid-depth (>15-30 cm) and very few occur deep (> 30 cm) in the sediment. Further, if biomass is used as an indicator of the maximum potential for sediment disturbance by a BIO "community", values for interval 3 (i.e., core depths >30 cm) were substantially lower than observed for intervals 1 and 2 (Figure 3.1-3). This is generally consistent with the overall mean values (all stations combined by interval) summarized in Figure 4.1-1. These results are consistent with findings by Clarke et al. (2001).

Within the overall pattern of low abundance and biomass for BIO species, study areas with the highest relative values occurred northwest of the outfalls, particularly along Transects 3 and 4, but also including shallow (40-m) Stations 5-40 and LD27 and LU12, the latter two occurring within the respective LD and LU capping cells. This trend was similar to the patterns noted below for biodiffusion (Section 4.2), with higher mixing intensities in the northwest part of the study area (Figure 3.3-2). These similarities would be expected if the higher mixing intensities were influenced by higher biological activity. Particularly low values for abundance and biomass were observed at the 55-m and 70-m depth stations along Transect 7 (closest northwest of the outfalls) and continuing along each transect located southeast of the outfalls.

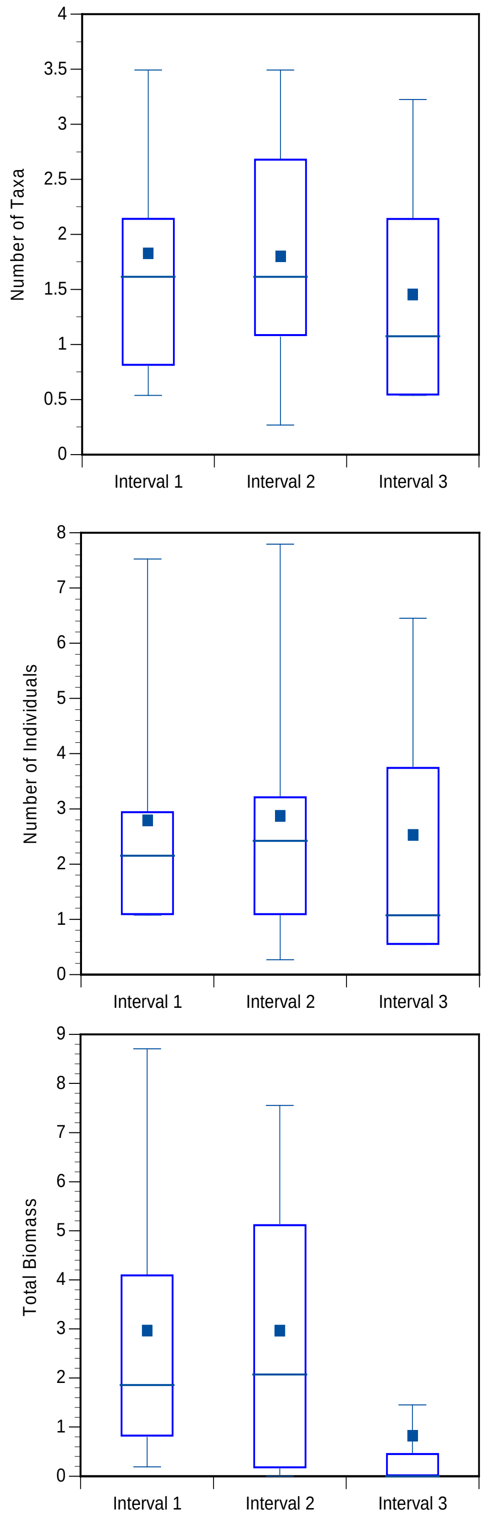


Figure 4.1-1. Box and Whisker Plot Summary of Number of Taxa (top), Abundance (middle), and Biomass (bottom) by Interval, Standardized to $0.1m^2$. The whiskers extend from the 10th percentile (bottom decile) and the top 90th percentile (top decile); the square within the box represents the mean for the data range and the line is the median.

Evaluation of 2004 data for the ghost shrimp, *Neotrypaea*, indicates a substantial influence of this species on biomass patterns. In particular, most of the highest biomass values for the BIO community were associated with this species (compare data in Figures 3.1-3 and 3.1-7 for Stations 3-40, 5-40, LD27, and LU12). Each of these stations is located at 40 m, consistent with typical limitations of this species to shallow depths (Hornig et al. 1989), although Montagne (2004, discussed below) also documented this species at 60-m depths in the study region. The strong relationship of biomass to *Neotrypaea* may serve as a useful indicator of potential bioturbation in the study region. This potential is consistent with the extensive deep (e.g., to 1 m) burrows and high sediment reworking rates observed for this species (Table A-2; Hornig et al. 1989).

Abundance of *Neotrypaea* on the PV Shelf has fluctuated over time (D. Montagne, LACSD, pers. comm.). For example, LACSD data from recent years indicated low abundance, consistent with the present study and general results from the 1970s. During the late 1980s to early 1990s, abundance was somewhat higher (e.g., 5 to 8 individuals/0.1m^2) at some sites, compared to a maximum mean abundance of about 4 individuals/0.1m^2 for the 2004 survey. This indicates the potential for higher abundance, and consequent higher bioturbation potential, but also suggests maximum near surface densities for *Neotrypaea* based on over 30 years of data. As a basis for comparison with these data from PV Shelf depths, maximum densities of *Callianassa* in optimum intertidal-to-shallow subtidal habitats (e.g., Mugu Lagoon) for this species have been documented up to 17/0.1m^2 (summarized in Ronan et al. 1981).

Stations that were typified by the highest abundance and/or biomass of *Neotrypaea californiensis* (Stations 3-40, 3-55, 4-40, 5-40, LD27, and LU12) correspond to areas of relatively high mixed sand and mud substrate, consistent with habitat preferences for this species (Hornig et al. 1989). These substrate types are as documented from Sample Collection Logs in SAIC (2004b). For example, stations with no or very low occurrences of *Neotrypaea* were mostly characterized by “green-black mud” or “dark-green mud”, while the stations with highest abundance and/or biomass ranged from “dark-green sandy mud” to “sand” (e.g., cap layers in interval 2 or near the bottom of interval 1 cores at Station LD27) to “green mud with sand and shell hash”. Similarly, based on Van Veen samples collected by LACSD since the 1970s at 30-m and 60-m stations on the PV Shelf, *Neotrypaea* is distributed in a pattern that suggests avoidance of fine sediment areas along the 60-m isobath west of the outfalls (D. Montagne, LACSD, pers. comm.).

Based on 2002 post-capping survey results (SAIC 2003), *Neotrypaea* occurred in areas with relatively thin and thick cap layers within the LD and LU capping cells (i.e., approximately 40-m depths; but not in Cell SU, approximately 70-m depths), although these were incidental, presence-absence observations that did not provide information on core depth or organism size. In several cases, *Neotrypaea* occurred at or near the interface between the bottom of the apparent cap layer and the surface of the underlying EA sediments. Thus, the presence of the test cap did not exclude burrowing activities by this species.

Other incidental BIO species from 2002 that were also collected during 2004 included the burrow-creating echiuroid worm *Listriolobus*, the free-burrowing nemertean worm *Cerebratulus*, the burrowing polychaete *Glycera*, and the seapen *Stylatula*. BIO species from 2002 that were not collected during 2004 included “bull-dozing” gastropods such as *Megasurcula*. The BIO species from 2002 and 2004 are also generally consistent with large burrowing species collected by LACSD in 1986 (Montagne 2004, LACSD, unpublished report), including *Callianassa* (now *Neotrypaea*), *Marphysa*, *Glycera*, *Nereis*, *Gymnonereis*, and *Pinnixa*. The 1986 study involved collection of 0.05 m^2 cores at four 60-m sites, three of which (3C, 6C, and 8C; Figure 2.1-1) correspond to other LACSD data summarized in Section 3.4, and that focused on sectioning and separate processing of infauna at discrete intervals (0 to 2 cm, 2 to 6 cm, 6 to 10 cm, etc. to 34 cm, then a single interval for all cores deeper than 34 cm). In general, the polychaete species were broadly distributed over the range of core intervals and stations, similar to the 2004 BIO results. In contrast, *Callianassa* was only collected from shallow core intervals (6 to 10 cm and 10 to 14 cm at Station 3C and 6 to 10 cm at Station 1C), compared to 0 to 15, >15 to 30, and >30 cm intervals for the 2004 survey. Further, the 1986 depths of occurrence were at 60 m, compared to maximal depths of 40 m in 2004. Both studies only collected this species from stations located northwest of the outfalls.

Based on LACSD data collected since the 1970s (D. Montagne, LACSD, pers. comm.), other species with bioturbation potential on the PV Shelf include the axiid shrimp, *Calocarides spinulicauda* and *C. quinqueseriatus* (e.g., described by Pemberton and Risk 1976 for a related species, *Axius serratus*). These shrimp are collected occasionally on the outer shelf and upper slope, including LACSD transects 3, 4, 6, and 9, but apparently not in sufficient abundance to represent a significant bioturbation concern. Another potential bioturbator collected in trawls at 25-m and occasionally 60-m depths, is the stomatopod *Hemisquilla ensiger*. This species is large-sized (10 to 15cm long) and reportedly burrows to depths up to about two times its body length (Basch and Engle 1989). An additional BIO species from the outer PV Shelf and upper slope is the stomatopod, *Schmittius politus*. Evaluation of 2004 length data for *Neotrypaea* (Table A-1) indicates a generally broad range in specimen size (e.g., approximately 12 to 90.6 mm at Station 5-40), suggesting a range of age classes. Data summarized in Hornig et al. (1989) indicate adult size ranges from about 50 to 115 mm and initial growth rates of approximately 15 to 30 mm/yr. Life span estimates are at least 3-5 years, corresponding to observed upper sizes of specimens from 2004. Hypothetically, at the pilot cap cells, smaller individuals could represent recruits from larval settlement after the 2000 capping experiment, while larger specimens such as the single, large (106 mm) specimen collected at Station LU12 may have survived the capping experiment or migrated from adjacent, uncapped areas. *Neotrypaea* (*Callianassa*) *californiensis* has been documented to survive burial by up to at least 30 cm of sand, but also to recolonize disturbed areas by migration from unaffected areas (summarized in Ronan et al. 1981). Further, Ogden (1994) concluded that deep-burrowing species such as ghost shrimp in San Diego Bay could compromise sediment caps up to about 1-m thick. Under these scenarios, it is possible that existing individuals could survive sand placement for a capping program, but also result in additional colonization (recruitment and/or migration) of a constructed cap at shallow- to mid-depths on the shelf (e.g., 40 to 60 m). This potential is based on the occurrence of *Neotrypaea* in uncapped, mixed sediment areas and at the test cell stations, although in generally low abundance. This species appears to be naturally limited in depth distribution, as noted above, so there should be less concern for colonization and subsequent bioturbation by *Neotrypaea* at deeper water depths. Controlling factors for depth limitations of this species are generally unknown, although predation by fish may be an important component (summarized in Hornig et al. 1989). Water temperature is unlikely to be a direct factor since the range for ghost shrimp beds off Oregon extends down to at least 9° C (Hornig et al. 1989) and bottom temperatures in the Southern California Bight are generally above this level (Hickey 1993) over the range of potential capping depths.

The other key BIO species, *Marphysa*, based on abundance across three core depth-intervals for the 2004 survey, was characterized by mean biomass that was approximately two times to one order of magnitude lower than *Neotrypaea* (compare Figures 3.1-7 and 3.1-8). *Marphysa* and other relatively common polychaetes (e.g., *Glycera*, *Nereis*, and *Gymnonereis*) are predatory to omnivorous species that contribute to bioturbation while moving through sediments, but their effect would be inconsequential compared to an actively burrowing and excavating species such as ghost shrimp. These polychaetes occurred over a broader survey-depth range than *Neotrypaea*, but the generally low biomass across the core intervals (Table A-1) and lower bioturbation potential suggests that these species would not contribute substantially to disturbance of a sediment cap. The only other BIO species that contributed a relatively high percentage of biomass over at least several stations was the echiuroid *Listriolobus* (e.g., note Station 4-70 in Table A-1). However, this species is principally limited to near-surface habitats and also should not represent a significant bioturbation potential for a sediment cap.

4.2 SEDIMENT MIXING AND BIOTURBATION RATES

Biodiffusivity values based on thorium-234 profiles from the present study ranged from 3 to 23 cm^2/yr, with an average of 13 ± 6 cm^2/yr (Section 3.3). This average value was almost a factor of three lower than the mean value of 37 ± 23 cm^2/yr measured in 1992 and 1993 at LACSD Stations 3C and 6C (Wheatcroft and Martin 1996; LACSD station locations shown in Figure 2.1-1). Santschi et al. (2001) reported values for D_b, based on thorium-234 profiles collected in 1996, of 18 cm^2/yr at LACSD Station 3C, 33 cm^2/yr at Station 5C, and from 13 to 200 cm^2/yr at Station 6C (Figure 2.1-1). Given the high degree of variability in these data sets (e.g., the average biodiffusivity rate estimated from all the thorium-234 data from 2004 was 19 ± 21 cm^2/yr versus 31 ± 20 cm^2/yr for 1992/1993), the mixing intensity on the PV Shelf measured during the present study appeared to be comparable to values measured about a decade earlier. Swift et al. (1996) estimated D_b values for the PV Shelf based on the composition and distribution of the infaunal community. However, these D_b values were expressed as "relative bioturbation activity", and could not be compared directly with those obtained from the present study. Based on excess thorium-234 values reported by Wheatcroft and Martin (1994), Sherwood et al. (1996) and Sherwood et al. (2002) used Db values of 49 cm^2/yr and 23 cm^2/yr to predict future bed sediment contaminant profiles at Stations 3C and 6C, respectively.

Results from the 2004 study, as well as those from Wheatcroft and Martin (1996), indicated that the highest mixing intensities were in the northwest portion of the study area and there was a progressive decrease toward the outfalls region. This pattern was generally consistent with spatial patterns in abundance and biomass of BIO (Section 3.1) and would be expected if the higher mixing intensities were influenced by higher biological activity. In contrast, results from Santschi et al. (2001) were not consistent with this spatial pattern, instead suggesting higher but variable biodiffusivity rates at sites closer to the outfalls. However, their study was based on a limited number of sites and values from replicate cores showed high, small-scale, spatial variability.

For the present study, excess thorium results indicated biodiffusive mixing to a depth of 6 cm. As discussed in Section 2.2, the vertical activity profile of a short-lived radionuclide (e.g., thorium-234) is controlled by a balance between bioturbation and radioactive decay. Bioturbation may occur at depths below the mixed layer, as defined by the excess thorium profiles, but this occurs at a longer time scale than represented by the half-life of thorium-234. This is consistent with the principal vertical distributions of infaunal organisms described by Wheatcroft (1994) and Stull et al. (1996), in which 40 to 60% of the infaunal organisms occurred in the upper 2-cm layer. Similarly, Santschi et al. (2001) did not detect excess thorium below a depth of 7 cm. The Santschi et al. (2001) study also used X-radiographs of cores to document the presence of burrowing fauna at depths below 10 cm, and inferred that biological mixing was minimal below the surface layer because of low abundance of deep-burrowing fauna. They also concluded that model fits of radionuclide and metal profiles in sediment cores were consistent with a maximum mixing depth of 3 cm. This conclusion is similar to average RPD depths observed from 2004 SPI images (Section 3.2), and consistent with general depth distributions of the predominant infaunal communities on the PV Shelf (LACSD data in Section 3.4). In contrast, Swift et al. (1996) concluded that "much of the bioturbation is due to the behavior of a few species that are incompletely sampled due to limited core volume", suggesting non-local mixers account for over 85% of bioturbation on the PV Shelf. By extrapolation, limited core volume would mean insufficient core depths. However, based on 2004 results the Swift et al. (1996) supposition does not appear to reflect recent conditions on the PV Shelf: relatively few BIO and little sediment mixing was evident below surface layers (e.g., below 10 to 15 cm).

