2005 Monitoring Studies at the Mouth of the Columbia River (MCR) Ocean Dredged Material Disposal Deep Water Site (DWS)

FINAL DATA REPORT

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LIST OF ACRONYMS AND ABBREVIATIONS

Φ	phi
μm	micrometer
ARI	Analytical Resources, Inc.
cm	centimeter(s)
CPUE	catch per unit effort
CR	Columbia River
CW	carapace width
DGPS	Differential Global Positioning System
DO	dissolved Oxygen
DWS	Deep Water Site
fm	fathom(s)
GIS	Geographic Information Systems
GPS	Global Position System
ha	hectare(s)
ind	individual
kg	kilogram(s)
m	meter(s)
MCR	Mouth of the Columbia River
MCY	million cubic yard(s)
MEC	Weston Solutions (formerly)
mL	milliliter(s)
mm	millimeter(s)
ºC	degrees Celsius
ODMDS	Ocean Dredge Material Disposal Site
OSI	Organism-Sediment Index
REMOTS	Remote Ecological Monitoring Of The Seafloor
RPD	redox potential discontinuity
SA.F	fine sand
SA.M	medium sand
SAIC	Science Applications International Corporation
SPI	Sediment Profile Imaging
TOC	Total Organic Compound
UN.SS	fine sand/silty material
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency

1.0 INTRODUCTION

This report presents the results and analysis of the monitoring of the Ocean Dredge Material Disposal Site (ODMDS) identified as the Deep Water Site (DWS). This monitoring effort was conducted under contract (**W912DW-05-D-1003-DT01)** for the U.S. Army Corps of Engineers (USACE), Portland District (Portland, OR) and in conjunction with site use requirements established by the U.S. Environmental Protection Agency (USEPA), Region X (Seattle, WA). The 2005 monitoring studies were conducted by Science Applications International Corporation (SAIC), located in Bothell, WA, and Weston Solutions, Inc., located in Port Gamble, WA.

The monitoring effort conducted in 2005 was based on previous baseline studies completed in 2002 when the DWS was proposed as an ocean disposal site (MEC and SAIC 2003). The 2002 baseline survey provided information on the existing biological conditions at the DWS prior to the placement of dredged material. Dredged material has since been placed at the DWS in 2004 (1.7 MCY) and 2005 (1.04 MCY) from the maintenance dredging of the navigational channel of the Mouth of the Columbia River (MCR) in the designated 3,000- by 3,000-foot MCR DWS drop zone. In 2005, dredged material (1.32 MCY) was also placed from the Columbia River Channel Improvement Project in the designated 3,800- by 3,800-foot Columbia River (CR) DWS drop zone Figure 1-1). Field activities for the 2005 monitoring effort were conducted in both June and September, thereby bracketing the 2005 dredging season by collected data before and after the placement of dredged material in the DWS.

The main objectives of the 2005 monitoring were as follows:

- Provide a physical characterization of the benthic habitat.
- Characterize the benthic invertebrate community.
- Characterize the demersal fish and invertebrate community (type and abundance).
- Assess the Dungeness crab population (relative abundance).
- Compare the baseline (2002) and newly collected (2005) data.
- Compare the impacted and non-impacted areas within the DWS.

2.0 DATA COLLECTION METHODS

The study design of the 2005 monitoring effort was based on the data collection methods utilized in the 2002 baseline investigation (MEC and SAIC 2003). However, the study design and sampling locations for the current effort was modified to reflect site usage during the 2004 and 2005 dredged material disposals, by placing sampling locations in the vicinity of the MCR DWS drop zone. Data collection efforts included sediment profile imaging (SPI) photography, benthic and fish community analysis, Dungeness crab abundance, and analysis of sediment conventionals.

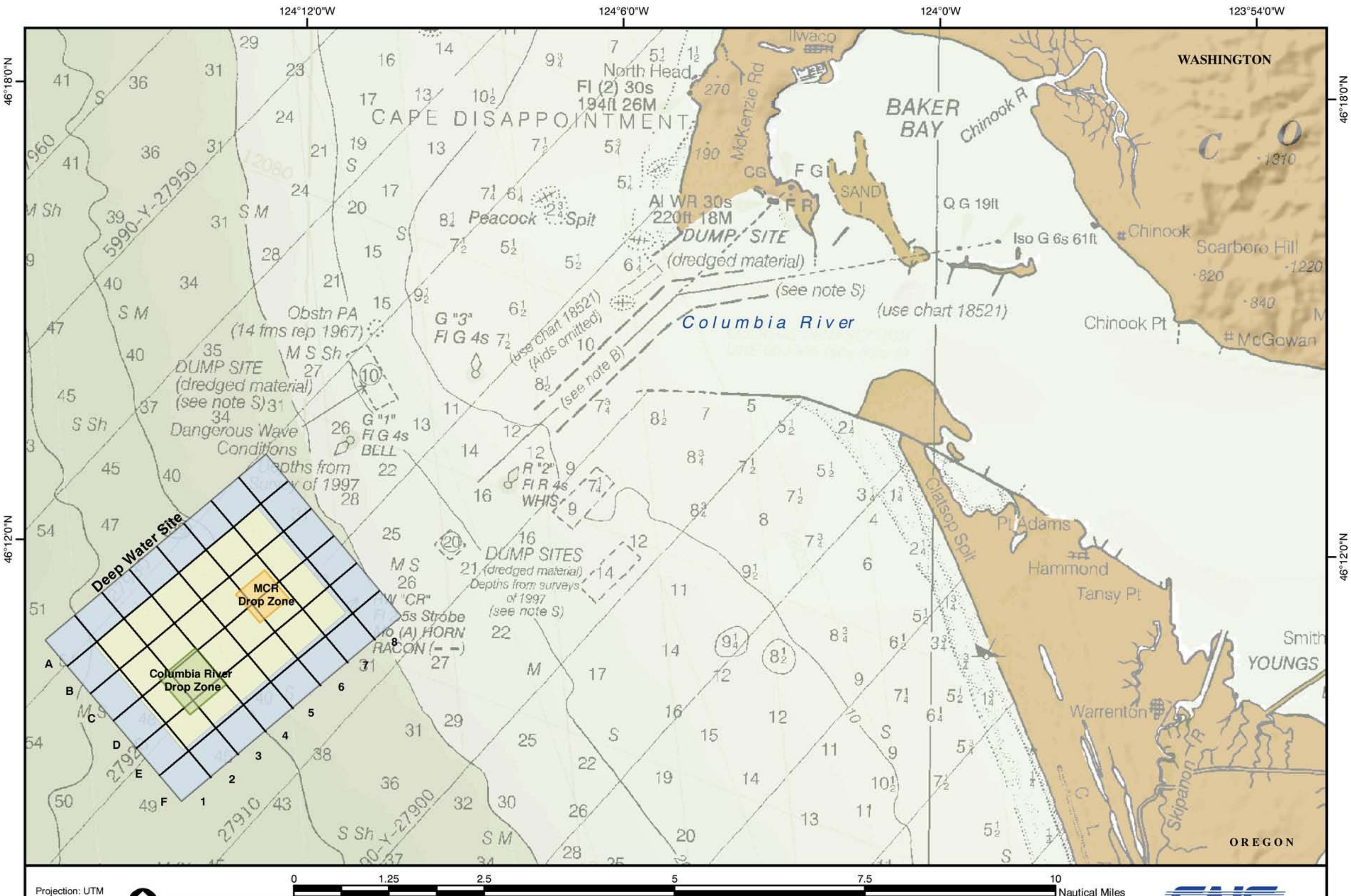

Figure 1-1. Location of the Deep Water Site and Associated Dredged Material Drop Zones Located Off the Mouth of the Columbia River

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M.Goff, SAIC, October 2005

2.1 Data Types

The data types collected for this study included SPI images of the sediment-water interface, sediment grab samples for analysis of benthic community structure, grain size distribution, total organic carbon (TOC), commercial crab pot sampling for Dungeness Crab, and bottom trawls for demersal fish and epibenthic invertebrates (Table 2-1). Detailed descriptions of the sample collection methods are presented in Sections 2.5 through 2.9.

Table 2-1. Data Collection Methods

Data Type	SPI	Grab Samples	Bottom Trawl	Crab Pots
Benthic Infauna	X	X		
Epifauna		X	X	
Dungeness Crab			X	X
Demersal Fish & Invertebrates			X	
Benthic Habitat	X	X		
Sediment Conventionals	X	X		

2.2 Sampling Locations

The sampling locations for the 2005 field efforts were based on a grid system used for the 2002 investigation and the locations of the dredged material drop zones. The grid system consisted of subdividing the DWS into 48 equally spaced grid cells to ensure consistent spatial coverage of the entire site. Each of the 48 cells is approximately 873,152 m^2 (934 m by 934 m) within both the placement (24 locations) and surrounding buffer areas (24 locations). For designation of sampling locations, the grid cells were designated A through F along the western boundary and 1 through 8 along the southern boundary. However, rather than reoccupy all the 2002 stations, the placement of sampling locations for the 2005 survey were adjusted to increase sampling density near the MCR DWS drop zone. Bathymetric data collected following the 2004 dredged material disposal were also used to refine the placement of sampling locations. The most frequent sampling was conducted with the SPI camera, which was deployed at 36 locations during each of the June and September 2005 sampling events (Figure 2-1). Three replicate images were collected at each location during each sampling event. Sediment conventionals and benthic infauna samples were collected at 9 locations colocated with selected SPI stations (Figure 2-2). Grid cells selected for benthic infauna sampling were determined in the field based on the initial review of SPI images collected during the June 2005 survey and relative to the 2004 dredged material footprint. Crab pots were deployed at 24 locations, for two 24-hour periods within the DWS for each sampling event (Figure 2-3); however, four pots were relocated from the CR-DWS drop zone due to ongoing disposal activities during the September 2005 sampling event. Four trawl lines, two replicates each, including two trawl lines within the dredged material drop zones, were conducted traversing along a NW-SE transect across the DWS for each sampling event (Figure 2-4).

Station IDs for the various data types utilized this alphanumeric grid designation (i.e., A–F and 1–8) to the extent possible for developing corresponding sample IDs. However, due to the different data types, modified sampling locations, replicate samples, and samples across multiple grid cells (i.e., trawls), the sample identification naming scheme is not consistent across data types beyond the initial grid cell designation.

The station coordinates for the actual sampling locations are presented in Appendix A.

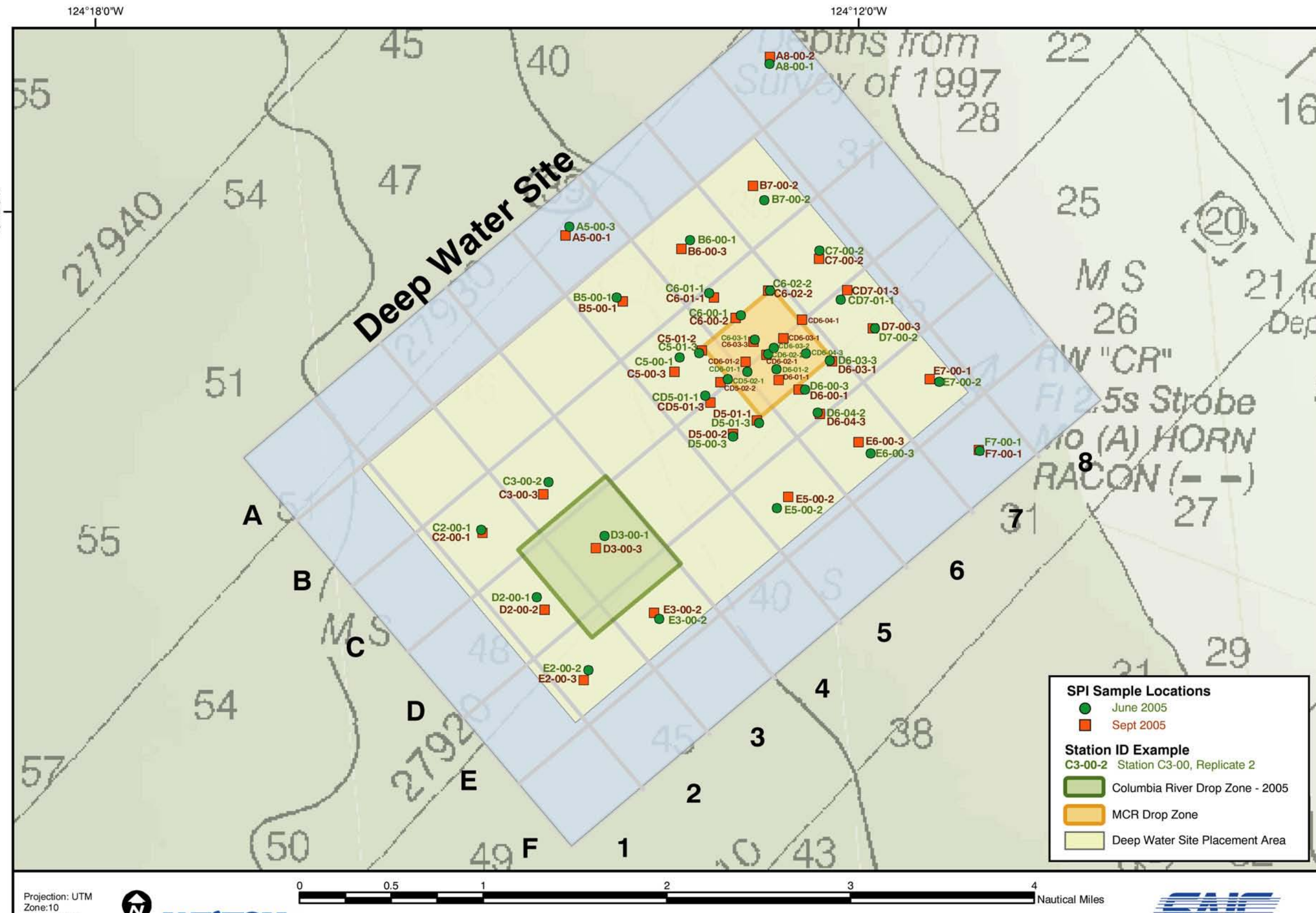

Figure 2-1. SPI Sampling Locations at the DWS (2005)