Conclusions regarding the importance of non-local mixers to bioturbation rates have important implications for predictions concerning the potential for biological mixing of buried EA sediment layers into a cap layer. Based on a review of infaunal community composition on the PV Shelf, Swift et al. (1996) concluded that bioturbation could extend to depths corresponding to the peak contaminant concentrations and, thereby, result in upwards advection of contaminants into cleaner near-surface layers. In contrast, Santschi et al. (2001) concluded from the relative magnitudes of biodiffusivity and sedimentation rates obtained from core profiles of radionuclides that EA sediment layers should continue to move deeper over time. The 2004 bioturbation assessment indicates that the PV Shelf study region appears to have relatively low abundance and biomass of large bioturbators, including principal species such as ghost shrimp that represent the greatest potential source of deep-mixing bioturbation. The relatively low biodiffusion rates documented in 2004 also suggest a low potential for substantial upward mixing, consistent with a low potential for bioturbation. Realistically, the mostly likely source of disturbance would occur if actively burrowing species such as ghost shrimp selectively colonized the cap, via larval recruitment and/or migration, based on preferences for sandier habitat than presently exists in target capping areas of the PV Shelf. Present (2004) and historical (1986 and 2002) data on ghost shrimp occurrence suggest a depth range from at least 40 to 60 m in the potential capping area, but include no records of occurrence from 70-m depths. The maximum mean abundance of *Neotrypaea* in 2004 was about 4 individuals/0.1 m^2 at an uncapped station (3-40), but less than 1/0.1 m^2 at Stations LD and LU that were capped in 2000 (Figure 3.1-7). Therefore, with respect to Question FS7, and assuming the LD and LU observations are representative of likely results from other capping areas on the PV Shelf, it does not appear that bioturbators would produce substantial disruption of a cap based on predicted low abundance/biomass. This conclusion is consistent with 2004 study results indicating low sediment mixing intensities within the survey area. However, even at hypothetically low abundance and biomass, colonization by BIO of the large potential capping area would increase the occurrence of these species in the shelf region.

5.0 SUMMARY AND CONCLUSIONS

Overall conclusions from the bioturbation assessment study are that there was relatively low abundance and biomass of BIO, including principal species such as ghost shrimp that represent the greatest potential source of bioturbation. Sediment dating and biodiffusion results suggest a low potential for substantial upward mixing, consistent with the low potential for bioturbation. This should translate into low potential for cap disruption by these species. Detailed information on which these conclusions are based is presented below.

The study region was characterized by relatively few BIO taxa (40), with low abundance (e.g., mean value by phylum and core depth interval of 1 to 13 for polychaetes, but less than 4 for other phyla) and biomass (e.g., highest mean values per core interval of 5 to 11 g), per 0.1 m^2. Notwithstanding, based on SPI camera results the overall infaunal community was characterized by advanced successional stages (Stage 1 on Stage III) typical of productive seafloor areas receiving relatively high organic inputs.

The most common BIO taxa were polychaetes (20 taxa), followed by crustaceans (6), nemerteans (5), and other phyla (1 to 3 per phylum). Relatively higher abundance and biomass of BIO taxa generally occurred northwest of the LACSD outfalls region, with corresponding lower values to the southeast. The majority of BIO occurred in the top two core depth intervals (0-15 cm and >15-30 cm), with substantially fewer at deeper intervals (>30 cm).

Key species, based on frequency of occurrence and abundance across the three main core depth intervals, included the ghost shrimp *Neotrypaea californiensis* (formerly *Callianassa californiensis*) and the polychaete worm *Marphysa disjuncta*. Other relatively common BIO taxa included the polychaetes *Glycera americana*, *G. capitata*, *Gymnonereis crosslandi*, and *Nereis procera*, and the echiuroid worm *Listriolobus pelodes*.

All ghost shrimp were collected northwest of the LACSD outfalls at 40-m and 55-m depth stations and represented a substantial component of many of the highest biomass values. No ghost shrimp were observed at 70-m stations. Highest abundance and/or biomass of this species was associated with mixed mud and sand habitats, including LU and LD capping cell stations. *Marphysa* had much lower biomass, higher abundance and a broader distribution, but also predominated northwest of the outfalls.

Ghost shrimp size-data and age-data extrapolations suggest a potential combination of new recruits (smaller-sized individuals) since the 2000 capping experiment, combined with larger-sized individuals that migrated from adjacent, uncapped areas or survived the capping experiment. However, for larger-sized individuals migration may be more likely since the pre-capping substrate was comparatively fine-grained, therefore representing a less-preferred habitat type. In general, recruitment or migration of ghost shrimp onto newly capped areas may result in abundance and biomass that is similar to occurrences documented from the uncapped, relatively sandy stations in the northwest part of the study area. However, this occurrence would be over a broader area of the shelf, generally corresponding to shallow- to mid-depth (e.g., 40 to 60 m) regions of the capping area.

Natural history characteristics of ghost shrimp, including deep-burrowing depths (e.g., to 1 m) and extensive sediment reworking, suggests that biomass of this species may serve as a useful indicator of potential bioturbation in the study region. However, based on the low overall biomass and abundance of ghost shrimp and other BIO, there appears to be a low potential for substantial bioturbation of new capping areas on the PV Shelf.

Biodiffusivity values based on thorium-234 profiles, coupled with sedimentation rate data from lead-210 analyses, indicated low sediment mixing intensities (e.g., 2004 average of 19 $\pm$ 21 cm^2/yr versus 1992/93 values of 31 $\pm$ 20 cm^2/yr). Sediment accumulation rates from the lead-210 data were low (about 0.8 to 1.6 mm/yr).

Thorium results indicated biodiffusive mixing to about 6-cm sediment depths, generally consistent with historical data on the principal vertical distributions of the infaunal community.

Overall, data from the 2004 assessment indicate low sediment mixing intensities below surface layers and low biomass and abundance of BIO, particularly for key species such as ghost shrimp that have high bioturbation potential. Therefore, with respect to Question FS7, it does not appear that bioturbators have a high potential for substantial disruption of a cap in the study region, even though there would be an expanded range of occurrence for ghost shrimp and other species that prefer sandier habitats.

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APPENDICES

APPENDIX A

RESULTS SUMMARY FROM BIOTURBATING INFAUNAL ORGANISM (BIO) SURVEY AT PALOS VERDES SHELF STATIONS, JULY/AUGUST 2004

Table A-1. Summary of BIO Data, July/August 2004.

Station	Interval	Replicate	Date	Phylum	Species	Number Individuals	Length (mm)	Weight (gms)	Comments
3-40	1	1	8/1/2004	Annelida	Harmothoe lunulata	1	6.8	0.1	w/head
3-40	1	1	8/1/2004	Nemertea	Lineidae	1	28.7	0.2	
3-40	1	1	8/1/2004	Nemertea	Lineidae	2	78.5	0.3	
3-40	1	1	8/1/2004	Annelida	Marphysa disjuncta	1	66.4	0.2	w/head
3-40	1	1	8/1/2004	Annelida	Marphysa disjuncta	1	65.2	0.1	w/head
3-40	1	1	8/1/2004	Arthropoda	Neotrypaea californiensis	1	42.1	1.0	
3-40	1	1	8/1/2004	Arthropoda	Neotrypaea californiensis	1	17.4	0.1	
3-40	1	1	8/1/2004	Nemertea	Tubulanus cingulatus	1	28.5	0.2	
3-40	1	2	8/1/2004	Annelida	Glycera americana	1	74.5	1.5	w/head
3-40	1	2	8/1/2004	Annelida	Marphysa disjuncta	1	63.3	0.5	w/head
3-40	1	2	8/1/2004	Annelida	Marphysa disjuncta	1	74.9	0.5	
3-40	1	2	8/1/2004	Annelida	Marphysa disjuncta	1	27.5	0.3	w/head
3-40	1	2	8/1/2004	Annelida	Marphysa disjuncta	frag	25.3	0.2	no head
3-40	1	2	8/1/2004	Arthropoda	Neotrypaea californiensis	1	29.1	1.5	end only
3-40	1	2	8/1/2004	Arthropoda	Neotrypaea californiensis	1	28.8	1.5	
3-40	1	2	8/1/2004	Arthropoda	Neotrypaea californiensis	1	21.7	1.2	
3-40	1	2	8/1/2004	Mollusca	Sinum scopulosum	1	4.7	0.1	shell width
3-40	1	3	8/1/2004	Nemertea	Nemertea	1	34.2	0.1	Unidentifiable
3-40	1	3	8/1/2004	Arthropoda	Neotrypaea californiensis	1	71.1	6.6	
3-40	1	3	8/1/2004	Arthropoda	Neotrypaea californiensis	1	37.3	1.1	
3-40	1	3	8/1/2004	Annelida	Notomastus lineatus	1	103.2	0.2	
3-40	1	3	8/1/2004	Annelida	Sthenelais verruculosa	1	37.1	0.1	
3-40	1	3	8/1/2004	Annelida	Sthenelanella uniformis	1			missing data
3-40	2	1	8/1/2004	Annelida	Drilonereis falcata	1	39.0	0.1	w/head
3-40	2	1	8/1/2004	Annelida	Glycera capitata	1	19.1	0.1	w/head
3-40	2	1	8/1/2004	Annelida	Marphysa disjuncta	1	52.3	0.5	w/head
3-40	2	1	8/1/2004	Annelida	Marphysa disjuncta	1	39.5	0.4	w/head
3-40	2	1	8/1/2004	Annelida	Marphysa disjuncta	1	30.5	0.3	w/head
3-40	2	1	8/1/2004	Annelida	Marphysa disjuncta	frag	55.4	0.3	no head
3-40	2	1	8/1/2004	Annelida	Marphysa disjuncta	frags	57.9	0.2	frags
3-40	2	1	8/1/2004	Arthropoda	Neotrypaea californiensis	1	46.0	1.8	
3-40	2	1	8/1/2004	Arthropoda	Neotrypaea californiensis	1	25.7	0.3	tail only
3-40	2	1	8/1/2004	Annelida	Sthenelanella uniformis	1	62.3	0.2	w/head
3-40	2	2	8/1/2004	Annelida	Glycera americana	1	66.6	0.7	w/head
3-40	2	2	8/1/2004	Annelida	Marphysa disjuncta	1	39.9	0.2	w/head
3-40	2	2	8/1/2004	Annelida	Marphysa disjuncta	frags	103.8	0.2	frags no head
3-40	2	2	8/1/2004	Arthropoda	Neotrypaea californiensis	1	68.5	5.1	
3-40	2	2	8/1/2004	Arthropoda	Neotrypaea californiensis	1	20.2	2.0	head only
3-40	2	2	8/1/2004	Arthropoda	Neotrypaea californiensis	1	39.3	2.4	
3-40	2	3	8/1/2004	Annelida	Marphysa disjuncta	1	151.2	0.5	w/head
3-40	2	3	8/1/2004	Annelida	Marphysa disjuncta	frags	49.1	0.3	no head
3-40	3	1	8/1/2004	No BIO	No BIO	0	0.0	0.0	
3-40	3	2	8/1/2004	No BIO	No BIO	0	0.0	0.0	
3-40	3	3	8/1/2004	No BIO	No BIO	0	0.0	0.0	
3-40	4	1	8/1/2004	No BIO	No BIO	0	0.0	0.0	
3-55	1	1	8/1/2004	Annelida	Marphysa disjuncta	1	30.1	0.1	w/head
3-55	1	1	8/1/2004	Annelida	Marphysa disjuncta	1	34.4	0.3	w/head

Notes: No BIO = No organsims collected; Frag(s) = 1 organism

Table A-1., continued.

Station	Interval	Replicate	Date	Phylum	Species	Number Individuals	Length (mm)	Weight (gms)	Comments
3-55	1	1	8/1/2004	Annelida	Marphysa disjuncta	1	51.1	0.2	w/head
3-55	1	1	8/1/2004	Annelida	Marphysa disjuncta	frag	35.9	0.1	no head
3-55	1	1	8/1/2004	Annelida	Marphysa disjuncta	frag	57.5	0.2	no head
3-55	1	1	8/1/2004	Annelida	Marphysa disjuncta	frags	80.9	1.1	no head
3-55	1	1	8/1/2004	Sipuncula	Thysanocardia nigra	1	33.4	0.3	Dirty white
3-55	1	2	8/1/2004	Annelida	Drilonereis falcata	1	62.1	0.2	no head
3-55	1	2	8/1/2004	Annelida	Marphysa disjuncta	1	32.8	0.3	w/head
3-55	1	2	8/1/2004	Annelida	Marphysa disjuncta	frag	60.7	0.5	no head
3-55	1	2	8/1/2004	Annelida	Marphysa disjuncta	frag	13.4	0.1	no head
3-55	1	2	8/1/2004	Annelida	Marphysa disjuncta	frag	14.1	0.1	no head
3-55	1	3	8/1/2004	Annelida	Eranno lagunae	1	69.7	0.3	w/head
3-55	1	3	8/1/2004	Annelida	Marphysa disjuncta	1	52.0	0.3	w/head
3-55	1	3	8/1/2004	Annelida	Marphysa disjuncta	1	42.2	0.2	w/head
3-55	1	3	8/1/2004	Annelida	Marphysa disjuncta	1	44.8	0.3	w/head
3-55	1	3	8/1/2004	Annelida	Marphysa disjuncta	frag	48.9	0.2	no head
3-55	1	3	8/1/2004	Annelida	Marphysa disjuncta	frags	483.0	2.0	
3-55	2	1	8/1/2004	Annelida	Marphysa disjuncta	1	37.9	0.2	w/head
3-55	2	1	8/1/2004	Annelida	Marphysa disjuncta	frag	45.5	0.1	no head
3-55	2	1	8/1/2004	Annelida	Marphysa disjuncta	frag	70.7	0.2	no head
3-55	2	1	8/1/2004	Annelida	Marphysa disjuncta	frag	63.3	0.3	no head
3-55	2	1	8/1/2004	Annelida	Marphysa disjuncta	1	49.2	0.1	w/head
3-55	2	1	8/1/2004	Annelida	Marphysa disjuncta	frag	36.1	0.1	no head
3-55	2	1	8/1/2004	Arthropoda	Neotrypaea californiensis	1	17.9	0.2	
3-55	2	1	8/1/2004	Annelida	Nereis procera	1	13.9	0.1	w/head
3-55	2	1	8/1/2004	Annelida	Nereis procera	1	34.4	0.1	w/head
3-55	2	1	8/1/2004	Annelida	Nereis procera	1	24.9	0.1	w/head
3-55	2	1	8/1/2004	Annelida	Sthenelanella uniformis	1	ND	ND	small head frag
3-55	2	2	8/1/2004	Annelida	Drilonereis falcata	1	26.7	0.1	w/head
3-55	2	2	8/1/2004	Annelida	Marphysa disjuncta	1	40.0	0.5	w/head
3-55	2	2	8/1/2004	Annelida	Marphysa disjuncta	1	56.3	0.3	no head
3-55	2	2	8/1/2004	Annelida	Marphysa disjuncta	frag	10.0	0.1	no head
3-55	2	2	8/1/2004	Annelida	Marphysa disjuncta	frag	12.3	0.1	no head
3-55	2	2	8/1/2004	Annelida	Nereis procera	1	37.2	0.2	w/head
3-55	2	2	8/1/2004	Annelida	Nereis procera	1	45.8	0.5	w/head
3-55	2	2	8/1/2004	Annelida	Nereis procera	1	51.6	0.3	no head
3-55	2	2	8/1/2004	Annelida	Sthenelanella uniformis	1	18.2	0.1	w/head
3-55	2	3	8/1/2004	Annelida	Marphysa disjuncta	1	9.1	0.1	w/head
3-55	2	3	8/1/2004	Arthropoda	Neotrypaea californiensis	1	33.3	1.5	
3-55	2	3	8/1/2004	Annelida	Nereis procera	1	11.5	0.1	w/head
3-55	2	3	8/1/2004	Annelida	Nereis procera	1	12.1	0.1	w/head
3-55	2	3	8/1/2004	Annelida	Sthenelanella uniformis	1	33.5	0.1	w/head
3-55	2	3	8/1/2004	Annelida	Sthenelanella uniformis	frags	31.4	0.2	no head
3-55	2	3	8/1/2004	Annelida	Sthenelanella uniformis	frag	12.8	0.1	no head
3-55	3	1	8/1/2004	No BIO	No BIO	0	0.0	0.0	
3-55	3	2	8/1/2004	No BIO	No BIO	0	0.0	0.0	
3-55	3	3	8/1/2004	No BIO	No BIO	0	0.0	0.0	
3-70	1	1	8/1/2004	Annelida	Gymnonereis crosslandi	1	32.5	0.2	w/head

Notes: No BIO = No organsims collected; Frag(s) = 1 organism

Table A-1., continued.

Station	Interval	Replicate	Date	Phylum	Species	Number Individuals	Length (mm)	Weight (gms)	Comments
3-70	1	1	8/1/2004	Echiura	Listriolobus pelodes	1	19.5	0.2	
3-70	1	1	8/1/2004	Annelida	Marphysa disjuncta	1	38.1	0.1	w/head
3-70	1	1	8/1/2004	Annelida	Marphysa disjuncta	frag	71.3	0.2	no head
3-70	1	1	8/1/2004	Annelida	Marphysa disjuncta	frag	36.4	0.2	no head
3-70	1	1	8/1/2004	Annelida	Marphysa disjuncta	frag	28.7	0.3	no head
3-70	1	1	8/1/2004	Cnidaria	Pennatulacea	1	23.7	0.4	Fragment
3-70	1	2	8/1/2004	Cnidaria	Athenaria	1	10.3	0.1	White knob, unidentified
3-70	1	2	8/1/2004	Annelida	Gymnonereis crosslandi	1	42.6	0.2	w/head
3-70	1	2	8/1/2004	Annelida	Gymnonereis crosslandi	1	30.0	0.1	w/head
3-70	1	2	8/1/2004	Annelida	Marphysa disjuncta	1	41.7	0.7	w/head
3-70	1	2	8/1/2004	Annelida	Marphysa disjuncta	1	56.3	0.6	w/head
3-70	1	2	8/1/2004	Annelida	Marphysa disjuncta	1	73.1	0.6	w/head
3-70	1	2	8/1/2004	Annelida	Marphysa disjuncta	frags	60.9	0.4	frags
3-70	1	2	8/1/2004	Cnidaria	Stylatula elongata	1	34.4	0.1	frag
3-70	1	3	8/1/2004	Annelida	Eranno lagunae	1	37.3	0.1	
3-70	1	3	8/1/2004	Annelida	Glycinde armigera	1	40.4	0.1	w/head
3-70	1	3	8/1/2004	Annelida	Gymnonereis crosslandi	1	52.8	0.2	w/head
3-70	1	3	8/1/2004	Annelida	Gymnonereis crosslandi	1	39.6	0.2	w/head
3-70	1	3	8/1/2004	Annelida	Gymnonereis crosslandi	1	23.9	0.1	w/head
3-70	1	3	8/1/2004	Annelida	Gymnonereis crosslandi	1	83.5	0.3	w/head
3-70	1	3	8/1/2004	Annelida	Gymnonereis crosslandi	1	27.6	0.2	w/head
3-70	1	3	8/1/2004	Annelida	Marphysa disjuncta	1	40.4	0.3	w/head
3-70	1	3	8/1/2004	Annelida	Marphysa disjuncta	1	28.8	0.2	w/head
3-70	1	3	8/1/2004	Annelida	Marphysa disjuncta	1	136.0	0.4	no head
3-70	1	3	8/1/2004	Annelida	Marphysa disjuncta	frag	129.5	0.4	no head
3-70	2	1	8/1/2004	Annelida	Lumbrineridae	1	20.5	0.1	w/head
3-70	2	1	8/1/2004	Annelida	Marphysa disjuncta	1	45.7	0.3	no head
3-70	2	1	8/1/2004	Annelida	Nereis procera	1	63.7	0.1	w/head
3-70	2	2	8/1/2004	Annelida	Glycera americana	1	68.8	2.3	
3-70	2	2	8/1/2004	Annelida	Gymnonereis crosslandi	1	42.6	0.3	w/head
3-70	2	2	8/1/2004	Annelida	Gymnonereis crosslandi	frags	110.0	1.0	frags
3-70	2	2	8/1/2004	Annelida	Marphysa disjuncta	1	74.2	0.6	w/head
3-70	2	2	8/1/2004	Annelida	Marphysa disjuncta	1	23.9	0.3	w/head
3-70	2	2	8/1/2004	Annelida	Marphysa disjuncta	frags	138.0	1.7	no heads
3-70	2	2	8/1/2004	Sipuncula	Thysanocardia nigra	1	53.2	0.6	Dirty white
3-70	2	3	8/1/2004	Annelida	Gymnonereis crosslandi	1	16.3	0.1	w/head
3-70	2	3	8/1/2004	Annelida	Marphysa disjuncta	1	27.2	0.3	w/head
3-70	2	3	8/1/2004	Annelida	Marphysa disjuncta	1	76.4	0.3	
3-70	2	3	8/1/2004	Annelida	Marphysa disjuncta	frags	62.8	0.2	no head
3-70	2	3	8/1/2004	Annelida	Marphysa disjuncta	frags	51.6	0.3	no head
3-70	2	3	8/1/2004	Annelida	Marphysa disjuncta	frag	10.5	0.1	no head
3-70	3	1	8/1/2004	No BIO	No BIO	0	0.0	0.0	
3-70	3	2	8/1/2004	Annelida	Glycera americana	1	25.5	0.3	no head; branchia, parapodia
3-70	3	3	8/1/2004	No BIO	No BIO	0	0.0	0.0	no head
4-40	1	1	7/29/2004	Echiura	Listriolobus pelodes	1	25.9	7.0	
4-40	1	1	7/29/2004	Annelida	Marphysa disjuncta	1	61.0	0.2	frag w/head; in LD27 jar
4-40	1	1	7/29/2004	Annelida	Marphysa disjuncta	1	40.3	0.2	frag w/head

Notes: No BIO = No organsims collected; Frag(s) = 1 organism

Table A-1., continued.

Station	Interval	Replicate	Date	Phylum	Species	Number Individuals	Length (mm)	Weight (gms)	Comments
4-40	1	2	7/29/2004	Annelida	Glycera americana	1	40.6	0.2	frag w/head
4-40	1	2	7/29/2004	Annelida	Marphysa disjuncta	1	79.9	0.2	
4-40	1	2	7/29/2004	Annelida	Marphysa disjuncta	1	96.4	0.2	
4-40	1	2	7/29/2004	Arthropoda	Neotrypaea californiensis	1	18.7	0.1	frag
4-40	1	3	7/29/2004	Echiura	Listriolobus pelodes	1	10.4	0.2	
4-40	1	3	7/29/2004	Arthropoda	Pinnixa	1	8.5	0.1	carapace width
4-40	2	1	7/29/2004	Echiura	Listriolobus pelodes	1	34.2	8.0	
4-40	2	2	7/29/2004	Annelida	Marphysa disjuncta	1	160.0	0.2	
4-40	2	2	7/29/2004	Arthropoda	Neotrypaea californiensis	1	37.7	1.0	
4-40	2	3	7/29/2004	Annelida	Marphysa disjuncta	1	56.4	0.4	
4-40	2	3	7/29/2004	Annelida	Marphysa disjuncta	1	56.8	0.2	
4-40	2	3	7/29/2004	Annelida	Marphysa disjuncta	1	114.8	0.7	
4-40	3	1	7/29/2004	Arthropoda	Neotrypaea californiensis	1	50.3	2.7	
4-40	3	2	7/29/2004	No BIO	No BIO	0	0.0	0.0	
4-40	3	3	7/29/2004	Annelida	Marphysa disjuncta	1	23.6	0.3	no head
4-40	4	1	7/29/2004	No BIO	No BIO	0	0.0	0.0	
4-55	1	1	7/29/2004	Annelida	Marphysa disjuncta	1	48.3	0.4	frag w/head
4-55	1	1	7/29/2004	Annelida	Marphysa disjuncta	1	42.8	0.3	frag w/head
4-55	1	1	7/29/2004	Arthropoda	Neotrypaea californiensis	1	10.6	0.1	no head
4-55	1	2	7/29/2004	Annelida	Marphysa disjuncta	1	44.6	0.1	frag w/head
4-55	1	2	7/29/2004	Arthropoda	Pinnixa occidentalis	1	5.8	0.1	
4-55	1	3	7/29/2004	Annelida	Marphysa disjuncta	1	63.0	0.7	frag w/head
4-55	1	3	7/29/2004	Annelida	Marphysa disjuncta	1	74.5	0.4	frag w/head
4-55	1	3	7/29/2004	Annelida	Marphysa disjuncta	frags	338.0	1.2	frags
4-55	2	1	7/29/2004	Annelida	Marphysa disjuncta	1 + frags	250.0	1.8	frags
4-55	2	1	7/29/2004	Arthropoda	Pinnixa occidentalis	1	8.2	0.1	carapace width
4-55	2	2	7/29/2004	Annelida	Marphysa disjuncta	1	99.4	0.6	
4-55	2	3	7/29/2004	No BIO	No BIO	0	0.0	0.0	
4-55	3	1	7/29/2004	No BIO	No BIO	0	0.0	0.0	
4-55	3	2	7/29/2004	Annelida	Marphysa disjuncta	1 + frag	39.0	0.4	frags (one with head)
4-55	3	3	7/29/2004	Annelida	Marphysa disjuncta	1 + frag	122.7	0.2	no head
4-55	3	3	7/29/2004	Cnidaria	Stylatula elongata	1	32.3	0.1	frag
4-70	1	1	8/2/2004	Annelida	Gymnonereis crosslandi	1	22.7	0.3	w/head
4-70	1	1	8/2/2004	Cnidaria	Stylatula elongata	1	228.0	2.1	frag
4-70	1	2	8/2/2004	Echiura	Listriolobus pelodes	1	26.9	7.6	
4-70	1	2	8/2/2004	Echiura	Listriolobus pelodes	1	20.5	5.2	
4-70	1	2	8/2/2004	Annelida	Marphysa disjuncta	1	175.0	1.0	w/head
4-70	1	2	8/2/2004	Annelida	Marphysa disjuncta	1	27.1	0.4	w/head
4-70	1	2	8/2/2004	Annelida	Marphysa disjuncta	1	10.0	0.1	w/head
4-70	1	2	8/2/2004	Annelida	Marphysa disjuncta	1	22.1	0.2	w/head
4-70	1	2	8/2/2004	Annelida	Marphysa disjuncta	frags	204.0	1.2	frags
4-70	1	3	8/2/2004	Echiura	Listriolobus pelodes	1	8.5	0.2	
4-70	1	3	8/2/2004	Sipuncula	Thysanocardia nigra	1	67.2	1.1	
4-70	2	1	8/2/2004	Annelida	Gymnonereis crosslandi	1	30.7	0.2	w/head
4-70	2	1	8/2/2004	Annelida	Marphysa disjuncta	1	24.2	0.4	w/head
4-70	2	1	8/2/2004	Annelida	Marphysa disjuncta	1	30.9	0.4	w/head
4-70	2	1	8/2/2004	Annelida	Marphysa disjuncta	frags	264.0	1.7	no head

Notes: No BIO = No organsims collected; Frag(s) = 1 organism

Table A-1., continued.

Station	Interval	Replicate	Date	Phylum	Species	Number Individuals	Length (mm)	Weight (gms)	Comments
4-70	2	1	8/2/2004	Cnidaria	Stylatula elongata	1	217.0	2.2	frag
4-70	2	2	8/2/2004	Annelida	Gymnonereis crosslandi	1	29.6	0.3	same as previous errant
4-70	2	2	8/2/2004	Nemertea	Nemertea unidentified	1	24.3	0.1	Stripe
4-70	2	2	8/2/2004	Cnidaria	Pennatulacea	1	47.3	0.3	Base only, dirty yellow
4-70	2	3	8/2/2004	Annelida	Gymnonereis crosslandi	1	60.8	0.2	w/head
4-70	2	3	8/2/2004	Annelida	Gymnonereis crosslandi	1	53.8	0.2	w/head
4-70	2	3	8/2/2004	Annelida	Gymnonereis crosslandi	frag	11.9	0.1	no head
4-70	2	3	8/2/2004	Annelida	Marphysa disjuncta	1	29.1	0.3	w/head
4-70	2	3	8/2/2004	Annelida	Marphysa disjuncta	frags	174.0	1.9	frags
4-70	3	1	8/2/2004	No BIO	No BIO	0	0.0	0.0	
4-70	3	2	8/2/2004	No BIO	No BIO	0	0.0	0.0	
4-70	3	3	8/2/2004	No BIO	No BIO	0	0.0	0.0	
5-40	1	1	7/27/2004	Arthropoda	Pinnixa occidentalis	1	7.1	0.1	
5-40	1	2	7/27/2004	Arthropoda	Neotrypaea californiensis	1	12.1	0.1	
5-40	1	3	7/27/2004	No BIO	No BIO	0	0.0	0.0	
5-40	2	1	7/27/2004	No BIO	No BIO	0	0.0	0.0	
5-40	2	2	7/27/2004	Arthropoda	Neotrypaea californiensis	1	25.1	0.3	
5-40	2	3	7/27/2004	No BIO	No BIO	0	0.0	0.0	
5-40	3	1	7/27/2004	Arthropoda	Neotrypaea californiensis	1	90.6	13.4	Carapace length
5-40	3	1	7/27/2004	Mollusca	Sinum scopulosum	1	21.5	5.5	Shell width
5-40	3	2	7/27/2004	No BIO	No BIO	0	0.0	0.0	
5-40	3	3	7/27/2004	Arthropoda	Pinnixa occidentalis	1	8.5	0.1	carapace width
5-55	1	1	7/27/2004	Cnidaria	Stylatula elongata	frag	92.5	0.7	Combined with other intervals
5-55	1	1	7/27/2004	Echiura	Listriolobus pelodes	1	24.4	4.0	
5-55	1	2	7/27/2004	Nemertea	Tubulanus polymorphus	1	30.2	0.1	
5-55	1	3	7/27/2004	Echiura	Listriolobus pelodes	1	11.5	0.4	
5-55	2	1	7/27/2004	Cnidaria	Stylatula elongata	1	102.0	0.9	Combined with other intervals
5-55	2	2	7/27/2004	No BIO	No BIO	0	0.0	0.0	
5-55	2	3	7/27/2004	No BIO	No BIO	0	0.0	0.0	
5-55	3	1	7/27/2004	Cnidaria	Stylatula elongata	frag	90.3	1.4	Combined with other intervals
5-55	3	2	7/27/2004	No BIO	No BIO	0	0.0	0.0	
5-55	3	3	7/27/2004	No BIO	No BIO	0	0.0	0.0	
5-70	1	1	7/27/2004	Nemertea	Cerebratulus californiensis	1	183.0	6.9	large purple-combined, 5 fragments
5-70	1	1	7/27/2004	Nemertea	Nemertea unidentified	1	109.0	0.3	Skinny red
5-70	1	2	7/27/2004	Annelida	Arctonoe pulchra	1	24.7	0.1	
5-70	1	2	7/27/2004	Annelida	Glycera americana	1	24.5	0.1	
5-70	1	2	7/27/2004	Annelida	Glycera capitata	1	20.0	0.1	
5-70	1	2	7/27/2004	Annelida	Glycera capitata	1	18.3	0.1	
5-70	1	2	7/27/2004	Echiura	Listriolobus pelodes	1	13.7	1.0	
5-70	1	3	7/27/2004	No BIO	No BIO	0	0.0	0.0	
5-70	2	1	7/27/2004	Nemertea	Cerebratulus californiensis	1	24.8	0.2	large purple-combined, 2 fragments
5-70	2	2	7/27/2004	Annelida	Nereis procera	1	125.0	0.3	
5-70	2	3	7/27/2004	Annelida	Glycera americana	1	210.0	10.0	
5-70	2	3	7/27/2004	Arthropoda	Pinnixa occidentalis	1	7.1	0.1	
5-70	2	3	7/27/2004	Arthropoda	Pinnixa occidentalis	1	8.1	0.1	
5-70	3	1	7/27/2004	Nemertea	Cerebratulus californiensis	1	10.3	0.1	large purple
5-70	3	2	7/27/2004	No BIO	No BIO	0	0.0	0.0	

Notes: No BIO = No organsims collected; Frag(s) = 1 organism

Table A-1., continued.