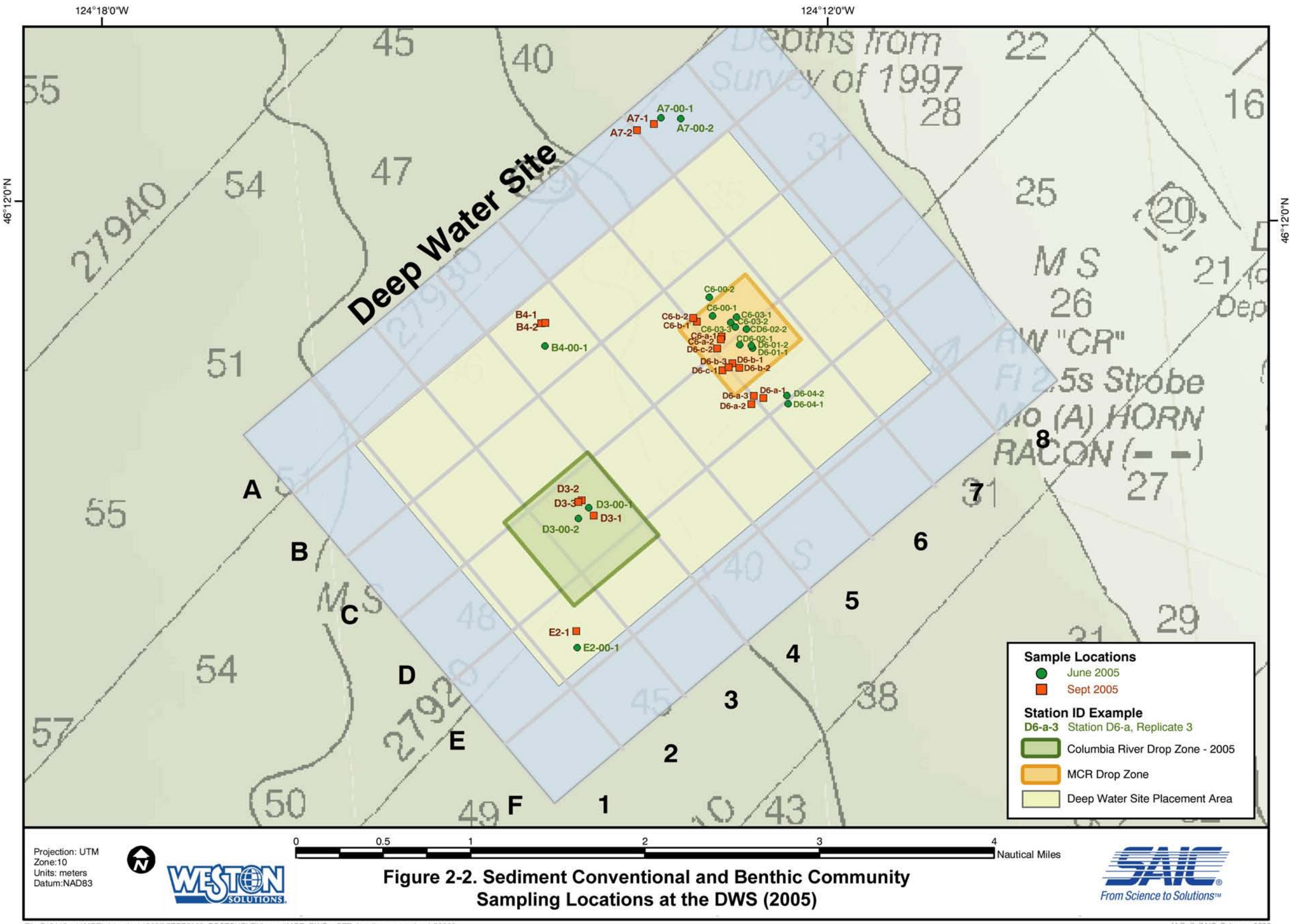

Figure 2-2. Sediment Conventional and Benthic Community Sampling Locations at the DWS (2005)

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M.Goff, SAIC, February 2006

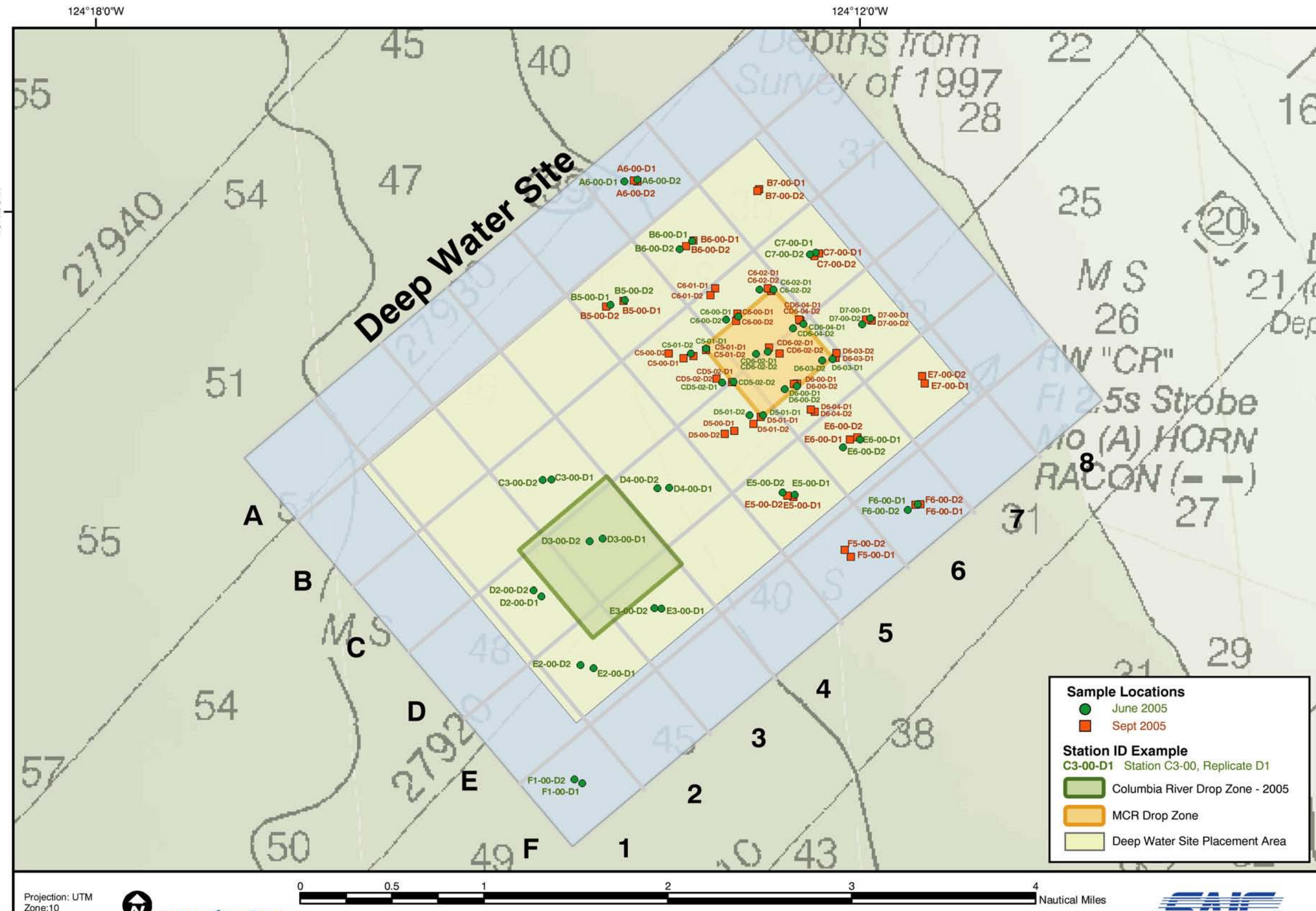

Figure 2-3. Crab Pot Sampling Locations at the DWS (2005)

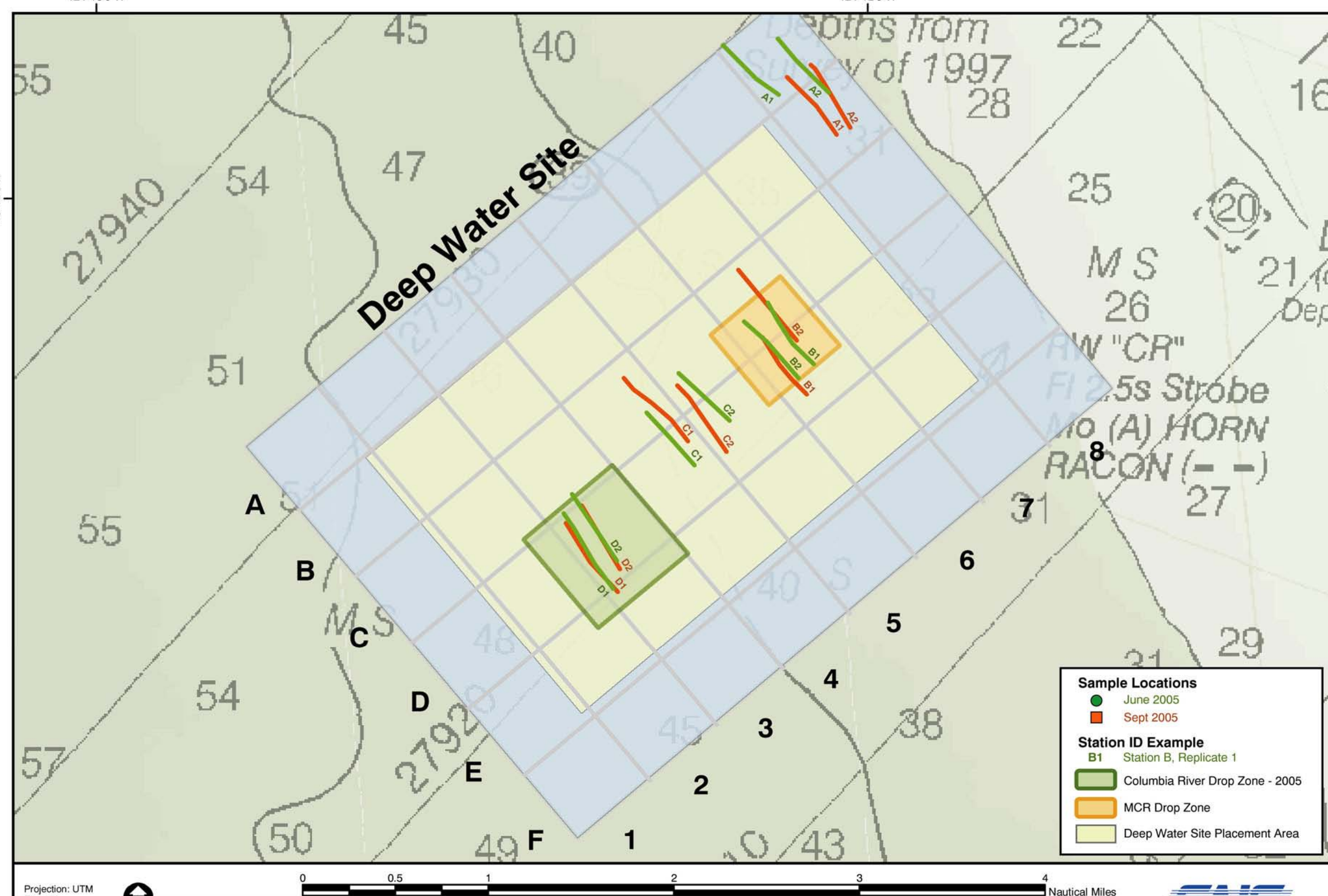

Figure 2-4. Bottom Trawl Sampling Locations at the DWS (2005)

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M.Goff, SAIC, February 2006

2.3 Sampling Vessel

The F/V *Iron Lady*, an 81 ft commercial bottom trawler stationed in Warrenton, OR, was used for the SPI, crab pot, bottom trawling, and sediment sampling activities. This vessel was outfitted to accommodate both commercial otter trawl demersal fish trawling, as well as scientific and engineering consulting services off the coasts of Washington and Oregon. The F/V *Iron Lady* is owned by Ms. Trisha Bisby, and is registered in South Bend, WA. The vessel was operated by Captain Kevin Dunn, a skipper with more than 20 years of experience in Oregon and Washington coastal waters, including the Columbia River Bar and surrounding coastal areas. The vessel is equipped with winches, davits, and an A-frame to accommodate the various sampling instruments. The back deck provided extensive open area to accommodate the sampling gear and operations conducted for this investigation.