Station	Interval	Replicate	Date	Phylum	Species	Number Individuals	Length (mm)	Weight (gms)	Comments
5-70	3	3	7/27/2004	No BIO	No BIO	0	0.0	0.0	
LD27	1	1	7/29/2004	Echiura	Listriolobus pelodes	1	10.2	0.2	
LD27	1	1	7/29/2004	Echiura	Listriolobus pelodes	1	14.9	1.0	
LD27	1	2	7/29/2004	Echiura	Listriolobus pelodes	1	12.5	1.3	
LD27	1	2	7/29/2004	Arthropoda	Neotrypaea californiensis	1	23.9	0.7	
LD27	1	3	7/29/2004	No BIO	No BIO	0	0.0	0.0	
LD27	2	1	7/29/2004	No BIO	No BIO	0	0.0	0.0	
LD27	2	2	7/29/2004	Annelida	Marphysa disjuncta	2			missing data
LD27	2	2	7/29/2004	Annelida	Nereis procera	1	111.0	0.1	
LD27	2	3	7/29/2004	Annelida	Marphysa disjuncta	1	172.0	0.2	Long - in rep 2 jar
LD27	2	3	7/29/2004	Arthropoda	Neotrypaea californiensis	1	86.2	12.2	
LD27	3	1	7/29/2004	No BIO	No BIO	0	0.0	0.0	
LD27	3	2	7/29/2004	No BIO	No BIO	0	0.0	0.0	
LD27	3	3	7/29/2004	No BIO	No BIO	0	0.0	0.0	
LU12	1	1	7/28/2004	Annelida	Goniada brunnea	1	13.1	0.1	fragment w/o head
LU12	1	2	7/28/2004	Annelida	Glycera americana	1	43.0	0.1	
LU12	1	2	7/28/2004	Annelida	Glycera capitata	1	27.0	0.1	
LU12	1	2	7/28/2004	Annelida	Lumbrineris limicola	1	34.0	0.1	
LU12	1	3	7/28/2004	No BIO	No BIO	0	0.0	0.0	
LU12	1	4	7/28/2004	Annelida	Eranno lagunae	1	34.0	0.1	
LU12	1	4	7/28/2004	Annelida	Lumbrineris sp.	1	35.0	0.1	
LU12	2	1	7/28/2004	Annelida	Glycera americana	1	250.0	4.9	
LU12	2	1	7/28/2004	Annelida	Polychaete - errant	1	44.1	0.1	
LU12	2	2	7/28/2004	No BIO	No BIO	0	0.0	0.0	
LU12	2	3	7/28/2004	Arthropoda	Neotrypaea californiensis	1	106.0	15.0	
LU12	2	3	7/28/2004	Arthropoda	Pinnixa	1	10.4	0.1	carapace width
LU12	2	4	7/28/2004	No BIO	No BIO	0	0.0	0.0	
LU12	3	2	7/28/2004	No BIO	No BIO	0	0.0	0.0	
LU12	3	3	7/28/2004	No BIO	No BIO	0	0.0	0.0	
LU12	3	4	7/28/2004	No BIO	No BIO	0	0.0	0.0	
7-55	1	1	7/28/2004	Annelida	Glycera americana	1	75.3	1.2	
7-55	1	1	7/28/2004	Annelida	Glycera americana	1	54.5	0.6	
7-55	1	2	7/28/2004	No BIO	No BIO	0	0.0	0.0	
7-55	1	3	7/28/2004	Echiura	Listriolobus pelodes	1	9.0	0.2	
7-55	2	1	7/28/2004	No BIO	No BIO	0	0.0	0.0	
7-55	2	2	7/28/2004	No BIO	No BIO	0	0.0	0.0	
7-55	2	3	7/28/2004	No BIO	No BIO	0	0.0	0.0	
7-55	3	1	7/28/2004	No BIO	No BIO	0	0.0	0.0	
7-55	3	2	7/28/2004	No BIO	No BIO	0	0.0	0.0	
7-55	3	3	7/28/2004	No BIO	No BIO	0	0.0	0.0	
SU22	1	1	7/28/2004	Annelida	Goniada brunnea	1	44.2	0.1	
SU22	1	1	7/28/2004	Annelida	Nereis procera	1	48.6	0.1	
SU22	1	2	7/28/2004	Annelida	Nereis procera	1	29.4	0.1	
SU22	1	2	7/28/2004	Arthropoda	Schmittius politus	1	ND	ND	head only
SU22	1	3	7/28/2004	No BIO	No BIO	0	0.0	0.0	
SU22	2	1	7/28/2004	No BIO	No BIO	0	0.0	0.0	
SU22	2	2	7/28/2004	No BIO	No BIO	0	0.0	0.0	

Notes: No BIO = No organsims collected; Frag(s) = 1 organism

Table A-1., continued.

Station	Interval	Replicate	Date	Phylum	Species	Number Individuals	Length (mm)	Weight (gms)	Comments
SU22	2	3	7/28/2004	Annelida	Nereis procera	1	172.0	0.3	
SU22	3	1	7/28/2004	No BIO	No BIO	0	0.0	0.0	
SU22	3	2	7/28/2004	No BIO	No BIO	0	0.0	0.0	
SU22	3	3	7/28/2004	No BIO	No BIO	0	0.0	0.0	
SU22	4	1	7/28/2004	No BIO	No BIO	0	0.0	0.0	
SU22	4	3	7/28/2004	No BIO	No BIO	0	0.0	0.0	
9-40	1	1	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-40	1	2	7/30/2004	Annelida	Nereis procera	1	48.2	0.2	
9-40	1	3	7/30/2004	Annelida	Glycera americana	1	28.0	0.5	smaller
9-40	2	1	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-40	2	2	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-40	2	3	7/30/2004	Annelida	Glycera americana	1	45.0	1.2	thick one
9-40	3	1	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-40	3	2	7/30/2004	Mollusca	Sinum scopulosum	1	11.3	1.5	shell width
9-40	3	3	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-55	1	1	7/30/2004	Annelida	Marphysa disjuncta	1	32.2	0.3	frag w/head
9-55	1	1	7/30/2004	Annelida	Marphysa disjuncta	frag	39.9	0.3	no head
9-55	1	2	7/30/2004	Annelida	Marphysa disjuncta	1	99.8	0.5	frag w/head
9-55	1	2	7/30/2004	Annelida	Marphysa disjuncta	frag	73.4	0.2	no head
9-55	1	2	7/30/2004	Annelida	Nereis procera	1	88.6	0.4	
9-55	1	3	7/30/2004	Echiura	Listriolobus pelodes	1	9.9	0.1	
9-55	2	1	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-55	2	2	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-55	2	3	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-55	3	1	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-55	3	2	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-55	3	3	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-70	1	1	7/30/2004	Annelida	Marphysa disjuncta	1	37.9	0.3	frag w/head
9-70	1	1	7/30/2004	Arthropoda	Pinnixa occidentalis	1	7.6	0.1	
9-70	1	1	7/30/2004	Arthropoda	Pinnixa occidentalis	1	7.2	0.1	
9-70	1	2	7/30/2004	Echiura	Listriolobus pelodes	1	12.8	1.4	
9-70	1	2	7/30/2004	Annelida	Marphysa disjuncta	1	48.0	0.2	frag w/head
9-70	1	2	7/30/2004	Annelida	Marphysa disjuncta	frags	210.0	0.6	no head
9-70	1	2	7/30/2004	Annelida	Marphysa disjuncta	1	40.0	0.2	frag w/head
9-70	1	3	7/30/2004	Annelida	Marphysa disjuncta	1	44.7	0.2	frag w/head
9-70	1	3	7/30/2004	Annelida	Marphysa disjuncta	1	30.1	0.2	frag w/head
9-70	1	3	7/30/2004	Annelida	Marphysa disjuncta	1	37.7	0.2	frag w/head
9-70	1	3	7/30/2004	Annelida	Marphysa disjuncta	1	19.8	0.1	frag w/head
9-70	1	3	7/30/2004	Annelida	Marphysa disjuncta	1	22.3	0.1	frag w/head
9-70	1	3	7/30/2004	Annelida	Marphysa disjuncta	frag	39.7	0.1	no head
9-70	1	3	7/30/2004	Arthropoda	Shrimp - unidentified	1	9.7	0.1	
9-70	2	1	7/30/2004	Annelida	Marphysa disjuncta	1	69.7	0.2	frag w/head
9-70	2	2	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-70	2	3	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-70	3	1	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-70	3	2	7/30/2004	No BIO	No BIO	0	0.0	0.0	
9-70	3	3	7/30/2004	No BIO	No BIO	0	0.0	0.0	

Notes: No BIO = No organsims collected; Frag(s) = 1 organism

Table A-1., continued.

Station	Interval	Replicate	Date	Phylum	Species	Number Individuals	Length (mm)	Weight (gms)	Comments
10-40	1	1	7/31/2004	Annelida	Marphysa disjuncta	1	68.5	0.2	w/head
10-40	1	1	7/31/2004	Annelida	Marphysa disjuncta	frag	113.3	0.4	no head
10-40	1	2	8/2/2004	Annelida	Glycera americana	1	95.5	7.5	no head
10-40	1	2	8/2/2004	Annelida	Polychaete - Nereid	1	36.0	0.2	w/head; counted
10-40	1	2	8/2/2004	Arthropoda	Sicyonia ingentis	1	61.2	3.4	carapace length
10-40	1	3	8/2/2004	Mollusca	Gari furcata	1	35.3	2.9	
10-40	1	3	8/2/2004	Annelida	Polychaete - errant	frags	34.9	0.2	frags; counted
10-40	2	1	7/31/2004	No BIO	No BIO	0	0.0	0.0	
10-40	2	2	8/2/2004	Annelida	Glycera americana	1 + frag	102.9	5.2	frags
10-40	2	3	8/2/2004	No BIO	No BIO	0	0.0	0.0	
10-40	3	1	7/31/2004	No BIO	No BIO	0	0.0	0.0	
10-40	3	2	8/2/2004	No BIO	No BIO	0	0.0	0.0	
10-40	3	3	8/2/2004	No BIO	No BIO	0	0.0	0.0	
9.5-55	1	1	7/31/2004	Annelida	Drilonereis falcata	1	154.0	0.2	no head
9.5-55	1	1	7/31/2004	Annelida	Nephtys sp.	1	88.1	1.2	no head
9.5-55	1	2	7/31/2004	Sipuncula	Thysanocardia nigra	1	52.7	2.2	Dirty white
9.5-55	1	3	7/31/2004	No BIO	No BIO	0	0.0	0.0	
9.5-55	2	2	7/31/2004	No BIO	No BIO	0	0.0	0.0	
9.5-55	2	3	7/31/2004	No BIO	No BIO	0	0.0	0.0	
9.5-70	1	1	7/31/2004	Cnidaria	Athenaria	1	22.4	0.3	White knob
9.5-70	1	1	7/31/2004	Echinodermata	Chirodota sp.	1	30.5	0.3	Red knob
9.5-70	1	1	7/31/2004	Echinodermata	Chirodota sp.	1	39.2	1.1	Red knob
9.5-70	1	1	7/31/2004	Echinodermata	Henricia	1	20.5	0.2	
9.5-70	1	2	7/31/2004	No BIO	No BIO	0	0.0	0.0	no interval 2 or 3
9.5-70	1	3	8/2/2004	Nemertea	Nemertea unidentified	1	48.3	0.2	Tan
9.5-70	2	1	7/31/2004	Sipuncula	Thysanocardia nigra	1	77.1	0.3	Dirty white
10-70	1	1	7/31/2004	Annelida	Marphysa disjuncta	1	39.3	0.2	frag w/head
10-70	1	1	7/31/2004	Annelida	Polychaete - errant	frag	29.9	0.1	no head
10-70	1	1	7/31/2004	Annelida	Polychaete - errant	1	59.5	0.2	frag w/head; counted
10-70	1	2	7/31/2004	Annelida	Marphysa disjuncta	1	85.6	0.3	frag w/head; same as red spot poly
10-70	1	2	7/31/2004	Annelida	Marphysa disjuncta	1	71.8	0.2	frag w/head; same as red spot poly
10-70	1	2	7/31/2004	Annelida	Marphysa disjuncta	1	54.0	0.1	frag w/head; same as red spot poly
10-70	1	3	7/31/2004	Annelida	Goniada brunnea	1	33.0	0.1	frag w/head
10-70	2	1	7/31/2004	Sipuncula	Thysanocardia nigra	1	74.6	1.0	Dirty white
10-70	2	2	7/31/2004	Annelida	Marphysa disjuncta	1	135.0	0.4	whole worm
10-70	2	2	7/31/2004	Annelida	Marphysa disjuncta	2	56.4	0.3	frag w/head
10-70	2	3	7/31/2004	Cnidaria	Stylatula elongata	1	113.8	0.4	frag
10-70	2	3	7/31/2004	Sipuncula	Thysanocardia nigra	1	96.5	4.5	Dirty white

Notes: No BIO = No organsims collected; Frag(s) = 1 organism

Table A-2. Summary of Bioturbation Literature Search Results.