2.4 Station Positioning

Prior to field operations, Coastal Oceanographic's HYPACK® Max software was used to establish the planned survey lines and stations that were occupied in the survey. Navigation and positioning was accomplished using a differential global positioning system (DGPS) integrated with the HYPACK® Max navigation system. The use of U.S. Coast Guard differential corrections and a Trimble DSM212L DGPS receiver provided positional accuracy of ± 3 meters. Vessel coordinates were updated every 2 seconds and transmitted directly to the onboard system. The HYPACK® Max survey and data acquisition software provided real-time data display and a plan-view chart display to aid the helmsman, as well as logged the vessel position and associated data. All station coordinates were reported in latitude and longitude using decimal minutes, accurate to 1/1000 of a minute (UTM NAD 83, Zone 10). The station coordinates for the actual sampling locations are presented in Appendix A.

2.5 Sediment Profile Imaging

The SPI survey was conducted using a specially designed, high-resolution underwater camera that collects a vertical image of the upper 15–20 cm of the sediment-water interface. A digital camera-equipped Benthos 3731 sediment profile imaging system (Benthos, Inc. North Falmouth, MA) was used to survey the benthic habitat conditions of the study area (Figure 2-5). The sediment-profile camera consists of a wedge-shaped prism with a Plexiglas face plate and a back mirror mounted at a 45° angle. Light was provided by an internal strobe. The mirror reflects the image of the profile of the sediment-water interface to a digital camera that is mounted horizontally on top of the prism.

The camera prism is mounted on an assembly that can be moved up and down within a stainless steel frame by allowing tension or slack on the winch wire. As the camera is lowered, tension on the winch wire keeps the prism in the up position. Once the camera frame touches the bottom, slack on the winch wire allows the prism to vertically intersect the seafloor. The rate of fall of the prism (6 cm/second) is controlled by an adjustable passive hydraulic piston, which minimizes the disturbance of the sediment-water interface. A trigger is tripped on impact with the bottom, activating a 10-second time-delay on the shutter release; this gives the prism a chance to obtain maximum penetration before a photograph is taken. When the camera is raised from the bottom, a wiper blade automatically cleans off any sediment adhering to the prism faceplate and the strobes are recharged. The camera can then be lowered to collect another replicate image. Due to the predominantly sandy conditions at the site, two weight racks, each capable of holding 125 lbs of lead (in 25 lb increments), were loaded to maximize penetration.

The SPI survey consisted of collecting a total of 216 digital images from the study area. The total images collected included 36 sampling locations (three replicates each) in both June and September 2005.

A formal analysis of the SPI survey results was conducted to assess the condition of the benthic habitat and determine the physical characteristics of the surface sediment. A single replicate image was selected for analysis from each location. Parameters assessed from the images include:

- Grain size mode and range
- Prism penetration depth
- Dredged material thickness
- Surface boundary roughness
- Depth of apparent redox potential discontinuity
- Benthic habitat classification
- Infaunal successional stage
- Calculation of the organism-sediment index

Analysis of the SPI images was conducted using the REMOTS (Remote Ecological Monitoring Of The Seafloor) system. REMOTS is a formal and standardized technique for SPI image acquisition, image analysis, and interpretation developed by SAIC scientists (Rhoads and Germano, 1982 and 1986; SAIC 1986a). Physical and biological parameters were measured directly from the SPI digital images using a computer image analysis system. The image analysis system can discriminate up to 256 different tonal scales, so subtle features can be accurately measured from the digital images. The image analysis software allows the measurement and storage of data from up to 21 different variables for each image. All data were edited and verified by a senior-level scientist before final data synthesis, statistical analyses, and interpretation. A more detailed discussion of the SPI parameters evaluated is presented in Appendix B.

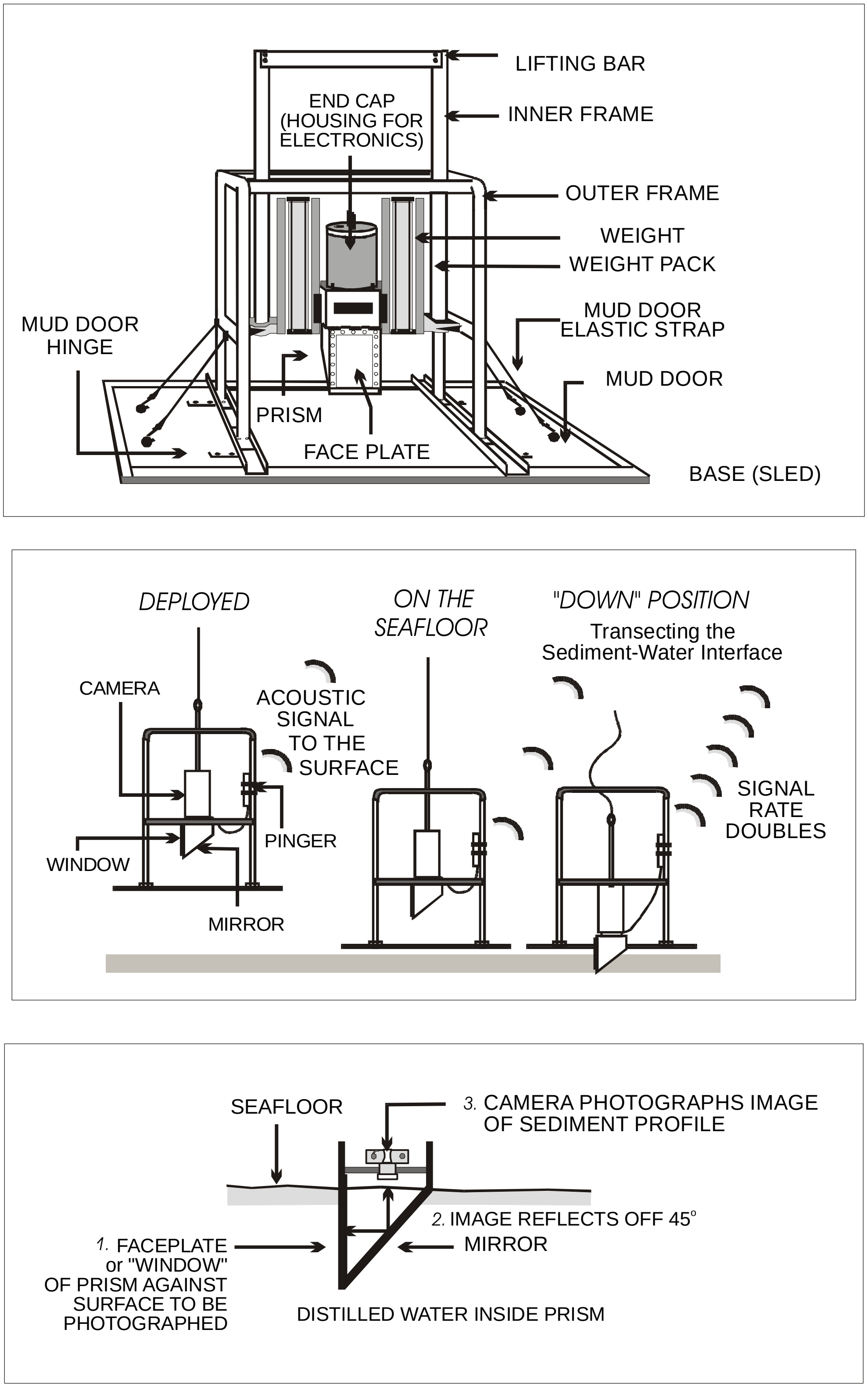


Figure 2-5. Sediment Profile Imaging Camera

2.6 Benthic Community

The benthic infaunal community was characterized at nine stations in the DWS and the surrounding buffer area. Triplicate samples were collected from four stations in the MCR-DWS drop zone and one station in the CR-DWS drop zone. In addition, triplicate samples were collected from two reference locations for the MCR-DWS drop zone and a single replicate was collected from two reference locations for the CR-DWS drop zone. Reference station locations were selected based on depth (similar bathymetric contours), benthic community (based on baseline surveys; MEC and SAIC 2003), and distance from the disposal site (out of the expected area of influence from disposal activities).

Benthic samples were collected using a double, modified van Veen grab sampler with a combined surface area of 0.2 m^2. The grab sampler consists of two side-by-side, stainless steel 0.1 m^2 van Veen grabs. Each grab opens and closes independently, allowing the collection of one grab and reducing the chance for dual failure (debris caught in one sampler doesn't affect the other sampler). The double van Veen grab sampler was used to ensure that acceptable sediment samples of ample surface area were effectively and efficiently obtained. The dual grabs also allowed the collection of two benthic community replicates in a single attempt, thereby reducing the overall level of effort. A single replicate consisted of the entire contents of a van Veen grab (0.1 m^2). Thus, the double van Veen grab sampler provided two replicates for each successful deployment with each benthic replicate being processed separately.

Acceptable grab samples were determined by meeting the following criteria (PSEP 1987):

- Sampler is not overfilled.
- Overlying water is present.
- There is no leakage of water during recovery.
- Sediment surface is relatively flat with no evidence of disturbance or winnowing.
- A minimum penetration depth of 10 cm is achieved in sandy silt or silty sand environments and greater than 5 cm of penetration in medium to coarse sands.

Adequate penetration into sediments is based on the location of the typical benthic infauna within a column of sediment. Penetration of various sediment types ranging from 5 cm in coarse sands to 10 cm in finer grained silt and clay environments is based on the collection of >90% of the individuals and species that would typically be encountered within those sediment types when box cores are used to sample to sediment depths of >20 cm.

Once a sample was accepted, a description of the collected material was then recorded in logbooks, including information such as penetration depth, color, texture, odor, biological structures, or any other notable features.

The sediment from each grab was processed in the field. The samples were sieved on board through a 1.0 mm screen. Water used to sieve the organisms was obtained from the surrounding seawater after being filtered to remove water column organisms that might be encountered in these sieving waters. Organisms and debris collected on the 1.0 mm screen were placed in magnesium sulfate solution to relax the organisms and then was preserved using a seawater-buffered formalin solution of at least 8–10%. The samples were labeled internally and externally and placed in a container appropriate for the volume of the sample. Sieved residue <100 mL in volume was placed in plastic whirl pack bags. Larger volumes of debris were placed in larger containers made of either glass or plastic. Each sample or each group of samples from a single grab were stored together in a separate container. Field notes and chain-of-custody records were maintained to indicate the number and size of sample containers obtained from each grab sample. Samples were sent via courier to Weston's benthic laboratory in Port Gamble, WA, for further analysis and archival.

In the laboratory, samples were transferred to 70% ethanol. Samples were sorted by microscope to remove all animals and then grouped by major taxa. Once sorted, each individual organism was identified to lowest taxonomic level by a regional expert in benthic taxonomy. Species identification was conducted by Dr. Sandy Lipovsky at Columbia Science, Royston, British Columbia.

2.7 Sediment Conventional Parameters

Sediment grain size distribution and TOC content are important sediment characteristics that influence benthic infaunal assemblages. Sediment grain size and TOC analysis were conducted to help characterize the benthic community and to ground-truth the grain size determinations acquired by the SPI. Grain size distributions were characterized by the percent fractions of gravel, sand, silt, and clay comprising the substrate material. TOC is a measure of the total amount of nonvolatile, volatile, semi-volatile, and particulate organic compounds.

Single samples were analyzed for grain size and TOC from each of the stations sampled for benthic community analysis, with the sediment from one grab sample at each benthic station collected for conventionals analysis. The sediment aliquot was removed from the upper 2 cm using a clean, stainless-steel spoon. The samples for grain size and TOC were kept cool at approximately 4°C. Samples were shipped via overnight delivery at 4°C to the analytical laboratories.