Phyla/Class	Taxonomic Category	Reworking Rate	Burrowing Rate	Max Feeding Rate	Burrow Depth	Reference	Comment
Gastropod	*Amphibola crenata*			25 mg/mg bw		Juniper (1981)	Table 1; Lopez and Levinton (1987)
Polychaete	Arctonoe pulchra						
Polychaete	*Arenicola claparedi*			25 mg/mg bw		Hobson (1967)	Table 1; Lopez and Levinton (1987)
Polychaete	*Arenicola gouldii*			21 mg/mg bw		Gordon (1966)	Table 1; Lopez and Levinton (1987)
Polychaete	*Arenicola marina*			5.1 mg/mg bw		Jacobsen (1967)	Table 1; Lopez and Levinton (1987)
Cnidaria	Athenaria						
Polychaete	*Axiothella rubrocincta*			10-30 mg/mg bw		Kudenov (1982)	Table 1; Lopez and Levinton (1987)
Polychaete	*Axiothella rubrocincta*	5 g dry sed/d (adult 1gm worm)				Kudenow (1982)	Tomales Bay
Echinodermata	*Brissopsis lyrifera*	22 ml sediment/h at 13C				Hollertz and Duchene (2001)	
Echinodermata	*Brissopsis lyrifera*	14 ml sediment/h at 7C				Hollertz and Duchene (2001)	
Crustacean	*Callianassa* (Large Mounds - Aug 1981)	417-690 cc/d				Suchanek and Colin (1986)	Production rate = reworking rate?
Crustacean	*Callianassa* (Large Mounds - Jun 1982)	332 cc/d				Suchanek and Colin (1986)	Production rate = reworking rate?
Crustacean	*Callianassa* (Large Mounds- May 1981)	344-387 cc/d			1-2 m	Suchanek and Colin (1986)	Production rate = reworking rate?
Crustacean	*Callianassa* (Small Mounds)	4 cc/day				Suchanek and Colin (1986)	Production rate = reworking rate?
Crustacean	*Callianassa californiensis*	20-50 cc/day			20 in (51 cm)	MacGinitie and MacGinitie (1968)	
Crustacean	Callianassa filholi	96 kg (dry)/m2/yr				Berkenbusch and Rowden (1999)	Annual turnover rate - New Zealand
Crustacean	*Callianassa subterranea*				86 cm	Nickell and Atkinson (1995)	west coast of Scotland
Polychaete	*Capitella capitata*			8-10 mg/mg bw		T. Forbes (1984)	Table 1; Lopez and Levinton (1987)
Polychaete	*Capitella capitata*	200 g/m2/d		100 mg/d	5-15 cm	Forbes and Lopez (1990)	Table 1 in Shull et al. (1998)
Nemertea	Cerebratulus californiensis						
Crustacean	*Chasmagnathus granulata*	2234.6 g/m2/d				Botto, F. and O. Iribarne (2000)	Atlantic Coast mud flats
Holothuroidea	Chirodota sp.						
Polychaete	*Clymenella torquata*	274 ml/yr				Rhoads (1963)	Table 1; Rhoads (1974)
Polychaete	*Clymenella torquata*	246 ml/yr				Mangum (1964)	Table 1; Rhoads (1974)
Polychaete	*Clymenella torquata*	96 ml/yr				Mangum (1964)	Table 1; Rhoads (1974)
Polychaete	*Clymenella torquata*	300-2400 g/m^2/d		4000 mg/d	5-30 cm	Rhoads (1967); Fuller (1994)	Table 1 in Shull et al. (1998)
Polychaete	Drilonereis falcata						
Crustacean	*Enteropneusts (Large Mounds)*	55-432 cc/day				Suchanek and Colin (1986)	Production rate = reworking rate?
Crustacean	*Enteropneusts (Small Mounds)*	11 cc/day				Suchanek and Colin (1986)	Production rate = reworking rate?
Polychaete	Eranno lagunae						
Bivalvia	Gari furcata						
Polychaete	Glycera americana						
Polychaete	Glycera capitata						
Polychaete	Glycinde armigera						
Polychaete	Goniada brunnea						
Polychaete	Gymnonereis crosslandi						
Polychaete	Harmothoe lunulata						
Echinodermata	Henricia						
Polychaete	*Heteromastus filiformis*	8-400 g/m^2/d		80 mg/d	10-30 cm	Schafer (1972); Cadee (1979)	Table 1 in Shull et al. (1998)
Polychaete	*Heteromastus filiformis*	175 ml/m2/day				Neira and Hoepner (1993)	NE Atlantic
Holothurian	*Holothuria tubulosa*			0.049-0.489 g dw sed/h		Coulon and Jangoux (1993)	Italy (Med)
Arthropod	*Hyalella azteca*			1.3 mg/mg bw		Hargrave (1972)	Table 1; Lopez and Levinton (1987)
Gastropod	*Hydrobia neglecta*			2.9 mg/mg bw		Hylleberg (1975)	Table 1; Lopez and Levinton (1987)
Gastropod	*Hydrobia ventrosa*			4.3 mg/mg bw		Hylleberg (1975)	Table 1; Lopez and Levinton (1987)
Gastropod	*Ilyanassa obsoleta*			0.4 mg/mg bw		Connor & Edgar (1982)	Table 1; Lopez and Levinton (1987)
Arthropod	*Ilyoplax pusilla*			5.7 mg/mg bw		Ono (1965)	Table 1; Lopez and Levinton (1987)
Crustacean	*Jaxea nocturna*				92 cm	Nickell and Atkinson (1995)	west coast of Scotland
Polychaete	*Leitoscoloplos robustus*	40-600 g/m2/d		200 mg/d	4-8 cm	Rice (1986)	Table 1 in Shull et al. (1998)
Holothurian	*Leptosynapta tenuis*	19.5 cc/day				Myers (1977)	range: 11.3 to 30.6 cc/animal/day
Nemertea	Lineidae						
Echiura	Listriolobus pelodes						
Polychaete	Lumbrineridae						
Polychaete	Lumbrineris limicola						
Polychaete	Lumbrineris sp.						

Note: Red text indicates taxa collected in July/August 2004 surveys.

Table A-2., continued.

Phyla/Class	Taxonomic Category	Reworking Rate	Burrowing Rate	Max Feeding Rate	Burrow Depth	Reference	Comment
Bivalve	*Macoma balthica*			9 mg/mg bw		Kofoed unpubl.	Table 1; Lopez and Levinton (1987)
Bivalve	*Macoma balthica*	2-20 g/m2/d		20 mg/d	4-6 cm	Reise (1983)	Table 1 in Shull et al. (1998)
Bivalve	*Macoma nasuta*			1-2 mg/mg bw		Hylleburg & Gallucci (1975)	Table 1; Lopez and Levinton (1987)
Polychaete	Marphysa disjuncta						
Nemertea	Nemertea						
Nemertea	Nemertea unidentified						
Crustacea	Neotrypaea californiensis						
Crustacea	Neotrypaea sp.						
Polychaete	Nephtys sp.						
Polychaete	Nereis procera						
Polychaete	Nereis procera						
Polychaete	*Nereis succinea*			3.5 mg/mg bw		Cammen (1980a)	Table 1; Lopez and Levinton (1987)
Polychaete	Notomastus lineatus						
Bivalve	*Nucula annulata*			2-5 mg/mg bw		Cheng (1983)	Table 1; Lopez and Levinton (1987)
Bivalve	*Nucula annulata*	365 ml/yr				Young (1971)	Table 1; Rhoads (1974)
Crustacea	*Oxyurostylis smithi*		0.125 cc/day			Myers (1977)	Table 4; Myers (1977)
Crustacea	*Paraphoxus spinosus*		5.4 cc/dy			Myers (1977)	Table 4; Myers (1977)
Polychaete	*Pectinaria gouldii*	400 ml/yr				Gordon (1966)	Table 1; Rhoads (1974)
Cnidaria	Pennatulacea						
Crustacea	Pinnixa						
Crustacea	Pinnixa occidentalis						
Polychaete	Polychaete - errant						
Polychaete	Polychaete - Nereid						
Gastropod	*Potamopyrgus jenkensi*			5.9 mg/mg bw		Heywood & Edwards (1962)	Table 1; Lopez and Levinton (1987)
Polychaete	*Praxillella pacifica*	164.5-636.51 mg wet/animal/d				Harkantra, Yun, and Kikuchi (1989)	lab work - Japan
Polychaete	*Praxillella pacifica*	84.3 kg. wet/m2 = Annual				Harkantra, Yun, and Kikuchi (1989)	lab work - Japan
Polychaete	*Praxillella pacifica*	164.5-636.51 mg wet/indiv/d				Harkantra, Yun, and Kikuchi (1989)	Japan
Crustacea	Schmittius politus						
Polychaete	*Scoloplos armiger*	40-600 g/m2/d		200 mg/d	4-8 cm	Rice (1986)	Table 1 in Shull et al. (1998)
Polychaete	*Scoloplos robustus*	0.06 cc/day	0.31 cc/day			Myers (1977)	Table 4; Myers (1977)
Polychaete	*Scoloplus sp.*			45-120 mg/mg bw		D. Rice unpubl.	Table 1; Lopez and Levinton (1987)
Arthropod	*Scopimera globosa*			0.8 mg/mg bw		Ono (1965)	Table 1; Lopez and Levinton (1987)
Crustacea	Shrimp - unidentified						
Crustacea	Sicyonia ingentis						
Mollusca	Sinum scopulosum						
Polychaete	Sthenelais verruculosa						
Polychaete	Sthenelanella uniformis						
Cnidaria	Stylatula elongata						
Bivalve	*Tellina agilis*				4-6 cm	Aller and Yingst (1985)	Table 1 in Shull et al. (1998)
Sipuncula	Thysanocardia nigra						
Polychaete	*Tubifex tubifex*			1.6 mg/mg bw		Ivlev (1939)	Table 1; Lopez and Levinton (1987)
Nemertea	Tubulanus cingulatus						
Nemertea	Tubulanus polymorphus						
Crustacean	*Uca uruguayensis*	678.9 g/m2/d				Botto, F. and O. Iribarne (2000)	Atlantic Coast mud flats
Crustacean	*Upogebia stellata*				26.5 cm	Nickell and Atkinson (1995)	west coast of Scotland
Echiura	*Urechis caupo*		266 + 158 ml/min			Osovitz and Julian (2002)	Burrowing irrigation rate
Bivalve	*Yoldia limatula*			10-20 mg/mg bw		Bender & Davis (1984)	Table 1; Lopez and Levinton (1987)
Bivalve	*Yoldia limatula*	257 ml/yr				Rhoads (1963)	Table 1; Rhoads (1974)
Bivalve	*Yoldia limatula*	6-38 g/m2/d		280 mg/d	2-4 cm	Rhodes (1963); Bender & Davis (1984)	Table 1 in Shull et al. (1998)

Note: Red text indicates taxa collected in July/August 2004 surveys.

APPENDIX B

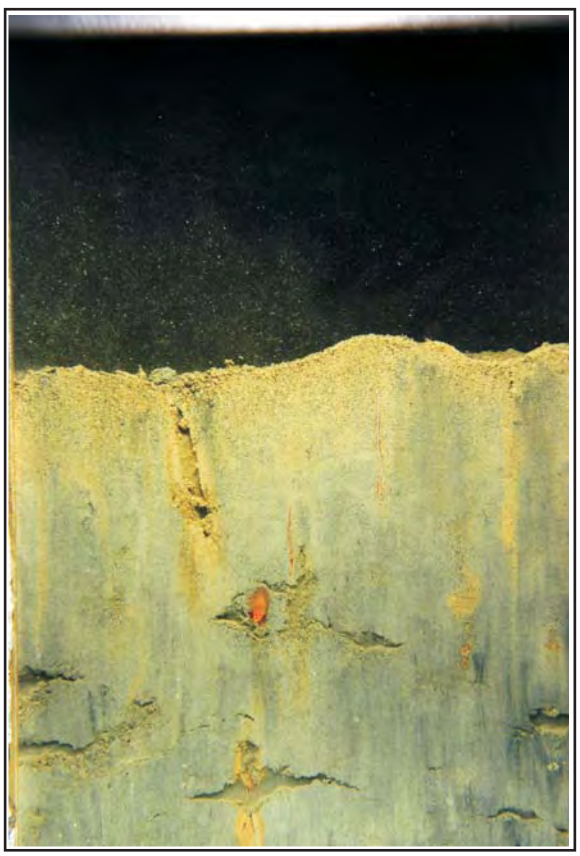
RESULTS SUMMARY AND PHOTOGRAPHS FROM SEDIMENT-PROFILE IMAGERY (SPI) AND PLAN-VIEW CAMERA SURVEY AT PALOS VERDES SHELF STATIONS, JULY 2004

FIGURE B-1

PHOTOGRAPHS FROM
SEDIMENT-PROFILE IMAGERY (SPI)
AND PLAN-VIEW CAMERA,
JULY 2004

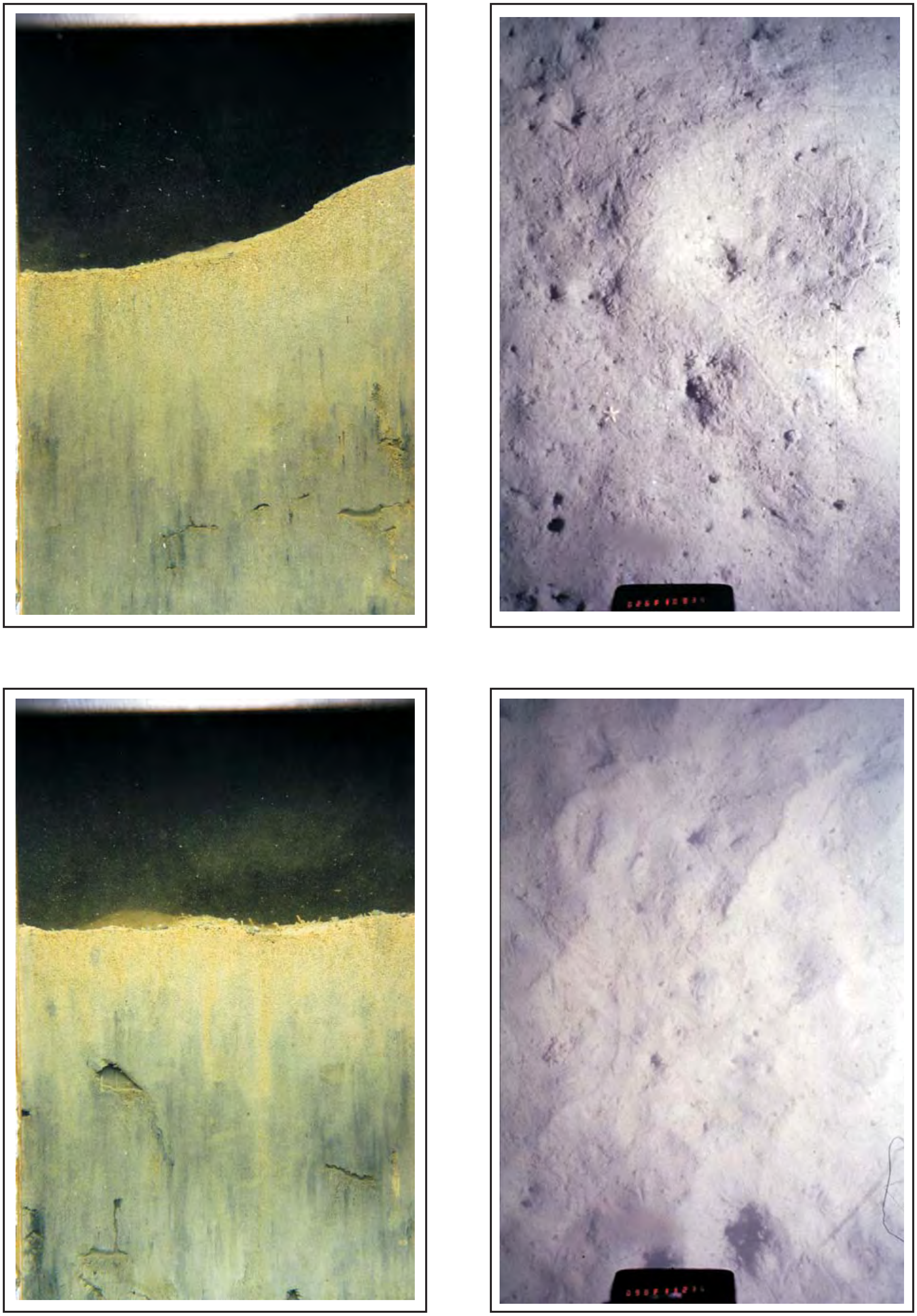
(SPI viewing area is 20 cm high x 14 cm wide;
plan-view area is approximately 0.3 m^2)

Figure B-1. Photographs from Sediment-Profile Imagery (SPI) and Plan-View Camera Survey at Palos Verdes Shelf Stations, July 2004.



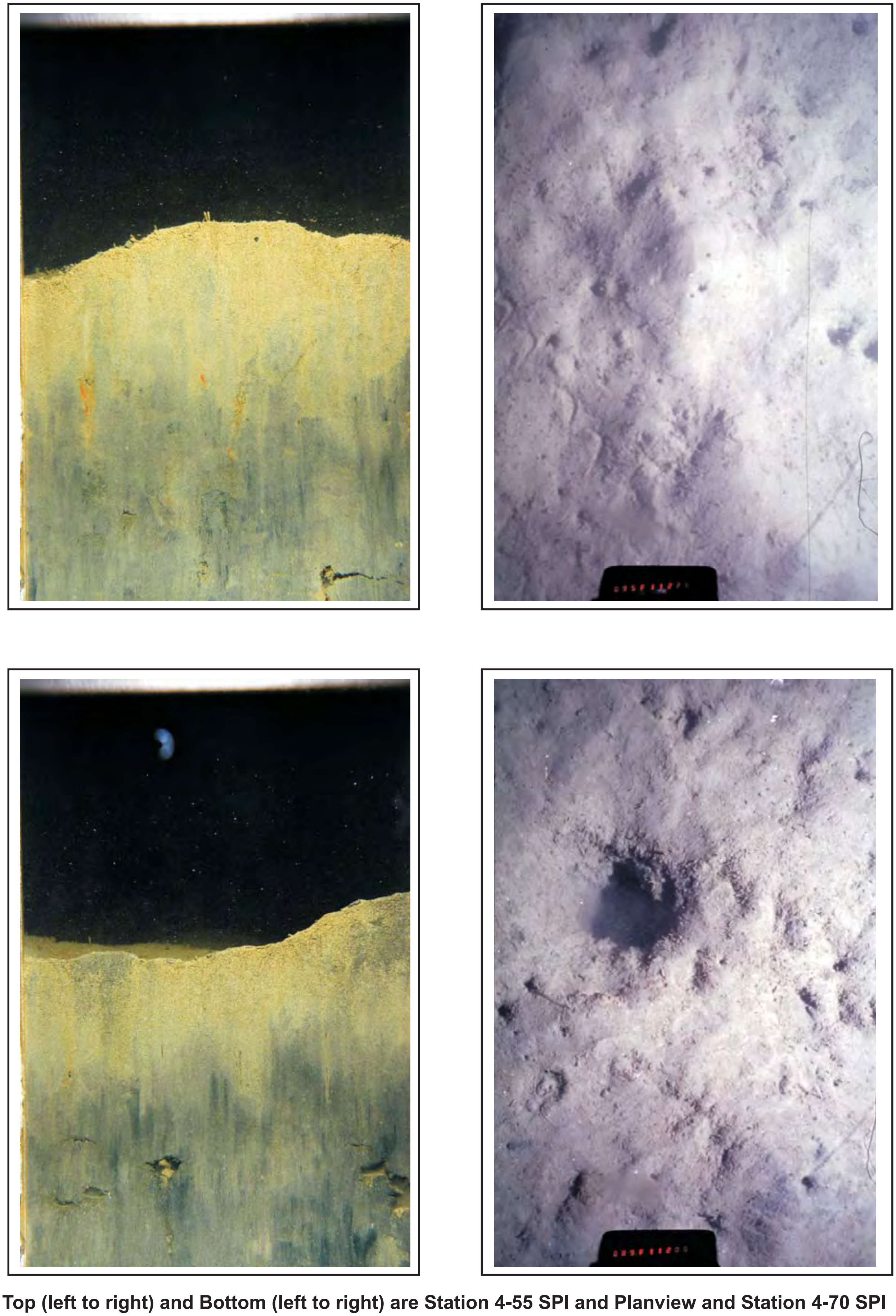
Top (left to right) and Bottom (left to right) are Station 3-40 SPI and Planview and Station 3-55 SPI and Planview, Respectively.

Figure B-1., continued.



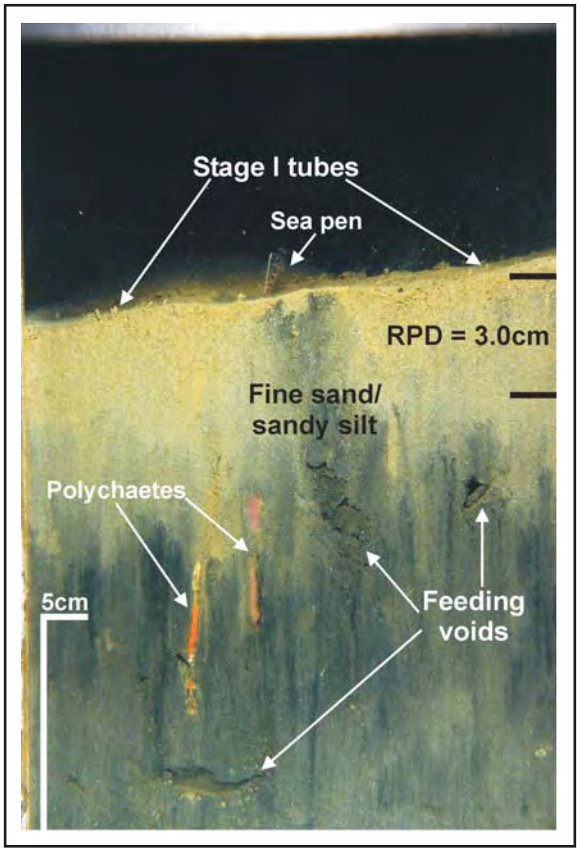
Top (left to right) and Bottom (left to right) are Station 3-70 SPI and Planview and Station 4-40 SPI and Planview, Respectively.

Figure B-1., continued.



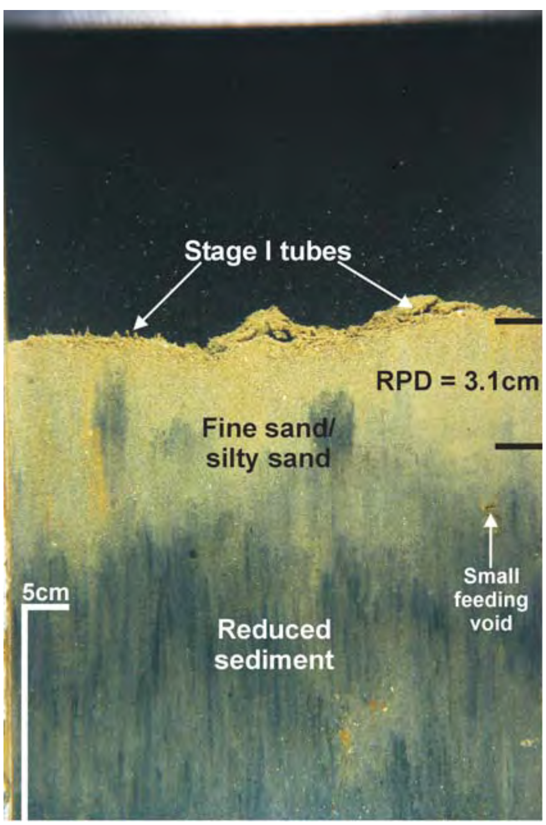
Top (left to right) and Bottom (left to right) are Station 4-55 SPI and Planview and Station 4-70 SPI and Planview, Respectively.

Figure B-1., continued.



Top (left to right) and Bottom (left to right) are Station 5-40 SPI and Planview and Station 5-55 SPI and Planview, Respectively.

Figure B-1., continued.

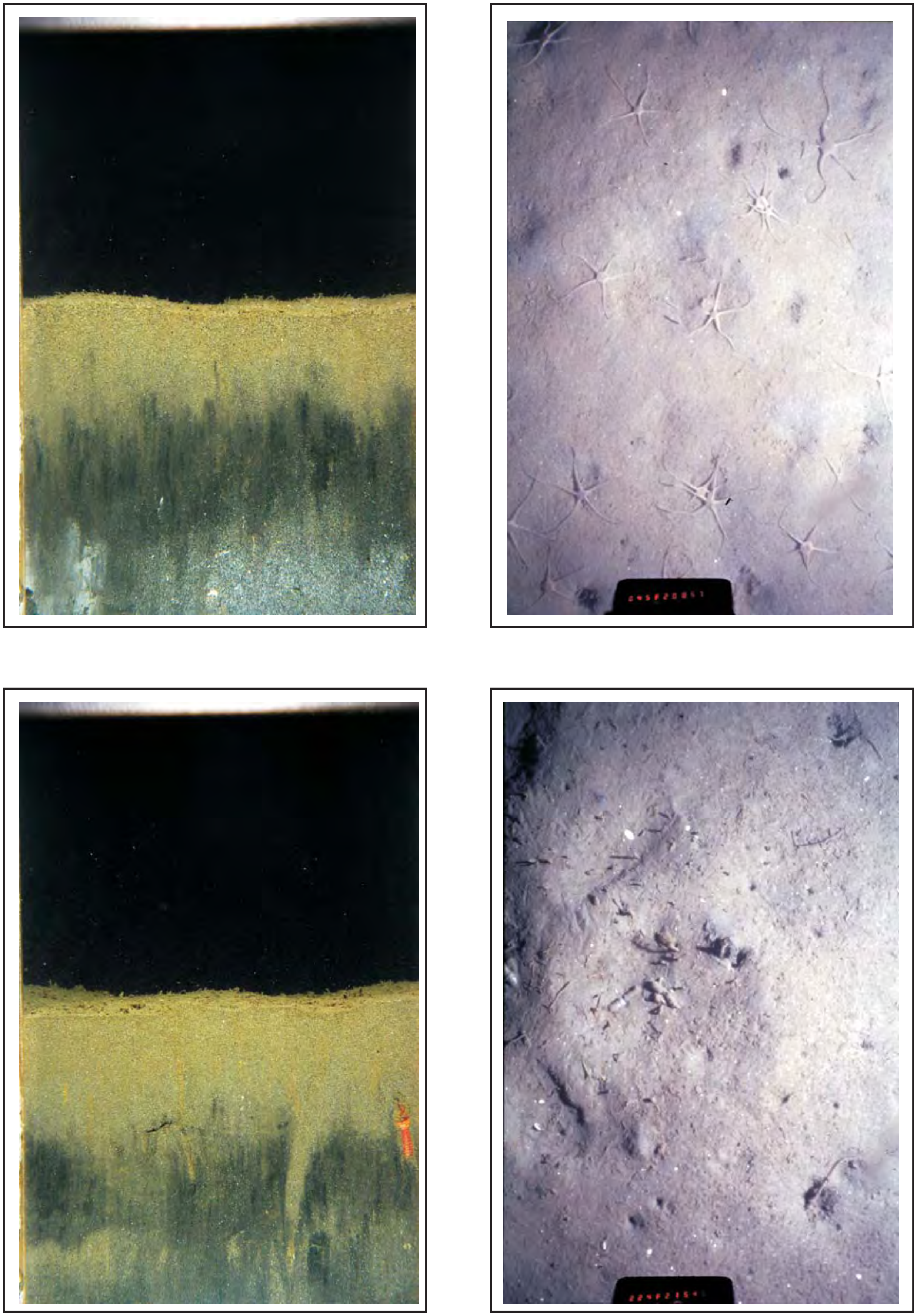


Top (left to right) and Bottom (left to right) are Station 5-70 SPI and Planview and Station LD27 SPI and Planview, Respectively.

Figure B-1., continued.

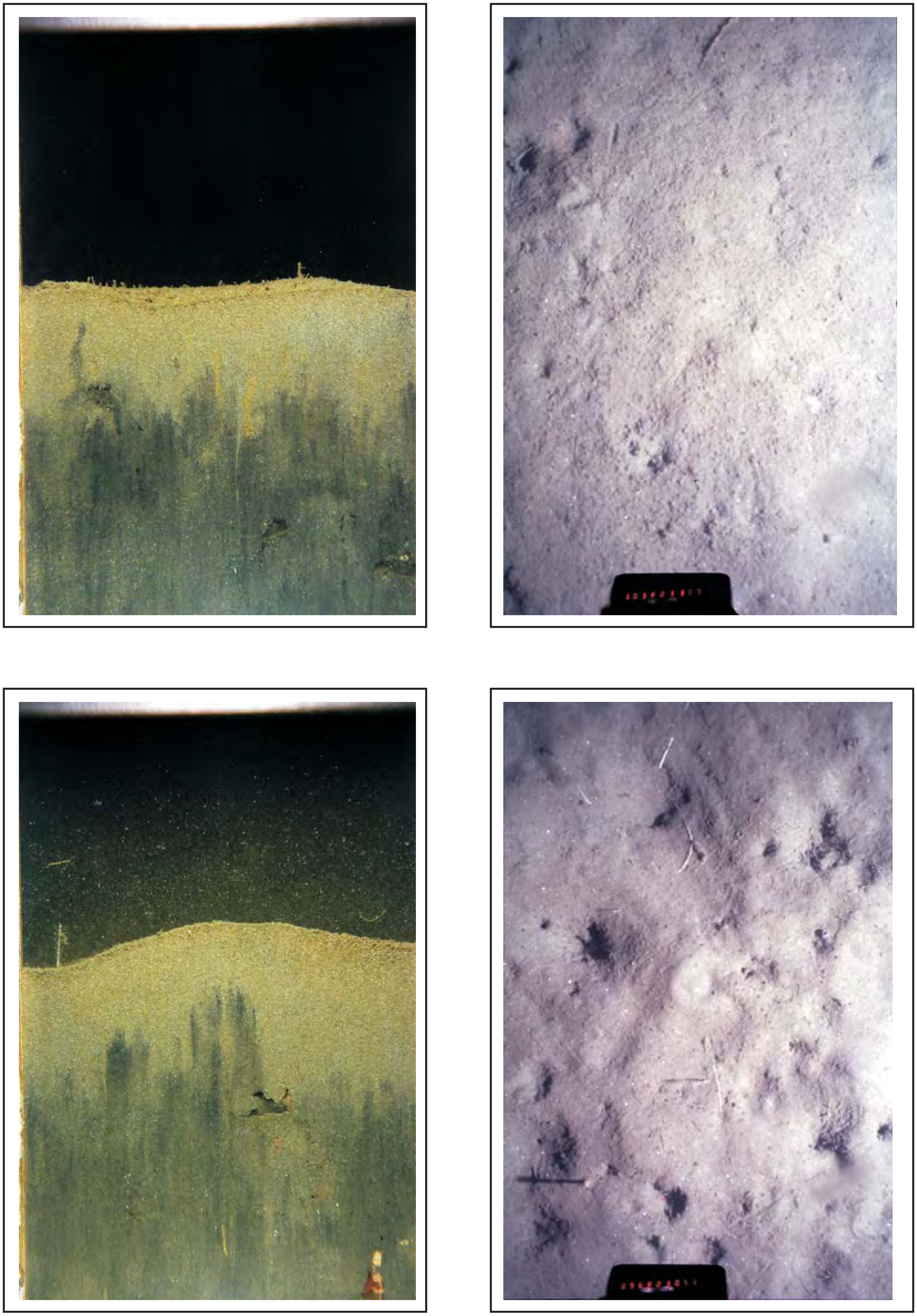
Top (left to right) and Bottom (left to right) are Station LU12 SPI and Planview and Station 7-55 SPI and Planview, Respectively.

Figure B-1., continued.



Top (left to right) and Bottom (left to right) are Station SU22 SPI and Planview and Station 9-40 SPI and Planview, Respectively.

Figure B-1., continued.