TOC analyses were conducted by Analytical Resources, Inc. (ARI), Tukwila, WA (June 2005), and Weston Solutions, Inc., Carlsbad, CA (September 2005). Each sample was homogenized and aliquoted into dishes. Samples were then acidified and warmed to remove inorganic carbon by converting it to carbon dioxide. The samples were then dried and ground into fine powder and placed in the TOC analyzer, where the organic carbon was converted to carbon dioxide through high temperature combustion. The concentration of carbon dioxide is determined by infrared spectrophotometry.

Grain size analyses were conducted by ARI (June 2005) and Weston Solutions Inc. (September 2005). Grain size is the percentage of gravel, sand, silt, and clay components based on the weights of phi (size) fractions of the sediment sample using the sieve-pipette method (Plumb 1981). The frequency distribution of the size ranges (reported in micrometers [µm]) of the sediment is then reported.

2.8 Dungeness Crab Survey

Two sampling methods were used to determine the relative abundance of Dungeness crabs within the DWS: 1) deployment of commercial crab pots (with an emphasis on the 2005 dredged material placement area), and 2) bottom trawls (see Section 2.9). The resulting data from the crab pot deployment was then used to determine the catch per unit effort (CPUE) of Dungeness crabs, based on site-specific data interpolation using Geographic Information Systems (GIS). The bottom trawls provided an estimate of the total number of crabs caught per hectare of seafloor trawled. The combination of these methods allowed for the determination of the relative abundance of crabs within the disposal site. The size distribution and physical descriptions of the crabs found in this location was characterized from crab pot and trawl sampling described below.

Commercial crab pots (0.91 m diameter by 0.36 m deep) were deployed at 24 locations within the DWS. Sampling locations were selected to provide general coverage of the disposal site, with an increased sampling density near the MCR-DWS drop zone. These locations were altered slightly for the September 2005 survey to avoid the operation of the Dredge Sugar Island, which was actively disposing of dredged material at the CR-DWS drop zone. The commercial crab pots were deployed twice during each sampling event at each location. Each crab pot was retrieved after a minimum 24-hour soak time for each replicate.[1] Dungeness crab in each pot were sexed, measured, examined for shell condition, and carefully returned to the water. If more than 50 crabs were present in a single pot, the remaining crabs were simply counted and returned to the water. Crab measurements consisted of carapace width taken immediately anterior to the tenth anterolateral spine, to the nearest millimeter using Vernier calipers. Appearance and pliability of the smaller legs were used to determine shell condition and strength. Crab pots were then re-baited and redeployed for a second 24-hour period. The crab bait consisted of a commercial stainless steel baiter filled with squid and herring placed in each crab pot. The depth, Global Positioning System (GPS) location, and the time of pot set and retrieval were recorded for each sampling station.

Dungeness crabs collected in the bottom trawls were processed in the same manner as in the crab pot survey.

2.9 Demersal Fish and Invertebrate Community Studies

The demersal fish and invertebrate community were characterized using a research otter trawl. Trawls were conducted across the MCR-DWS and CR-DWS disposal sites, as well as across reference areas for each disposal site. Four stations, A (MCR-DWS Ref), B (MCR-DWS), C (CR-DWS Ref), and D (CR-DWS), were identified in the DWS from 30 fm (shallow) to 50 fm (deep) (Figure 2-4). The station locations were based on a stratified sampling design used during the 2002 and 2003 DWS surveys (Word et al. 2003, Word et al. 2004) and were intended to represent the placement area and the surrounding area. Two replicate trawls were conducted at each station.

Trawls were conducted using a 7.6 m Willis/SCCWRP otter trawl (Figure 2-6). The trawl net was constructed with coated nylon mesh (5/8” by 5/8” and 1.3 cm stretch mesh liner at the cod end), with an opening of 1 m in height and door spread of 4.6 m (Mearns and Stubbs 1974, Gunderson 2003). The net was fitted with 0.5 m by 0.75 m mahogany otter boards, with a 4-chain bridle oriented to drive the boards downward and outward. Chain sewn into the foot rope and a float line in the head rope maintained the open net. The direction of each trawl was determined by the direction and strength of the prevailing current at the time of sampling.

[1] The first replicate for the June 2005 deployment of the commercial crab pots was a 48-hour soak time due to adverse weather conditions. The additional soak time allowed other data collection activities (SPI survey) to be completed during favorable sea conditions in order to maintain project schedule.

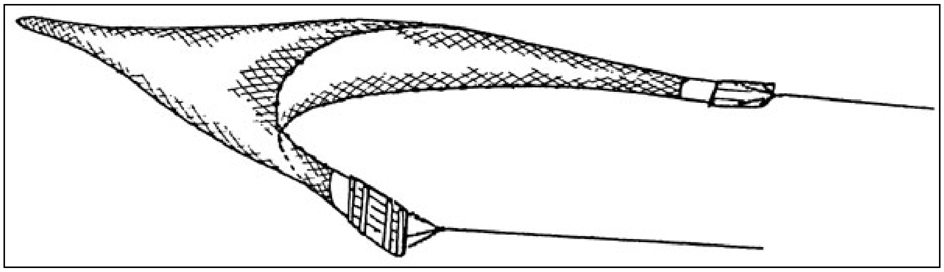


Figure 2-6. Schematic of Otter Trawl Net

Following each trawl, the net was retrieved and the collected organisms were slaked to the end of the net where they were released into large plastic tubs. The fish and invertebrates were sorted into species, measured, and weighed. The demersal fish were identified and measured to the nearest millimeter. Length and weight were measured for the first 30 individuals of a given fish species. Length was measured for the next 40 fish and weights were recorded for the batch. Any remaining fish were counted and weighed as a batch. Demersal invertebrates were identified to species, counted, and weighed. Individual weights, sex, carapace width, and shell hardness were recorded for Dungeness crab. Great care was taken to avoid excessive mortality by minimizing fish handling, processing each catch as quickly as possible, and carefully returning each specimen to the water. Individuals that could not be identified or had uncertain identification were preserved in 10% formalin for later identification. Uncommon species were retained for archival purposes.

Mean abundance, biomass, and standard deviations were calculated for each station for both the benthic and demersal communities.

In order to allow for comparison of stations within the 2005 survey, as well as comparison with the baseline surveys (2002), the data were evaluated using Bray-Curtis cluster analysis. The Bray Curtis analysis is influenced by the similarity in relative numerical abundance for each species (Romesburg 1984). Each cluster analysis was performed with raw data using all species collected at each trawl location, and using only those species occurring more than once.

3.0 RESULTS

This section provides the results by data type for both the June and September 2005 DWS monitoring surveys.

3.1 SPI Survey Results

A minimum of three replicate images were collected at 36 sampling locations at the DWS in both the June and September 2005 SPI surveys (Figure 3-1). From this dataset, 72 representative images were selected (one replicate per location per sampling event) and analyzed using the REMOTS system to examine for the presence of dredged material and determine several physical and biological parameters. Summaries of the June and September 2005 image analyses are provided in Tables 3-1 and 3-2, respectively, and are presented in Sections 3.1.1 through 3.1.7. A detailed description of the REMOTS parameters is provided in Appendix B for reference. The SPI images that were collected and analyzed are presented in Appendix C.

3.1.1 Grain Size

The grain size distribution in SPI images, as determined by REMOTS analysis, is reported as the major mode in phi size. The phi size range for sediments is from -1 phi (gravel), -1 to 4 phi (sand), 4 to 8 phi (silt), to greater than 8 phi (clay). The June 2005 survey indicated a grain size distribution that consisted predominantly of fine sand (3 to 2 phi; 58%), with areas of medium sand (2 to 1 phi; 25%) and very fine sand (4 to 3 phi; 17%). The coarser grained medium sand was limited to the area near the MCR DWS drop zone, where coarse-grained dredged material had been placed in 2004. The grain size distribution during the September 2005 survey demonstrated a slight shift towards finer grained material, with medium sand at 11%, fine sand at 55%, and very fine sand at 33% of the locations surveyed. Locations consisting primarily of very fine sand were all located outside of the dredged material drop zones (Figure 3-1). Changes in grain size major mode within the drop zones (slightly finer in the MCR-DWS, slightly coarser in the CR-DWS) were within the range of grain size found throughout the site.

3.1.2 Prism Penetration Depth

The SPI prism penetration depths were similar during the June and September 2005 sampling events ranging from 2.09 to 9.79 cm with an overall mean of 4.75 cm penetration. In general, prism penetration depths were deeper in the western portion of the site and shallower in the eastern half of the site. Since the camera weight was constant for each survey, the deeper prism penetration represents a consolidated "soft" bottom with a relatively lower bearing capacity and shear strength. Figure 3-2 provides a graphical representation of the prism penetration depths for the June and September 2005 sampling events. The prism penetration depths were similar in both June and September 2005 throughout the DWS, though the sample within the CR-DWS did show a significant decrease in penetration following the disposal of dredged material.

3.1.3 Small-Scale Boundary Roughness

Small-scale boundary roughness features at the sediment surface are the result of depositional, erosional, and biogenic processes. Determining the source of the boundary roughness is based on visual analysis of the SPI images. At the DWS, physical processes have been identified as the primary source of observed boundary roughness. The mean height (in a given image) of the boundary roughness for the June 2005 survey ranged from 0.36 to 2.53 cm, with an average height of 1.07 cm. The mean height of the boundary roughness for the September 2005 survey ranged from 0.46 to 4.03 cm, with an average height of 1.12 cm.

The changes in boundary roughness coefficients between the June and September 2005 surveys are depicted in Figure 3-3. As evident in the figure, the changes in boundary roughness were nominal (± 2.09 cm) between sampling events, and do not appear to be significantly influenced by dredged material disposal activities.

3.1.4 Apparent Redox Potential Discontinuity Depths

Apparent redox potential discontinuity (RPD) depths at the DWS during the June 2005 survey had a mean depth (in a given image) ranging from 0.37 to 4.45 cm, with an average RPD depth of 1.40 cm throughout the site. During the September 2005 survey, the apparent RPD depths were generally greater with a range from 0.54 to 5.03 cm, and a site average of 1.61 cm. A frequency distribution of the RPD major mode indicated a positive increase in site-wide RPD depth over the summer with some localized decreases near the center of the DWS. The change in mean RPD depth from June to September 2005 is presented in Figure 3-4. The likely mechanism(s) for this increase in RPD depth are seasonal sedimentation of particles through the water column that provide additional oxidized material, and increased *in situ* bioturbation as benthic communities become more developed through the summer months. The majority of the locations (25 of 36) displayed an increase in RPD depth between June and September 2005. Of the locations for which a decrease in RPD depth was observed, the majority were within the drop zones (8 of 11). However, the changes were nominal, as the mean RPDs observed in September 2005 were within the range of RPDs observed in June 2005.

3.1.5 Benthic Habitat Type

Three basic types of benthic habitat (Appendix B) were identified in the images collected during the June 2005 survey: 1) fine sand (SA.F: 64%); 2) medium sand (SA.M: 25%); and 3) fine sand/silty material (UN.SS: 11%). Fine sand/silty material is present in the deeper, westernmost portion of the site with an area of unconsolidated soft bottom. The same habitat types were predominant during the September 2005 survey: 1) fine sand (SA.F: 78%); 2) medium sand (SA.M: 8%); and 3) fine sand/silty material (UN.SS: 14%). The slight changes in habitat type are reflective of increased natural (non-dredged material placement) sedimentation of fine-grained material during the calmer summer months.

3.1.6 Infaunal Successional Stage

The predominant infaunal successional stages observed in images collected in June 2005 were Stage I (86%). Other infaunal successional stages observed included one location identified as Stage I on II (3%), one location identified as Stage I on III (3%), and three locations identified as indeterminate (8%). This suggests that, in June 2005, the DWS was at a primary stage of infaunalization (i.e., Stage I), with a sediment-water interface composed of small, colonizing benthic organisms. In sandy, dynamic environments, such as those found at the DWS, the climax communities may consist primarily of surface dwellers (e.g., amphipods) that reside in the upper 1 cm of the sediment surface and have few, if any, naturally burrowing community members. These community types are classified as Stage I communities and are reflective of an area influenced by physical factors and the presence of a sandy substrate. A higher order successional stage would typically be assigned to a climax community in a depositional environment consisting of a silt/clay substrate. The Stage I on II and Stage I on III successional stages indicate that the infaunal community has been physically disturbed and is in the process of re-colonization, with the presence of some deeper infaunal organisms. The locations identified as Stage I on II (E2-00) and Stage I on III (D3-00) each represent the single replicate image demonstrating the most developed benthic habitat at that location (Figure 3-5). Despite the limited number of stations (n = 6) occupied in the deeper portion of the DWS, it is likely within the range of expected benthic habitat conditions following the mild winter conditions of 2004–2005.

It should be noted that 1.7 MCY of dredged material were placed in the MCR-DWS Drop Zone in 2004. However, in June 2005 the infaunal successional stage (Stage I) within the disposal area is no different than surrounding locations that did not receive any dredged material. Therefore, there appears to be no significant differences in the benthic habitat (as indicated by infaunal successional stage) between anthropogenic disturbances (i.e., dredged material placement) and the natural disturbances from winter storms.

The September 2005 images indicate that further benthic colonization had taken place over the summer months with fewer locations identified as Stage I (28%). The majority of the locations were characterized as a Stage I on III (69%), with a single location considered indeterminate (3%) (Figure 3-5). The September 2005 infaunal successional stage within the MCR-DWS drop zone remained constant as a Stage I community despite the ongoing placement of dredged material between sampling events.

The contrast between the two sampling events indicates that the infaunal community has increased in complexity, establishing itself to a higher order infaunal community (i.e., Stage I on III increasing 66%) during the time interval between surveys. This may be due in part to the relative time frame between surveys (i.e., 3 months), and favorable seasonal seafloor conditions (i.e., new deposition, calm weather) allowing for the initial indication of the establishment of a higher order benthic community typically found in a depositional environment.

3.1.7 Organism-Sediment Index

The Organism-Sediment Index (OSI) provides a relative measure of general benthic habitat quality based on the multiple parameters evaluated in SPI images, including the depth of RPD, infaunal successional stage, dissolved Oxygen (DO) conditions, and presence of methane. A more detailed description of the OSI calculation is presented in Appendix B. The OSI ranged from 2.0 to 8.0, with a mean value of 3.28 for the June 2005 survey. For the September 2005 survey, the OSI ranged from 2.0 to 10.0, with a mean value of 6.29. In general, the OSI values increased between the June and September 2005 sampling events largely due to the deepening of the RPD and the shifts in the infaunal successional stage due to benthic recolonization. Dissolved oxygen and methane are not an issue at the site, as anoxic conditions are not prevalent. OSI values less than 6 are typically indicative of recently disturbed areas. As evident in Figure 3-6, the OSI gradient shows an increasing trend across the site from June to September 2005, with the exception of the dredged material drop zones. The general increase in the OSI value is indicative of enhanced habitat conditions that are likely due to seasonal processes. The DWS undergoes dynamic, seasonal periods of disturbances such as winter storms, which, in conjunction with a predominantly sandy substrate, prevent the long-term establishment of Stage III communities. Instead it creates a (seasonal) cycle of re-colonization by a climax community of Stage I organisms. Benthic community re-colonization was inhibited in the drop zones due to ongoing physical disturbances from the placement of dredged material. However, it should be noted that the relative habitat quality within the drop zones in September 2005 is comparable to the conditions of the overall site in June 2005, where natural physical disturbances affected the seasonal habitat quality.

Table 3-1. Summary of REMOTS SPI Image Analysis for June 2005 DWS Survey

Station	Replicate[1]	Date	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Boundary Roughness Mean (cm)	Benthic Habitat	Highest Stage Present	RPD Mean (cm)	OSI Mean
A5-00	3	6/1/2005	3 to 2 phi	5.96	NA	1.14	SA.F	ST I	0.98	3
A8-00	1	6/2/2005	4 to 3 phi	3.8	NA	0.8	SA.F	ST I	1.28	3
B5-00	1	6/1/2005	3 to 2 phi	4.53	NA	1.21	SA.F	ST I	2.14	4
B6-00	1	6/2/2005	4 to 3 phi	3.61	NA	0.85	SA.F	ST I	1.68	4
B7-00	2	6/2/2005	3 to 2 phi	4.73	NA	1.23	SA.F	ST I	2.67	5
C2-00	1	6/2/2005	4 to 3 phi	9.43	NA	0.55	UN.SS	ST I	1.61	4
C3-00	2	6/2/2005	3 to 2 phi	7.3	NA	0.74	SA.F	ST I	1.73	4
C5-00	1	6/1/2005	3 to 2 phi	3.93	NA	0.57	SA.F	ST I	1.58	4
C5-01	3	6/2/2005	2 to 1 phi	3.79	3.79	1.44	SA.M	INDET	3.79	na
C6-00	1	6/2/2005	2 to 1 phi	3.89	3.89	1.62	SA.M	ST I	1.31	3
C6-01	1	6/2/2005	3 to 2 phi	2.84	NA	1.12	SA.F	ST I	1.28	3
C6-02	2	6/2/2005	2 to 1 phi	4.84	4.84	1.24	SA.M	ST I	1.18	3
C6-03	1	6/2/2005	2 to 1 phi	2.98	2.98	0.74	SA.M	ST I	2.98	na
C7-00	2	6/2/2005	3 to 2 phi	3.82	NA	0.76	SA.F	ST I	1.10	3
CD5-01	1	6/1/2005	3 to 2 phi	3.37	NA	0.76	SA.F	ST I	1.24	3
CD5-02	1	6/2/2005	2 to 1 phi	3.19	3.19	1.3	SA.M	ST I	0.79	3
CD6-01	1	6/2/2005	2 to 1 phi	4.45	4.45	0.36	SA.M	INDET	4.45	na
CD6-02	2	6/2/2005	2 to 1 phi	3.63	3.63	1.94	SA.M	ST I	0.73	2
CD6-03	2	6/2/2005	2 to 1 phi	3.46	3.46	1.81	SA.M	ST I	0.37	2
CD6-04	3	6/2/2005	2 to 1 phi	4.99	4.99	2.53	SA.M	ST I	0.57	2
CD7-01	1	6/2/2005	3 to 2 phi	3.64	NA	0.55	SA.F	ST I	0.39	2
D2-00	1	6/2/2005	4 to 3 phi	9.57	NA	0.95	UN.SS	ST I	1.94	4
D3-00	1	6/2/2005	4 to 3 phi	7	NA	1.18	UN.SS	ST I on III	2.20	8
D5-00	3	6/1/2005	3 to 2 phi	4.57	NA	0.54	SA.F	ST I	0.65	2
D5-01	3	6/2/2005	3 to 2 phi	3.83	3.83	0.74	SA.F	INDET	1.21	na
D6-00	3	6/2/2005	3 to 2 phi	3.03	3.03	1.21	SA.F	ST I	1.19	3
D6-01	2	6/2/2005	3 to 2 phi	4.24	4.24	1.95	SA.F	ST I	0.88	3
D6-03	3	6/2/2005	3 to 2 phi	5	NA	1.36	SA.F	ST I	0.46	2

Table 3-1. Summary of REMOTS SPI Image Analysis for June 2005 DWS Survey

Station	Replicate[1]	Date	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Boundary Roughness Mean (cm)	Benthic Habitat	Highest Stage Present	RPD Mean (cm)	OSI Mean
D6-04	2	6/2/2005	3 to 2 phi	3.03	NA	0.59	SA.F	ST I	0.83	3
D7-00	2	6/2/2005	3 to 2 phi	7.03	NA	1.49	SA.F	ST I	0.95	3
E2-00	2	6/2/2005	4 to 3 phi	7.89	NA	0.98	UN.SS	ST I to II	1.75	5
E3-00	2	6/2/2005	3 to 2 phi	4.7	NA	1.19	SA.F	ST I	0.86	3
E5-00	2	6/1/2005	3 to 2 phi	3.62	NA	0.6	SA.F	ST I	1.06	3
E6-00	3	6/2/2005	3 to 2 phi	3.92	NA	0.93	SA.F	ST I	0.88	3
E7-00	2	6/2/2005	3 to 2 phi	4.8	NA	1	SA.F	ST I	0.79	3
F7-00	1	6/2/2005	3 to 2 phi	5.71	NA	0.54	SA.F	ST I	0.97	3
AVG				4.73	3.86	1.07			1.40	3.28
MAX				9.57	4.99	2.53			4.45	8.00
MIN				2.84	2.98	0.36			0.37	2.00

1. Replicate image evaluated for this sampling event
INDET: indeterminate
RPD: Redox potential discontinuity
OSI: Organism Sediment Index
na: not applicable (benthic successional stage was indeterminate)

Table 3-2. Summary of REMOTS SPI Image Analysis for September 2005 DWS Survey

Station	Replicate[1]	Date	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Boundary Roughness Mean (cm)	Benthic Habitat	Highest Stage Present	RPD Mean (cm)	OSI Mean
A5-00	1	9/13/2005	3 to 2 phi	6.04	NA	0.54	UN.SS	ST I on III	1.60	8
A8-00	2	9/13/2005	3 to 2 phi	5.9	NA	1.26	UN.SS	ST I on III	2.62	9
B5-00	1	9/13/2005	3 to 2 phi	5.66	NA	0.71	SA.F	ST I on III	1.93	8
B6-00	3	9/13/2005	4 to 3 phi	5.4	NA	1.22	SA.F	ST I on III	1.77	8
B7-00	2	9/13/2005	4 to 3 phi	4.28	NA	1.11	SA.F	ST I on III	1.75	8
C2-00	1	9/14/2005	4 to 3 phi	9.79	NA	1.64	UN.SS	ST I	2.31	5
C3-00	3	9/13/2005	4 to 3 phi	8.39	6.78	0.46	SA.F	ST I on III	2.05	8
C5-00	3	9/13/2005	2 to 1 phi	5.56	5.56	1.19	SA.M	ST I on III	1.67	8
C5-01	2	9/13/2005	2 to 1 phi	3.55	3.55	0.78	SA.M	ST I on III	1.20	7
C6-00	2	9/13/2005	3 to 2 phi	3.28	3.28	1.93	SA.F	ST I	1.48	3
C6-01	1	9/13/2005	3 to 2 phi	5.01	NA	0.71	SA.F	ST I on III	3.50	10
C6-02	2	9/13/2005	3 to 2 phi	4.22	4.22	1.05	SA.F	ST I on III	0.76	7
C6-03	3	9/13/2005	3 to 2 phi	2.64	2.64	1.63	SA.F	ST I on III	0.96	7
C7-00	2	9/13/2005	3 to 2 phi	4.32	NA	0.66	SA.F	ST I on III	1.24	7
CD5-01	3	9/13/2005	3 to 2 phi	3.74	NA	0.46	SA.F	ST I on III	1.39	7
CD5-02	2	9/13/2005	3 to 2 phi	2.52	2.52	1.85	SA.F	ST I	0.75	2
CD6-01	2	9/13/2005	3 to 2 phi	4.14	4.14	1.11	SA.F	ST I	1.07	3
CD6-02	1	9/13/2005	3 to 2 phi	3.11	3.11	1.14	SA.F	ST I	1.46	3
CD6-03	1	9/13/2005	3 to 2 phi	3.17	3.17	0.58	SA.F	ST I	1.11	3
CD6-04	1	9/13/2005	3 to 2 phi	3.91	3.91	4.03	SA.F	ST I	0.54	2
CD7-01	3	9/13/2005	3 to 2 phi	4.73	NA	0.65	SA.F	ST I on III	0.95	7
D2-00	2	9/14/2005	4 to 3 phi	8.64	NA	0.86	SA.F	INDET	1.90	3
D3-00	3	9/13/2005	3 to 2 phi	3.17	3.17	0.74	SA.F	ST I	1.30	3
D5-00	2	9/13/2005	3 to 2 phi	4.86	NA	2.63	SA.F	ST I on III	1.98	8
D5-01	1	9/13/2005	3 to 2 phi	2.09	2.09	1.04	SA.F	ST I on III	0.71	6
D6-00	1	9/13/2005	2 to 1 phi	2.98	2.98	1.16	SA.M	ST I	0.74	2
D6-01	1	9/13/2005	2 to 1 phi	5.03	5.03	0.48	SA.F	ST I	5.03	na
D6-03	1	9/13/2005	3 to 2 phi	4.1	NA	1.31	SA.F	ST I on III	1.08	7

Table 3-2. Summary of REMOTS SPI Image Analysis for September 2005 DWS Survey

Station	Replicate[1]	Date	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Boundary Roughness Mean (cm)	Benthic Habitat	Highest Stage Present	RPD Mean (cm)	OSI Mean
D6-04	3	9/13/2005	3 to 2 phi	3.73	NA	0.76	SA.F	ST I on III	1.26	7
D7-00	3	9/13/2005	4 to 3 phi	5.3	NA	1.43	SA.F	ST I on III	1.82	8
E2-00	3	9/13/2005	4 to 3 phi	9.27	NA	0.64	UN.SS	ST I on III	2.17	8
E3-00	2	9/13/2005	4 to 3 phi	6.49	0.25	0.59	UN.SS	ST I on III	2.02	8
E5-00	2	9/13/2005	4 to 3 phi	3.26	NA	0.74	SA.F	ST I on III	1.32	7
E6-00	3	9/13/2005	4 to 3 phi	4.45	NA	1.33	SA.F	ST I on III	1.53	8
E7-00	1	9/13/2005	4 to 3 phi	4.15	NA	1.19	SA.F	ST I on III	1.90	8
F7-00	1	9/13/2005	4 to 3 phi	4.41	NA	0.76	SA.F	ST I on III	1.13	7
AVG				4.76	3.53	1.12			1.61	6.29
MAX				9.79	6.78	4.03			5.03	10.00
MIN				2.09	0.25	0.46			0.54	2.00