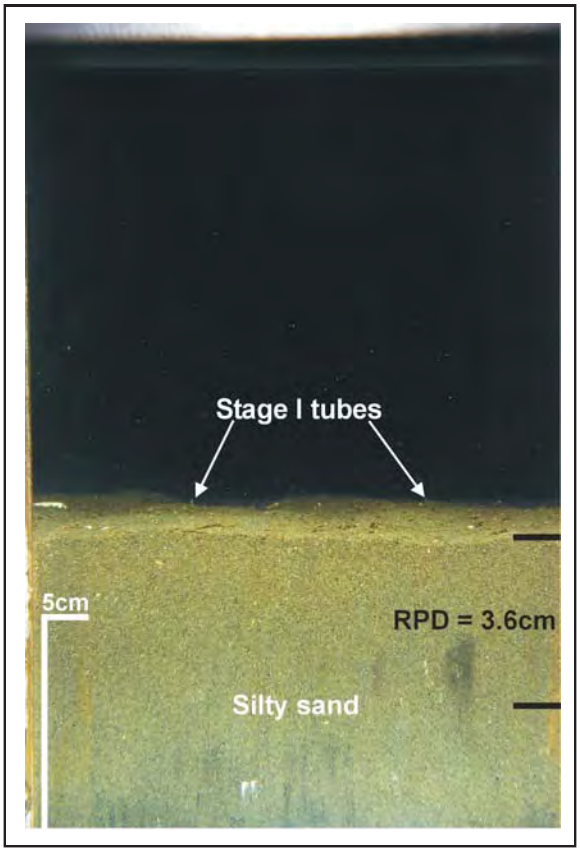


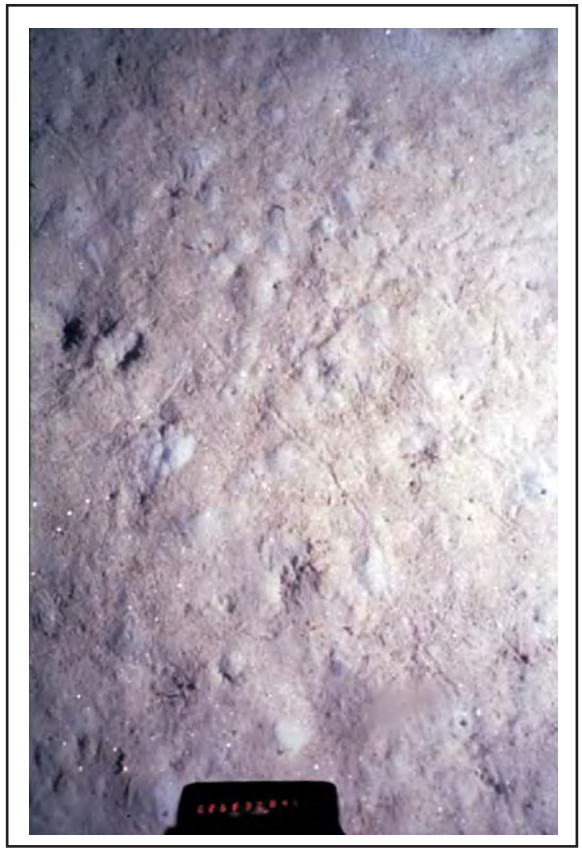
Top (left to right) and Bottom (left to right) are Station 9-55 SPI and Planview and Station 9-70 SPI and Planview, Respectively.

Figure B-1., continued.

Top (left to right) and Bottom (left to right) are Station 10-40 SPI and Planview and Station 10-55 SPI and Planview, Respectively.

Figure B-1., continued.





Station 10-70 SPI (left) and Planview (right).

Table B-1. Summary of SPI Results, July 2004.

Station	Replicate	Successional Stage	Grain Size Major Mode	Benthic Habitat *	Mean Camera Penetration (cm)	Mean Apparent RPD (cm)	OSI
3-40	A	ST I on III	3 to 2 phi	SA.F	9.9	4.91	11
	B	ST I	4 to 3 phi	UN.SS	10.25	3.06	6
3-55	A	ST I on III	> 4 phi	UN.SI	11.78	2.47	9
	B	ST I on III	> 4 phi	UN.SI	11.41	2.80	9
3-70	A	ST I on III	> 4 phi	UN.SI	10.81	3.06	10
	C	ST I on III	> 4 phi	UN.SI	13.24	4.09	11
4-40	A	ST I on III	> 4 phi	UN.SI	13.61	2.87	9
	B	ST I on III	> 4 phi	UN.SI	12.68	3.26	10
4-55	A	ST I on III	4 to 3 phi	UN.SI	13.69	3.42	10
	B	ST I on III	> 4 phi	UN.SI	11.98	3.62	10
4-70	A	ST I on III	> 4 phi	UN.SI	10.11	3.35	10
	B	ST I on III	> 4 phi	UN.SI	11.66	2.81	9
5-40	A	ST I on III	> 4 phi	UN.SI	12.98	3.75	10
	B	ST I on III	> 4 phi	UN.SI	12.65	3.80	11
5-55	A	ST I on III	> 4 phi	UN.SI	13.53	3.01	10
	B	ST I on III	4 to 3 phi	UN.SS	13.28	3.20	10
5-70	A	ST I on III	> 4 phi	UN.SI	14.54	3.30	10
	B	ST I on III	> 4 phi	UN.SI	13.47	3.30	10
LD 27	A	ST I on III	> 4 phi	UN.SI	12.25	3.09	10
	B	ST I on III	> 4 phi	UN.SI	10.91	2.56	9
LU12	A	ST I	4 to 3 phi	UN.SS	8.05	2.69	5
	C	ST I	> 4 phi	UN.SI	7.67	2.32	5
7-55	A	ST I on III	> 4 phi	UN.SI	12.5	2.62	9
	B	ST I on III	> 4 phi	UN.SI	11.05	3.00	9
SU-22	A	ST I on III	4 to 3 phi	UN.SS	9.7	2.60	9
	C	ST I on III	4 to 3 phi	UN.SI	10.35	3.31	10
9-40	A	ST I	4 to 3 phi	UN.SS	10.62	1.28	3
	C	ST I on III	> 4 phi	UN.SS	9.82	3.51	10
9-55	A	ST I on III	4 to 3 phi	UN.SS	10.83	3.73	10
	B	ST I on III	> 4 phi	UN.SI	9.91	3.24	10
9-70	A	ST I on III	4 to 3 phi	UN.SS	11.93	4.05	11
	B	ST I on III	> 4 phi	UN.SI	9.73	3.03	10
10-40	B	ST I on III	4 to 3 phi	UN.SS	9.4	3.27	10
	C	ST I	4 to 3 phi	UN.SS	10.14	3.14	6
10-55	A	ST I	4 to 3 phi	SA.F	4.98	2.54	5
	B	ST I	4 to 3 phi	SA.F	5.27	2.63	5
10-70	A	ST I	4 to 3 phi	UN.SS	6.52	3.49	6
	C	ST I	4 to 3 phi	UN.SS	7.03	3.64	6

* SA.F = fine sand; UN.SS = fine sand mixed with silt; UN.SI = unconsolidated silty sediment.

Table B-2. Plan-View Results, July 2004.

Station	Obscured	General Bottom Description	Sand	Silt/Clay	Epifauna	Infauna	Burrows	Bedforms	Shell Material	Other Notables
3-40	no	medium to fine sand	medium to fine	yes	no	tube worms	8+	no	little shell hash	Fecal mounds.
3-55	no	soft	fine	yes	no	tube worms	3+	no	yes	Mark in sediment from fish (flatfish?) or ray. Small tube in top left corner of image.
3-70	no	burrows/silt/fine sand	fine	yes	seastar	tube worms	36+	no	no	Seastar, fecal mound, organism tracks.
4-40	no	soft/ripples	fine	yes	no	no	5+	sand ripples	no	Debris on slide (bottom right). Small sand ripples.
4-55	no	soft	fine	yes	no	tube worms	10+	no	yes	Organism trail marks in mud. Debris on lens (bottom right).
4-70	no	large burrow/sea pens/soft sed w/ fine sand	fine	yes	sea pens	sea cucumber/ tube worms	19+	no	shell hash	Burrowing sea cucumber at left of image, one large burrow, possible ghost shrimp.
5-40	no	soft	fine	yes	no	tube worms	6+	sand ripples	no	Organism trails in mud.
5-55	no	large burrows/soft sed w/ fine sand	fine	yes	brittlestars	tube worms	18+	no	no	Brittlestar. Unknown biological feature in upper right corner.
5-70	no	brittle stars/burrows/soft sed w/ fine sand	fine	yes	brittlestars	tube worms	14+	no	few shell hash	Organism tracks. Detritus on left.
LD27	no	soft	fine	yes	sea pen	no	3+	no	yes	Sea pen (top right of image).
LU12	no	soft	fine	yes	organism?	tube worm	5+	no	yes	Organism (left side of image). Possible dead sea pen (bottom right). Brown algal mat.
7-55	no	numerous burrows/soft sed w/ fine sand	fine	yes	no	no	14+	no	no	Organism tracks.
SU22	no	soft/brittle stars	fine	yes	brittle stars/sea pen	tube worm	3+	no	yes	Many brittle stars. Tube worms and sea pen (center of image).
9-40	no	soft/large tube worms	fine	yes	no	tube worms	4+	no	yes	Large tube worms (center of image).
9-55	no	medium to fine sand	medium to fine	yes	no	tube worms	5+	no	little shell hash	Discarded tube on surface at top of image.
9-70	no	soft/dead sea pens	fine	yes	sea pen	tube worms	9+	no	yes	Dead sea pens.
10-40	no	soft/large burrow	fine	yes	no	tube worms	2+	no	yes	Two large burrows (top left of image). Brown algal mat. Fecal mounds.
10-55	no	soft sed w/ fine sand	fine	yes	no	tube worms	0	no	some shell hash	Fecal mounds, detritus.
10-70	no	soft sed w/ fine sand	fine	yes	no	tube worms	6+	no	few shell hash	Brown algal mat. Fecal mounds, organism tracks.

APPENDIX C

RESULTS SUMMARY FROM SEDIMENT MIXING RATES/BIOTURBATION POTENTIAL SURVEY AT PALOS VERDES SHELF STATIONS, JULY 2004

Table C-1. Total and Excess Pb-210 Results for Sediment Cores.

Core: DNW 7 G				lat.	33.73056465			
Collected: 7/23/04				long.	118.4064218			
Depth (cm)	Total Pb-210 (dpm/g)		count date	Δ time (d)	Pb-214 (dpm/g)		excess Pb-210 (dpm/g)	
0-2	8.34	0.25	9/2/04	41	2.56	0.08	5.78	0.34
2-4	9.28	0.25	9/4/04	43	2.67	0.11	6.61	0.35
4-6	8.87	0.29	9/3/04	42	2.54	0.10	6.33	0.39
6-8	8.42	0.25	9/7/04	46	2.66	0.11	5.76	0.36
8-10	7.61	0.22	9/7/04	46	2.80	0.08	4.81	0.30
10-12	7.44	0.23	9/11/04	50	2.86	0.11	4.57	0.35
12-14	7.50	0.23	12/5/04	135	3.01	0.12	4.49	0.35
14-16								
16-18	7.22	0.22	12/3/04	133	3.02	0.12	4.19	0.33
18-20								
20-22	7.02	0.21	12/7/04	137	2.61	0.11	4.41	0.32
22-24	7.09	0.22	12/12/04	142	2.43	0.11	4.67	0.32
24-26	6.36	0.19	12/16/04	146	2.73	0.11	3.63	0.30
26-28								
28-30	4.78	0.17	12/1/04	131	2.52	0.10	2.26	0.28
30-32	3.68	0.18	12/13/04	143	2.26	0.05	1.42	0.23
32-34	2.80	0.14	12/8/04	138	2.38	0.10	0.42	0.24
34-36								
36-38	2.51	0.12	12/2/04	132	2.38	0.09	0.13	0.21
38-40								
40-42	2.61	0.13	12/9/04	139	2.47	0.10	0.13	0.23
42-44								
44-46	2.03	0.13	12/6/04	136	2.60	0.10	0.00	0.23
46-48								
48-50	1.88	0.14	11/30/04	130	2.36	0.11	0.00	0.24

Table C-1. Continued.

Core	L4 NW 22 A			lat.	33.7251014			
Collected	7/23/04			long.	118.3833352			
	Total Pb-210						excess Pb-210	
Depth (cm)	(dpm/g)		count date	Δ time (d)	Pb-214 (dpm/g)		(dpm/g)	
0-1	10.48	0.29	8/24/04	32	2.82	0.10	7.66	0.39
1-2	9.88	0.27	8/26/04	34	2.98	0.11	6.90	0.38
2-3	9.27	0.26	8/31/04	39	2.91	0.10	6.36	0.36
3-4	8.36	0.24	8/27/04	35	2.63	0.11	5.73	0.35
4-5	7.82	0.22	9/15/04	54	2.56	0.11	5.27	0.33
5-7	7.72	0.25	8/27/04	35	2.96	0.11	4.76	0.36
7-9	8.06	0.28	9/27/04	66	3.04	0.09	5.02	0.37
9-11	7.74	0.23	8/25/04	33	2.61	0.11	5.13	0.33
11-13	6.97	0.21	9/29/04	68	2.96	0.11	4.01	0.32
13-15	9.11	0.25	12/15/04	145	3.62	0.14	5.49	0.39
15-17								
17-19	8.08	0.22	12/18/04	148	3.02	0.11	5.06	0.33
19-21								
21-23	7.59	0.20	12/10/04	140	2.68	0.10	4.91	0.31
23-25								
25-27	6.09	0.23	12/11/04	141	2.94	0.11	3.14	0.33
27-29								
29-31	6.89	0.20	12/19/04	149	2.99	0.11	3.90	0.31
31-33								
33-35	6.80	0.21	12/17/04	147	2.87	0.11	3.93	0.33
35-37	5.73	0.19	1/31/05	192	2.58	0.11	3.15	0.30
37-39	6.26	0.21	12/21/04	151	2.66	0.11	3.60	0.32
39-41	3.75	0.12	1/30/05	191	2.77	0.08	0.98	0.20
41-43	4.76	0.17	12/14/04	144	2.81	0.11	1.96	0.28
43-45	3.72	0.15	1/28/05	189	2.77	0.10	0.95	0.26
45-46	3.57	0.14	12/4/04	134	2.58	0.09	0.99	0.24

Table C-1. Continued.

Core	L5 NW 45 C			lat.	33.71880604			
Collected	7/24/04			long.	118.3746783			
	Total Pb-210			Δ time			excess Pb-210	
Depth (cm)	(dpm/g)		count date	(d)	Pb-214 (dpm/g)		(dpm/g)	
0-1	10.31	0.23	9/9/04	47	1.89	0.06	8.43	0.29
1-2	11.27	0.26	9/11/04	49	2.09	0.08	9.18	0.34
2-3	10.17	0.24	9/13/04	51	1.93	0.08	8.24	0.31
3-4	9.58	0.22	9/12/04	50	1.87	0.07	7.71	0.29
4-5	9.65	0.25	9/14/04	52	1.93	0.08	7.72	0.33
5-7	9.38	0.25	9/17/04	55	1.73	0.08	7.66	0.33
7-9	8.74	0.23	9/20/04	58	1.93	0.08	6.81	0.30
9-11	8.77	0.22	9/10/04	48	1.76	0.07	7.01	0.29
11-13	8.52	0.26	9/21/04	59	1.91	0.08	6.61	0.34
13-15	8.28	0.29	9/22/04	60	1.91	0.08	6.37	0.37
15-17	8.32	0.26	9/23/04	61	1.86	0.08	6.47	0.34
17-19	8.37	0.26	9/24/04	62	1.90	0.08	6.47	0.34
19-21	8.08	0.26	9/25/04	63	1.99	0.08	6.09	0.34
21-23	7.61	0.17	9/27/04	65	1.95	0.06	5.66	0.23
23-25	7.84	0.23	9/28/04	66	1.74	0.08	6.09	0.30
25-27	6.95	0.23	9/29/04	67	1.98	0.08	4.97	0.31
27-29								
29-31	6.64	0.21	12/10/04	139	1.87	0.08	4.77	0.29
31-33								
33-35	8.52	0.32	12/6/04	135	1.74	0.08	6.78	0.39
35-37								
37-39	8.42	0.24	12/4/04	133	1.79	0.07	6.62	0.31
39-41	6.81	0.22	12/11/04	140	1.51	0.06	5.30	0.28
41-43	7.05	0.23	12/5/04	134	1.67	0.08	5.38	0.30
43-45								
45-47	6.61	0.22	12/3/04	132	1.83	0.09	4.78	0.31

Table C-1. Continued.

Core	L9.5 55 F			lat.	33.7251014		
Collected	7/23/04			long.	118.3833352		
Depth (cm)	total Pb-210 (dpm/g)		count date	Δ time (d)	Pb-214 (dpm/g)		excess Pb-210 (dpm/g)
0-1	7.04	0.32	12/12/04	142	1.85	0.07	5.19
1-2							
2-3	6.91	0.21	12/18/04	148	2.03	0.07	4.88
3-4							
4-5	6.84	0.18	12/14/04	144	2.16	0.07	4.69
5-7	6.06	0.20	12/23/04	153	2.01	0.07	4.04
7-9	5.42	0.20	12/17/04	147	2.04	0.08	3.38
9-11	4.19	0.14	12/26/04	156	2.25	0.06	1.94
11-13	3.56	0.16	12/7/04	137	2.18	0.08	1.37
13-15	2.52	0.14	12/22/04	152	2.07	0.08	0.46
15-17	2.51	0.13	12/9/04	139	2.35	0.08	0.16
17-19	1.84	0.13	12/24/04	154	1.87	0.08	0.00
19-21	1.65	0.12	12/16/04	146	2.02	0.07	0.00
21-23							
23-25	1.94	0.12	12/19/04	149	2.06	0.08	0.00
25-27							
27-29	1.49	0.12	12/13/04	143	1.99	0.08	0.00
29.31							
31-33	1.72	0.12	12/15/04	145	2.04	0.08	0.00
33-35							
35-37	1.65	0.12	12/8/04	138	2.06	0.08	0.00

Table C-2. Total and Excess Th-234 Data from Detailed Stations.

Core	DNW 7 G			lat.	33.73056465			
Collected	7/23/04			long.	118.4064218			
Depth (cm)	Total Th-234 (dpm/g)		count date	Δ time (d)	supported Th-234 (dpm/g)		excess Th-234 (dpm/g)	
0-2	3.50	0.14	9/2/04	41	**2.21**	**0.14**	4.19	0.64
2-4	2.80	0.16	9/4/04	43	**2.23**	**0.12**	1.96	0.70
4-6	2.51	0.15	9/3/04	42	2.37	0.14	0.48	0.70
6-8	2.25	0.16	9/7/04	46	2.37	0.14		
8-10	2.38	0.12	9/7/04	46	2.37	0.14		
10-12	2.71	0.16	9/11/04	50	**2.67**	**0.17**		

Core	L4 NW 22 A			lat.	33.7251014			
Collected	7/23/04			long.	118.3833352			
Depth (cm)	Total Th-234 (dpm/g)		count date	Δ time (d)	supported Th-234 (dpm/g)		excess Th-234 (dpm/g)	
0-1	7.00	0.21	8/24/04	32	**2.30**	**0.16**	11.78	0.65
1-2	3.82	0.18	8/26/04	34	2.33	0.17	3.97	0.66
2-3	2.79	0.15	8/31/04	39	**2.21**	**0.17**	1.77	0.69
3-4	2.59	0.17	8/27/04	35	2.33	0.17	0.70	0.66
4-5	2.47	0.16	9/15/04	54	2.33	0.17	0.65	1.12
5-7	2.60	0.15	8/27/04	35	2.33	0.17		
7-9	2.57	0.13	9/27/04	66	2.33	0.17		
9-11	2.60	0.16	8/25/04	33	2.33	0.17		

Core	L4 NW 22 B			lat.	33.72515338			
Collected	7/23/04			long.	118.3833452			
Depth (cm)	Total Th-234 (dpm/g)		count date	Δ time (d)	supported Th-234 (dpm/g)		excess Th-234 (dpm/g)	
0-1	4.86	0.15	9/9/04	48	**2.01**	**0.14**	11.33	0.80
1-2	3.67	0.18	9/12/04	51	**2.23**	**0.14**	6.27	0.99
2-3	2.72	0.16	9/13/04	52	2.25	0.16	2.11	1.01
3-4	2.42	0.16	9/14/04	53	2.25	0.16	0.77	1.03
4-5	2.43	0.16	9/16/04	55	2.25	0.16		

Table C-2. Continued.

Core	L5NW45A			lat.	33.70821074			
Collected	7/24/04			long.	118.3624588			
Depth (cm)	Total Th-234 (dpm/g)		count date	Δ time (d)	supported Th-234 (dpm/g)		excess Th-234 (dpm/g)	
0-1	4.96	0.18	8/24/04	31	**2.02**	**0.12**	7.18	0.52
1-2	3.42	0.20	8/26/04	33	**2.51**	**0.20**	2.35	0.72
2-3	2.97	0.19	8/30/04	37	**2.54**	**0.17**	1.23	0.73
3-4	2.58	0.17	8/27/04	34	**2.65**	**0.15**		
4-5	2.72	0.19	9/16/04	54	**2.79**	**0.17**		
5-7	2.82	0.16	8/27/04	34	2.54	0.16		

Core	L5 NW 45 B			lat.	33.71450841			
Collected	7/24/04			long.	118.3651524			
Depth (cm)	Total Th-234 (dpm/g)		count date	Δ time (d)	supported Th-234 (dpm/g)		excess Th-234 (dpm/g)	
0-1	3.65	0.21	9/19/04	57	**2.10**	**0.15**	7.97	1.34
1-2	2.58	0.17	9/21/04	59	**2.45**	**0.16**	0.72	1.27
2-3	2.61	0.17	9/17/04	55	**2.30**	**0.18**	1.50	1.20
3-4	2.44	0.17	9/22/04	60	2.46	0.17		
4-5	2.27	0.16	9/18/04	56	2.46	0.17		
5-7	2.63	0.18	9/24/04	62	2.46	0.17		
7-9	2.45	0.17	9/23/04	61	**2.50**	**0.17**		
9-11	2.62	0.17	9/28/04	66	2.46	0.17		

Core	L5 NW 45 C			lat.	33.71880604			
Collected	7/24/04			long.	118.3746783			
Depth (cm)	Total Th-234 (dpm/g)		count date	Δ time (d)	supported Th-234 (dpm/g)		excess Th-234 (dpm/g)	
0-1	5.11	0.14	9/9/04	47	**2.31**	**0.16**	10.84	0.82
1-2	3.92	0.23	9/11/04	49	**2.56**	**0.15**	5.58	1.12
2-3	3.17	0.16	9/13/04	51	**2.59**	**0.16**	2.51	1.00
3-4	2.83	0.15	9/12/04	50	2.48	0.16	1.46	0.92
4-5	2.98	0.17	9/14/04	52	2.48	0.16		
5-7	2.68	0.16	9/17/04	55	2.48	0.16		
7-9	2.66	0.17	9/20/04	58	2.48	0.16		
9-11	3.08	0.16	9/10/04	48	2.48	0.16		
11-13	2.98	0.17	9/21/04	59	2.48	0.16		

Table C-2. Continued.

core	9-55-A			lat	33.69083731			
collected	7/14/04			long	118.3162223			
Depth (cm)	Total Th-234 (dpm/g)		count date	Δ time (d)	supported Th-234 (dpm/g)		excess Th-234 (dpm/g)	
0-1	6.51	0.21	8/2/04	19	**1.79**	**0.14**	8.15	0.44
1-2	3.33	0.18	7/24/04	10	**2.18**	**0.15**	1.54	0.31
2-3	2.89	0.17	7/21/04	7	**2.23**	**0.15**	0.80	0.28
3-4	2.51	0.16	7/19/04	5	**2.26**	**0.15**	0.29	0.25
4-5	2.22	0.16	7/20/04	6	2.07	0.15	0.18	0.26
5-7	2.09	0.17	7/22/04	8	2.07	0.15	0.03	0.28
7-9	2.66	0.17	7/23/04	9	**2.26**	**0.15**	0.52	0.29

Core	9 55 D			lat.	33.6908297			
Collected	7/15/04			long.	118.3162348			
Depth (cm)	Total Th-234 (dpm/g)		count date	Δ time (d)	supported Th-234 (dpm/g)		excess Th-234 (dpm/g)	
0-1	4.81	0.17	8/1/04	17	**1.97**	**0.18**	4.63	0.25
1-2	2.51	0.16	8/2/04	18	**1.56**	**0.15**	1.60	0.23
2-3	1.90	0.13	7/28/04	13	1.82	0.16	0.12	0.21
3-4	2.28	0.16	7/30/04	15	**1.92**	**0.15**	0.56	0.22
4-5	2.07	0.17	7/27/04	12	1.82	0.16	0.36	0.24

Core	9 55 E			lat.	33.68374793			
Collected	7/15/04			long.	118.3093659			
Depth (cm)	Total Th-234 (dpm/g)		count date	Δ time (d)	supported Th-234 (dpm/g)		excess Th-234 (dpm/g)	
0-1	3.23	0.17	8/2/04	18	**2.03**	**0.15**	2.01	0.38
1-2	6.87	0.27	7/29/04	14	**2.09**	**0.15**	7.15	0.47
2-3	2.38	0.14	7/28/04	13	**1.83**	**0.10**	0.81	0.25
3-4	2.27	0.15	7/30/04	15	2.22	0.14		
4-5	2.34	0.15	7/27/04	12	2.22	0.14		
5-7	2.42	0.13	8/1/04	17	**2.22**	**0.16**		

Table C-2. Continued.

Core	9.5 55 H			lat.	33.67602943			
Collected	7/26/04			long.	118.2994201			
Depth (cm)	Total Th-234 (dpm/g)		count date	Δ time (d)	supported Th-234 (dpm/g)		excess Th-234 (dpm/g)	
0-1	3.13	0.17	9/5/04	41	**1.77**	**0.15**	4.44	0.74
1-2	1.97	0.15	9/4/04	40	**1.92**	**0.11**	0.13	0.59
2-3	2.10	0.16	8/30/04	35	2.00	0.14	0.28	0.58
3-4	1.86	0.14	8/29/04	34	2.32	0.14	-1.23	0.53
4-5	2.28	0.15	9/15/04	51	2.32	0.14	-0.17	0.89
5-7	2.27	0.15	9/3/04	39	2.32	0.14	-0.15	0.62
7-9	2.23	0.16	9/22/04	58	2.32	0.14	-0.50	1.11
9-11	2.54	0.12	9/2/04	38	**2.32**	**0.14**	0.63	0.57

Core	10 55 F			lat.	33.66957564			
Collected	7/15/04			long.	118.2956612			
Depth (cm)	Total Th-234 (dpm/g)		count date	Δ time (d)	supported Th-234 (dpm/g)		excess Th-234 (dpm/g)	
0-1	4.21	0.18	8/2/04	18	**2.16**	**0.17**	3.44	0.42
1-2	2.93	0.18	7/24/04	9	**1.48**	**0.15**	1.88	0.30
2-3	2.20	0.16	7/21/04	6	1.92	0.16	0.32	0.27
3-4	2.10	0.16	7/19/04	4	1.92	0.16	0.19	0.25
4-5	2.25	0.17	7/20/04	5	1.92	0.16		
5-7	2.11	0.21	7/22/04	7	**2.03**	**0.18**		
7-9	2.27	0.16	7/23/04	8	**2.02**	**0.14**		

Table C-3. Th-234 data from Comparison Stations, with the Resultant Calculated Biodiffusivities (D_b, cm^2/yr).

Core	Interval (cm)	Mean depth (cm)	"+/- (cm)	Total Th-234 (dpm/g)		count date	Δ time (d)	Supported Th-234		excess Th-234 (dpm/g)		D_b (cm^2/yr)
L3NW6B	0-1	-0.5	0.25	3.62	0.17	8/3/04	15	1.90	0.14	2.64	0.35	
L3NW6B	1-5	-2	2	2.66	0.16	8/2/04	14	2.47	0.15	0.29	0.33	8
L3NW6Z	0-1	-0.5	0.25	4.48	0.18	8/20/04	28	2.29	0.16	4.90	0.55	
L3NW6Z	1-5	-2	2	3.44	0.15	8/21/04	29	**2.29**	**0.16**	**2.65**	**0.51**	89
L3NW17	0-1	-0.5	0.25	7.15	0.27	8/5/04	13	2.83	0.17	6.28	0.47	
L3NW17	1-5	-2	2	4.53	0.20	8/6/04	14	2.93	0.13	2.39	0.35	56
L3NW17Z	0-1	-0.5	0.25	4.55	0.20	8/23/04	31	2.07	0.15	6.06	0.61	
L3NW17Z	1-5	-2	2	2.64	0.16	8/22/04	30	2.11	0.15	1.28	0.51	18
L435D	0-1	-0.5	0.25	5.69	0.18	8/12/04	22	2.68	0.16	5.65	0.45	
L435D	1-5	-2	2	3.42	0.17	8/19/04	29	**2.68**	**0.16**	**1.71**	**0.53**	27
L435Z	0-1	-0.5	0.25	7.45	0.23	8/22/04	30	2.49	0.16	11.75	0.66	
L435Z	1-5	-2	2	4.69	0.00	8/23/04	31	2.77	0.19	4.69	0.48	63
L5NW49B	0-1	-0.5	0.25	6.41	0.18	8/31/04	41	2.40	0.15	13.03	0.76	
L5NW49B	1-5	-2	2	3.15	0.16	8/29/04	39	2.50	0.20	2.00	0.77	12
L5NW49C	0-1	-0.5	0.25	9.18	0.25	8/12/04	19	2.01	0.16	12.38	0.51	
L5NW49C	1-5	-2	2	3.44	0.17	8/19/04	26	2.26	0.15	2.50	0.49	17
L7OUT13A	0-1	-0.5	0.25	9.17	0.31	8/4/04	14	2.09	0.16	10.58	0.52	
L7OUT13A	1-5	-2	2	3.06	0.17	8/3/04	13	2.22	0.16	1.23	0.34	8
L7OUT13C	0-1	-0.5	0.25	7.09	0.22	8/7/04	14	1.88	0.18	7.79	0.43	
L7OUT13C	1-5	-2	2	2.69	0.15	8/20/04	27	2.29	0.15	0.86	0.45	8
L7OUT14A	0-1	-0.5	0.25	5.03	0.15	8/11/04	18	1.77	0.13	5.47	0.33	
L7OUT14A	1-5	-2	2	2.10	0.14	8/9/04	16	2.09	0.16	0.02	0.33	1
L7OUT14C	0-1	-0.5	0.25	5.18	0.15	8/11/04	18	1.63	0.14	5.97	0.35	
L7OUT14C	1-5	-2	2	2.30	0.14	8/9/04	16	1.74	0.16	0.90	0.34	11
L9OUT46C	0-1	-0.5	0.25	7.88	0.25	8/5/04	16	2.01	0.15	9.30	0.47	
L9OUT46C	1-5	-2	2	3.25	0.15	8/6/04	17	2.78	0.16	0.76	0.36	5

Table C-3. Continued.

Core	Interval (cm)	Mean depth (cm)	"+/- (cm)	Total Th-234 (dpm/g)		count date	Δ time (d)	Supported Th-234		excess Th-234 (dpm/g)		Db (cm2/yr)
L9OUT46D	0-1	-0.5	0.25	9.09	0.26	8/7/04	14	2.12	0.15	10.42	0.45	
L9OUT46D	1-5	-2	2	2.30	0.13	8/21/04	28	2.24	0.13	0.13	0.42	1
L10SE47G	0-1	-0.5	0.25	4.37	0.18	8/7/04	13	1.72	0.25	3.85	0.45	
L10SE47G	1-5	-2	2	2.11	0.15	8/8/04	14	1.69	0.25	0.63	0.43	13

* Bold values indicate that supported Th-234 activity is estimated.