1. Replicate image evaluated for this sampling event
INDET: indeterminate
RPD: Redox potential discontinuity
OSI: Organism Sediment Index
na: not applicable (benthic successional stage was indeterminate)

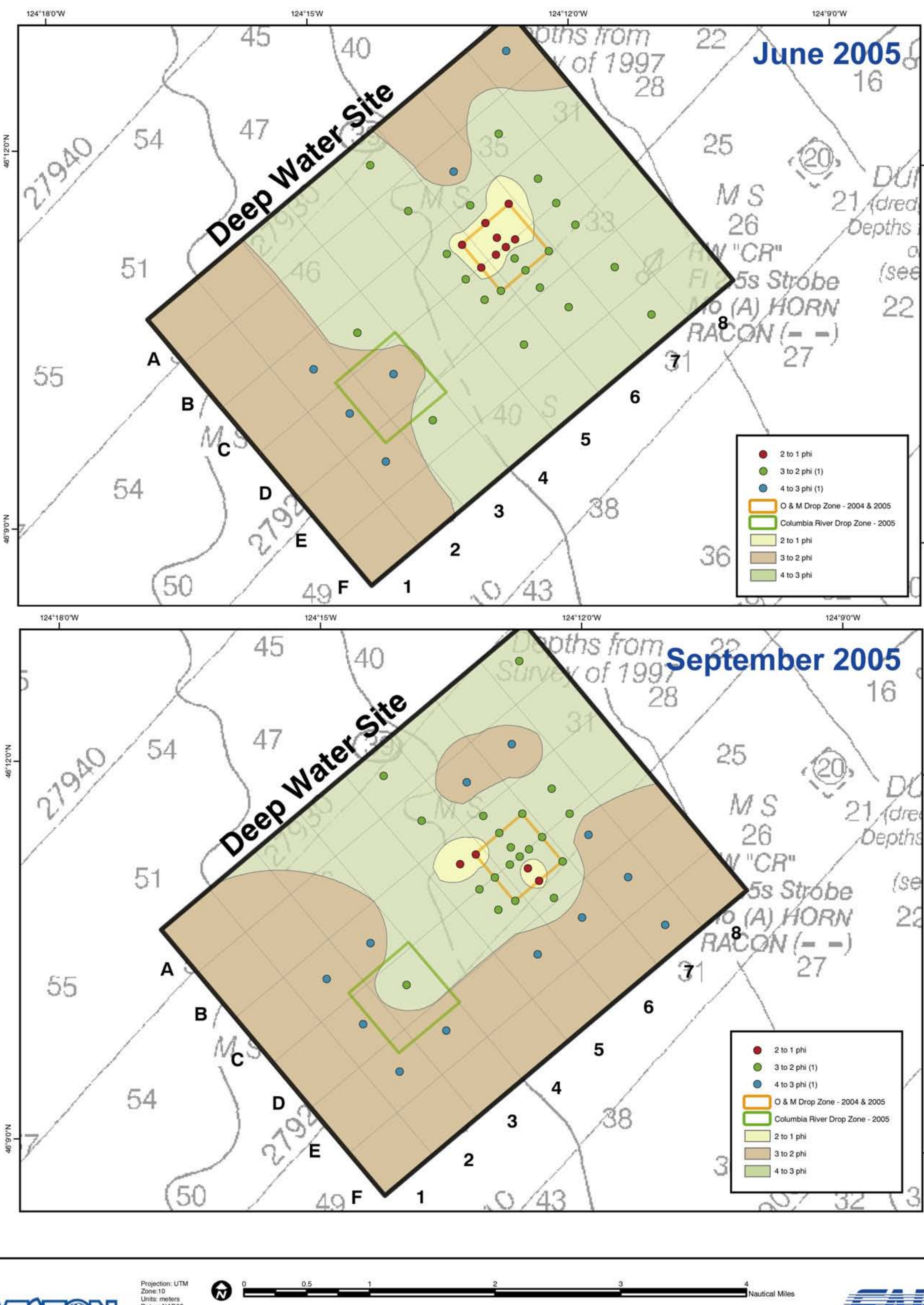


Figure 3-1. SPI Grain Size Major Mode Contours (DWS 2005)

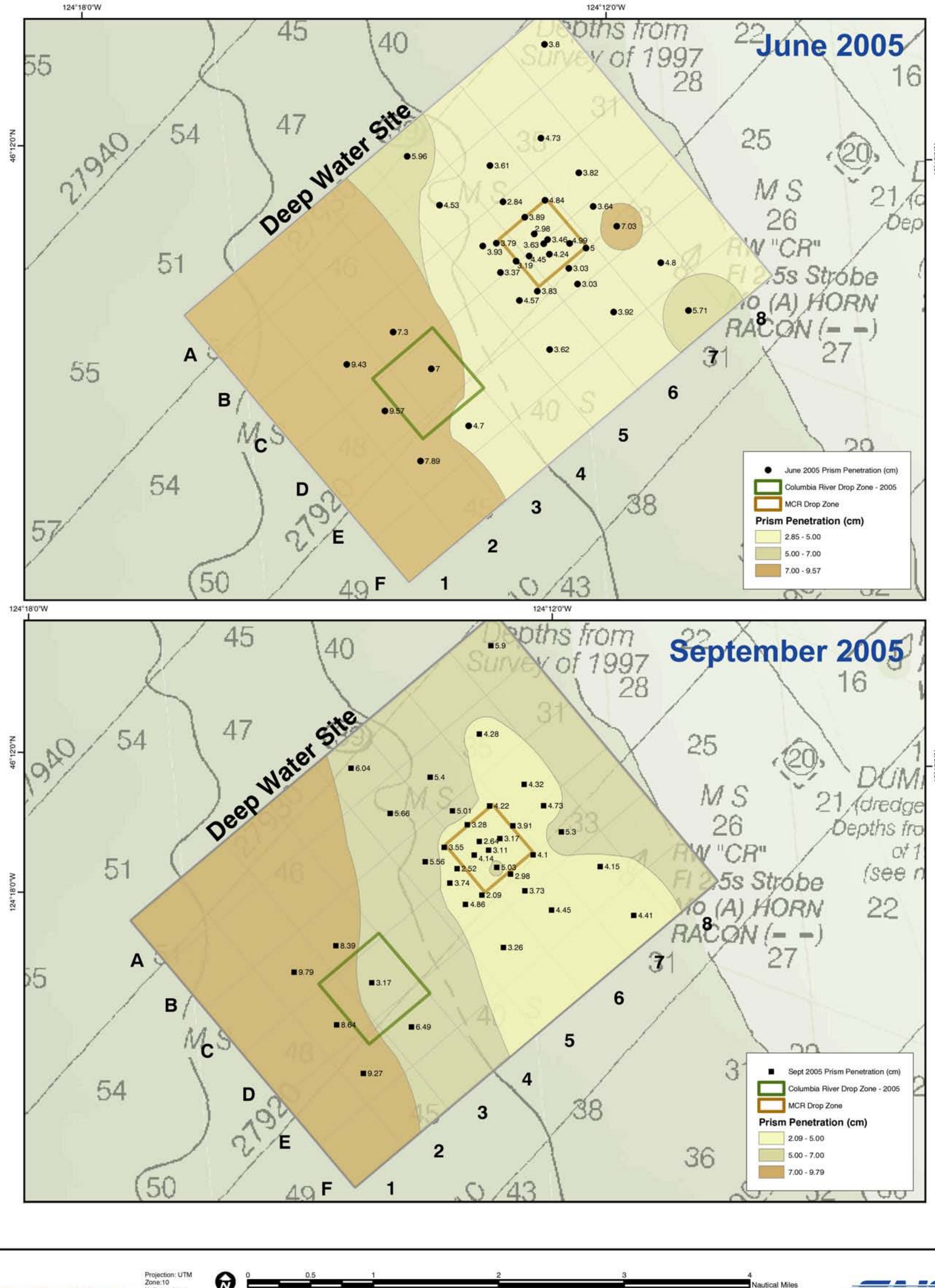
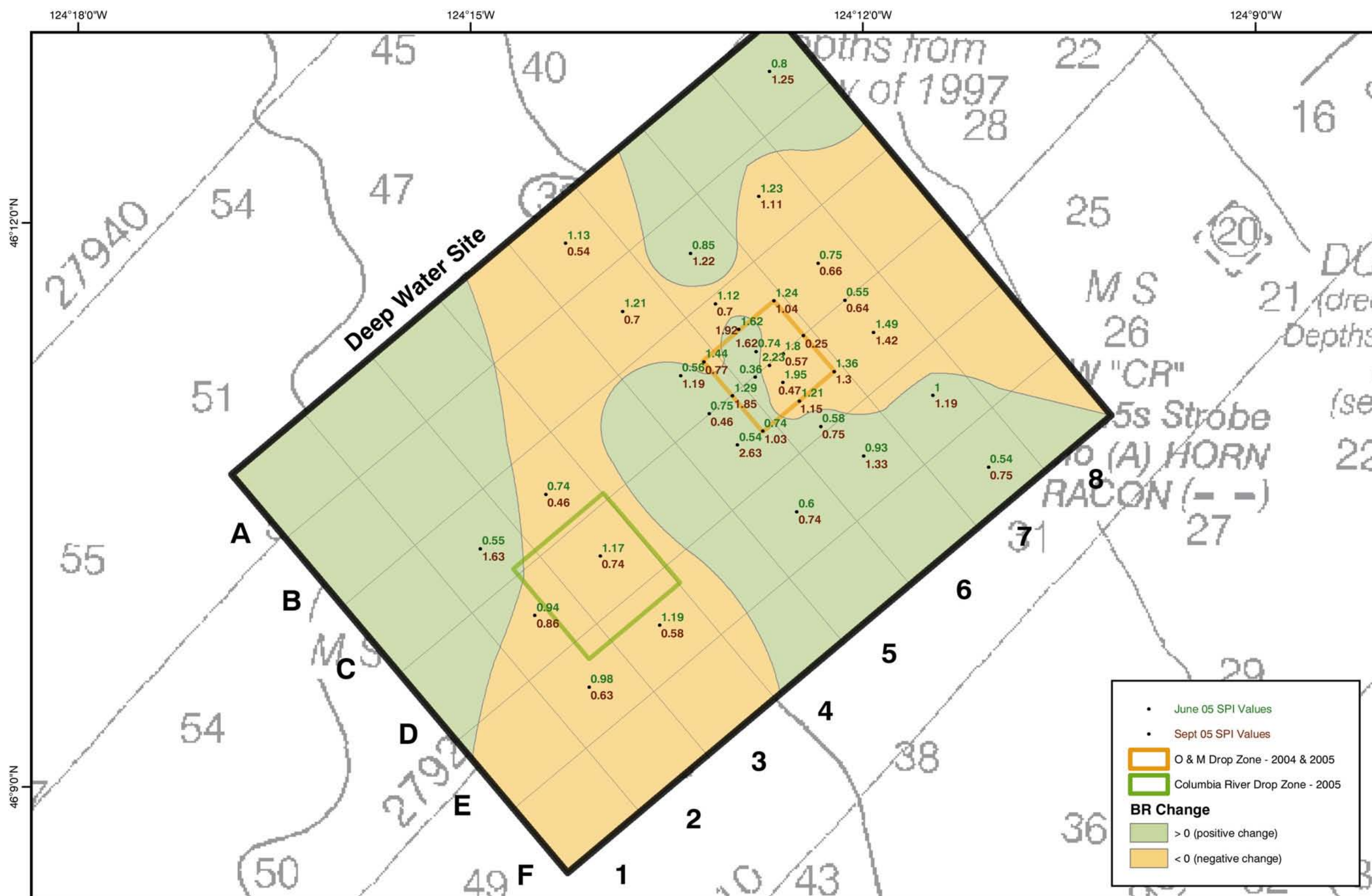


Figure 3-2. SPI Mean Prism Penetration Depth (cm) (DWS 2005)



Projection: UTM
Zone:10
Units: meters
Datum:NAD83

Figure 3-3. Change in Mean Small-scale Boundary Roughness from June 2005 to September 2005

File:C:\0440_gis\MCR\gis\Projects\2005\SEPT2005_POSTSURVEY\spi_idw\DWS_J05toS05_change_OSI.mxd 1:52000

M.Goff, SAIC, October 2005

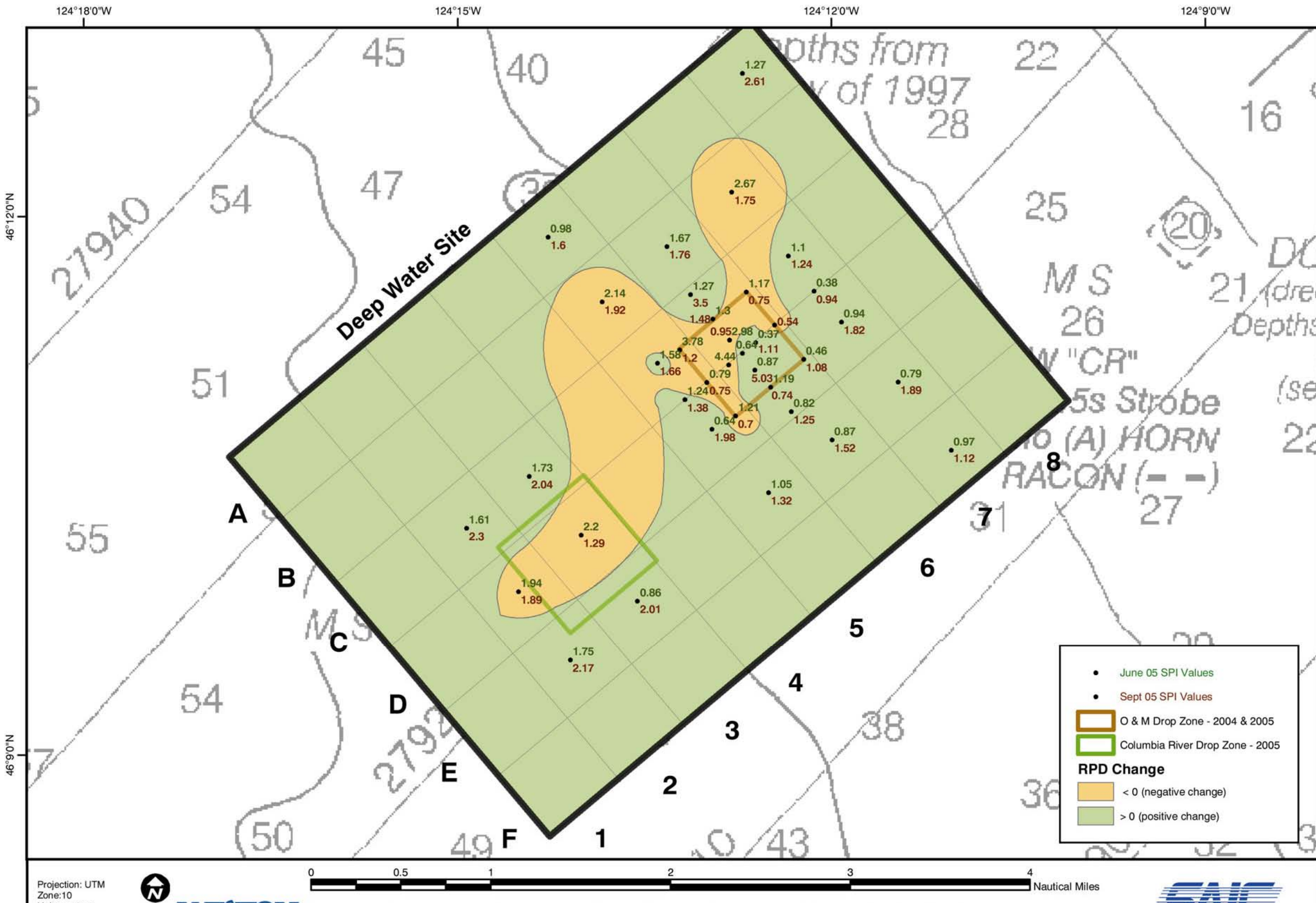


Figure 3-4. Change in Mean Redox Potential Discontinuity (cm) from June 2005 to September 2005

File:C:\0440_gis\MCR\gis\Projects\2005\SEPT2005_POSTSURVEY\report\IDW\DWS_J05toS05_change_RPD.mxd 1:52000

M.Goff, SAIC, October 2005

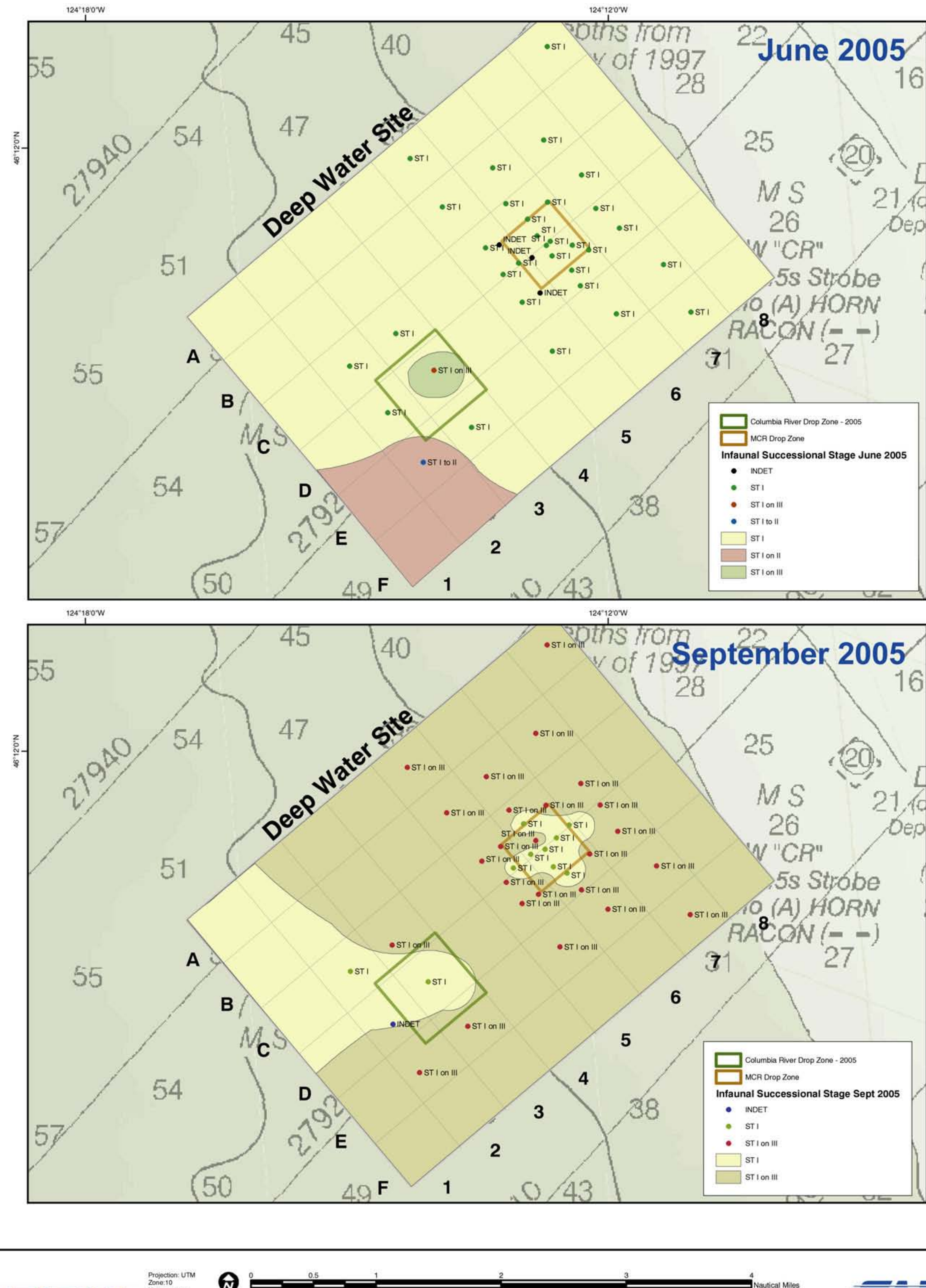


Figure 3-5. SPI Infaunal Successional Stage (DWS 2005)

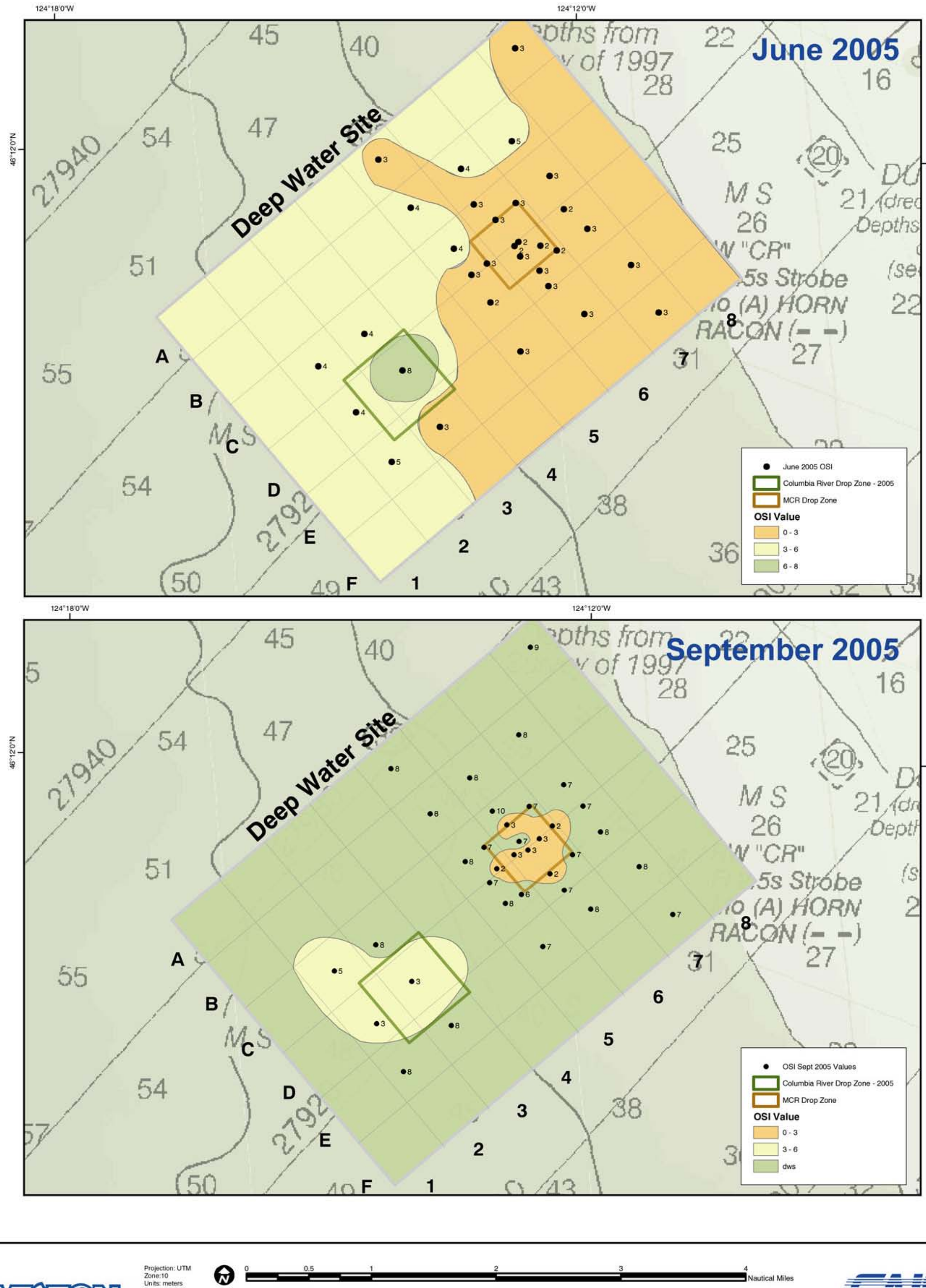


Figure 3-6. SPI Organism Sediment Index (DWS 2005)

3.2 Sediment Conventional Results

Nine sediment samples were evaluated for grain size and total organic carbon (TOC) in June and September 2005. Sediment samples were colocated with the benthic infauna samples. Sample locations are presented in Figure 2-2 and station coordinates are in Appendix A. A summary of grain size data is presented in Table 3-3 and the complete grain size distribution is provided in Appendix D.

Within the MCR-DWS sample locations, the percentage of sand was similar between June and September 2005, ranging from 97.2% to 98.7% in June and 97.3% to 98.2% in September. The percent sand measured in the two reference locations (A7 and D6-A04) were slightly lower, averaging 95.3% in June 2005 and 92.9% in September 2005. In all cases, TOC was higher in June than September 2005. The reference locations had 2 to 9 times higher TOC concentrations than sediments located within the MCR-DWS sites.

The sediment sample (D3) taken within the CR-DWS during June 2005 had similar sand and TOC content compared to the two reference samples. However, in September 2005 sediment at D3 had considerably more sand and less TOC than the reference sediments.

Table 3-3. Summary of Sediment Grain Size and Total Organic Carbon Results, MCR 2005

Station		Gravel (%)		Sand (%)		Silt + Clay (%)		TOC (%)	
		June	Sept	June	Sept	June	Sept	June	Sept
MCR-DWS	A7-00 (Ref)	0.0	0.0	93.9	90.7	6.1	9.3	0.69	0.27
	C6-b	0.2	0.4	98.7	97.3	1.1	2.4	0.08	0.06
	D6-c	0.1	0.0	98.3	98.2	1.6	1.8	0.10	0.04
	C6-a	0.1	0.4	97.2	97.6	2.7	2.0	0.11	0.05
	D6-b	0.1	0.0	98.3	98.0	1.6	2.0	0.07	0.05
	D6-A04 (Ref)	0.0	0.1	96.7	95.1	3.3	4.8	0.23	0.17
CR-DWS	B4 (Ref)	0.0	0.0	92.8	82.6	7.2	17.3	0.50	0.50
	E2 (Ref)	0.1	0.1	89.9	86.7	10.0	13.3	0.60	0.49
	D3	0.6	0.2	91.4	97.3	8.0	2.5	0.50	0.19

3.3 Benthic Invertebrate Community

Nine stations were sampled in June and September 2005 for benthic community analysis. The actual sampling locations are presented in Figure 2-2 and station coordinates are provided in Appendix A. Station locations were based on a transect along a bathymetric contour that crosses the MCR-DWS drop zone. Samples were collected at the edge of the disposal area, as well as near the center of the area. The SPI camera images were used to evaluate whether samples were collected inside or outside of the disposal area, with the presence of coarser, non-stratified sand being the primary indication of the presence of dredged material. Reference stations (Stations A7 and D6) for the MCR-DWS drop zone were located on similar bathymetric contours both north and south of the disposal area. One station was sampled in the CR-DWS disposal area, Station D3, with references along similar bathymetric contours at Stations B4 and E2.

Results of the benthic community analysis are summarized by major taxa in Tables 3-4 and 3-5, with the results for all individuals presented in Appendix E. In June 2005, mean total abundance in samples collected from the MCR-DWS reference stations (Stations A7 and D6-04) was 165 and 140 individuals per 0.1 m^2. Mean abundance in the MCR-DWS ranged from 53.7 to 111 ind./0.1 m^2, with the lowest abundance occurring at Station C6-03. Diversity was slightly higher at the reference stations (60 species), relative to the MCR-DWS stations (39 to 52 species). Molluscs and polychaetes were the dominant taxa at all MCR-DWS and corresponding reference stations, comprising 70–85% of the individuals observed.

In September 2005, mean abundance at the MCR-DWS reference stations increased, relative to the June 2005 sampling event, to 349 and 270 ind./0.1 m^2 at Stations A7 and D-04, respectively. Mean total abundance in the disposal site varied, with increased abundance at the northern edge of the site (Station C6-b), relative to June 2005. Mean abundance was similar to or lower than that of June 2005 in the samples collected in the center portions of the MCR-DWS (Stations C6-a, D6-b, and D6-c). Similar trends were observed with diversity, with the mean number of species increasing at the reference stations and Station C6-b and decreased diversity at Stations C6-a, D6-b, and D6-c. As in June 2005, the dominant taxa were molluscs and polychaetes.

The benthic community observed in June 2005 at the deeper CR-DWS drop zone and corresponding reference stations was characterized by greater abundance than in the shallower areas. Abundance at the CR-DWS reference stations was 306 and 256 ind./0.1m^2 and diversity was 59 species for Stations B4 and E2, respectively. Mean abundance at the CR-DWS (Station D3) in June 2005 was 220 ind./0.1m^2, representing 89 species. Polychaetes were the dominant taxa at all three stations in June 2005.

In September 2005, abundance at the CR-DWS reference stations increased to 410 and 536 ind./0.1m^2 for Stations B4 and E2, respectively. Diversity at the reference stations remained similar to or higher than that of June 2005. Both mean abundance and diversity in the MCR-DWS was substantially lower than in June 2005, with 46 ind./m^2, represented by 31 species. As in June 2005, polychaetes were the dominant taxa at the reference stations, comprising 75% of all individuals observed. However, polychaetes were less dominant within the CR-DWS, with increased numbers of crustaceans and molluscs.

To better understand the benthic community at each of the stations, cluster analysis was performed on the June and September 2005 datasets combined (Figure 3-7). The cluster analysis grouped stations that were similar to each other based on the numbers of each species that were observed. This not only allows for an understanding of which stations are similar to and dissimilar from each other, but also which species characterize the benthic community at the different station groupings.

In June 2005, the MCR-DWS reference stations A7 and D6-04 were clustered with MCR-DWS Station C6-00 (at the northern edge of the drop zone area) in Group A1a (Table 3-6). The benthic community at these stations was dominated by the clam, *Axinopsida serricata*, the ostracod, *Euphilomedes carcharodonta*, and the polychaetes Euclymeninae sp A. and *Leitoscopolos pugettensis*.

Stations within the MCR-DWS sampled in June 2005 were clustered into Group A1b, with the exception of Station C6-00, which was in Cluster A1a. The benthic community at Group A1b stations was also dominated by *A. serricata*, Euclymeninae sp A., as well as the polychaetes, *Spiophanes bombyx* and *L. pugettensis*. While the species composition in Group A1b was not dramatically different from that of the reference stations, this group was distinguished by the lower abundance of those dominant species.

In September 2005, the benthic community in reference stations A7 and D6-a were similar, clustering in Group B2a (Table 3-7). As in June 2005, the benthic community was dominated by *A. serricata* and *E. carcharodonta*. However, there was also dominance by the polychaetes *Pectinaria californiensis* and *Galatowenia oculata*. All of the MCR-DWS stations were grouped together with a species composition that was similar to that of June 2005. The community in the disposal area was domnated by *Spiophanes* spp.

and *L. pugettensis*. As in June 2005 Station C6-00, the corresponding September Station C6-B differed slightly from the other MCR-DWS stations, with a higher abundance of *A. serricata*.

At the CR-DWS, both of the reference stations and disposal site (Station D3) clustered similarly in June 2005 (Group B2b). The benthic community at these stations was dominated by the polychaete *Magelona* sp. with smaller numbers of the polychaetes *Scoletoma luti* and *P. californiensis*.

Interestingly, in September 2005 the reference stations for CR-DWS clustered with those of the MCR-DWS. As in June 2005, the community was dominated by *Magelona* sp.; however, *P. californiensis* and *G. oculata* were also dominant species. Station D3, in the CR-DWS, was an outlier (Group B2a OL), primarily due to the decreased abundance of common species, rather than due to a shift in the species present.

Table 3-4. Summary of Benthic Infauna Abundance (June 2005)

Taxon	MCR-DWS Ref		MCR-DWS				CR-DWS	CR-DWS Ref	
	A7	**D6-04**	**C6-00**	**C6-03**	**CD6-02**	**D6-01**	**D3**	**B4-00**	**E2**
Mean Total Abundance	**165**	**140**	**74.3**	**53.7**	**111**	**109**	**220**	**306**	**256**
Mean Number of Species	**62**	**60**	**51**	**39**	**52**	**39**	**89**	**59**	**59**
Abundance (Percentage of Total)									
Crustaceans	17	28	15	9	12	14	11	9	4
Echinoderms	5	1	5	6	1	4	6	3	4
Minor Phyla	1	0	0	0	2	1	2	4	3
Molluscs	38	25	43	50	28	43	16	9	14
Polychaetes	39	45	37	35	56	38	65	75	76
Number of Species (Percentage of Total)									
Crustaceans	19	23	18	17	23	25	13	14	12
Echinoderms	8	5	8	8	3	9	5	5	7
Minor Phyla	3	1	0	0	7	3	8	8	12
Molluscs	21	24	26	37	26	25	23	20	25
Polychaetes	49	48	49	38	41	39	51	53	44

Table 3-5. Summary of Benthic Infauna Abundance (September 2005)

Taxon	MCR-DWS Ref		MCR-DWS				CR-DWS	CR-DWS Ref	
	A7	D6-a	C6-b	C6-a	D6-c	D6-b	D3	B4	E2
Mean Total Abundance	**349**	**270**	**150**	**52**	**128**	**81**	**46**	**410**	**536**
Mean Number of Species	**83**	**75**	**62**	**35**	**48**	**36**	**31**	**56**	**72**
Abundance (Percentage of Total)									
Crustaceans	11	22	10	17	10	12	16	9	4
Echinoderms	2	3	3	1	3	2	7	3	3
Minor Phyla	1	1	1	0	1	2	0	2	1
Molluscs	28	27	36	18	33	26	35	13	14
Polychaetes	58	47	50	63	53	58	42	74	78
Number of Species (Percentage of Total)									
Crustaceans	11	24	16	25	21	24	21	13	16
Echinoderms	4	3	5	4	6	6	5	5	4
Minor Phyla	6	3	4	0	5	4	0	9	4
Molluscs	19	18	23	25	29	25	34	22	32
Polychaetes	60	52	52	45	39	41	39	51	44

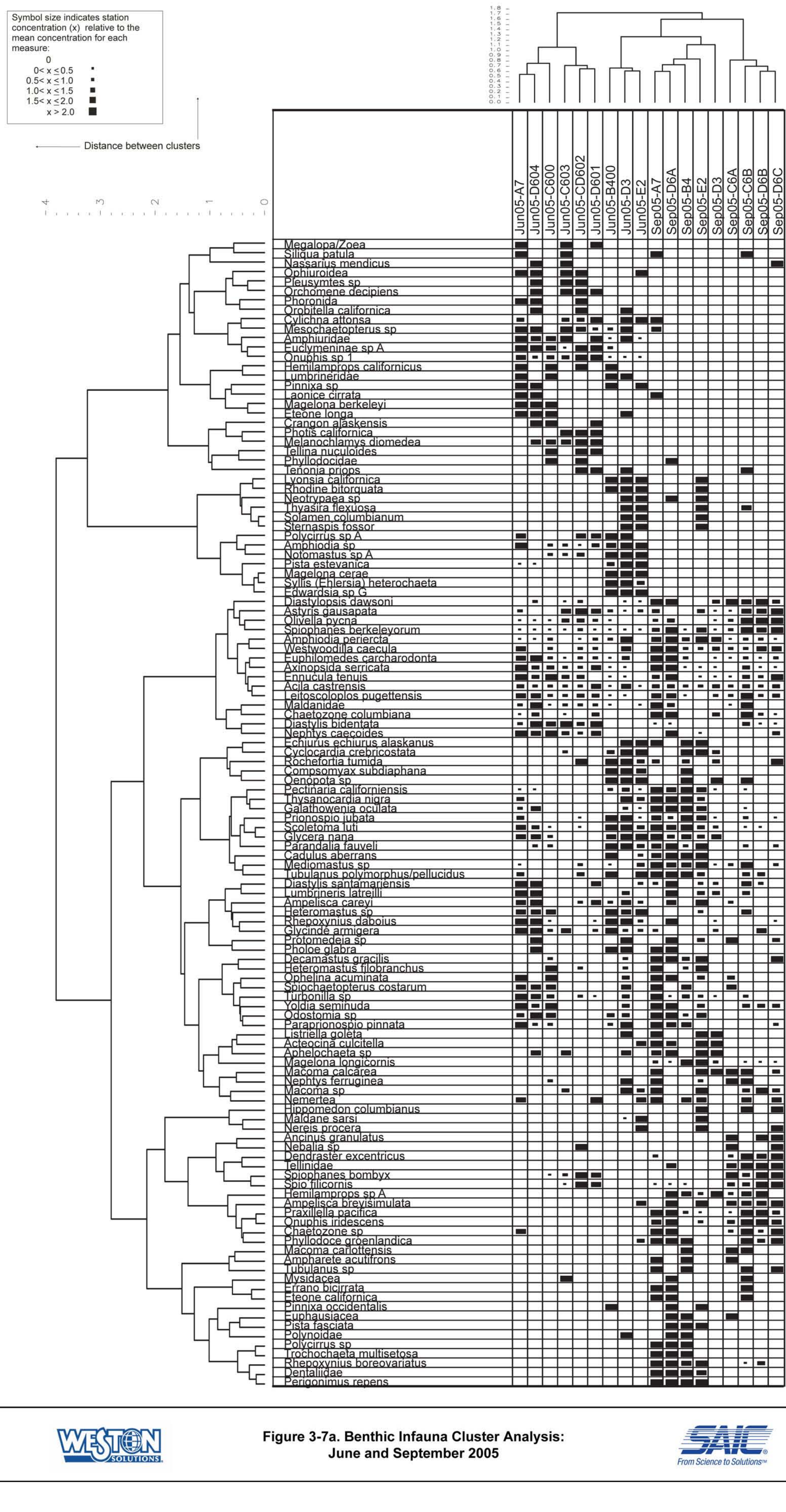


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Figure 3-7a. Benthic Infauna Cluster Analysis: June and September 2005

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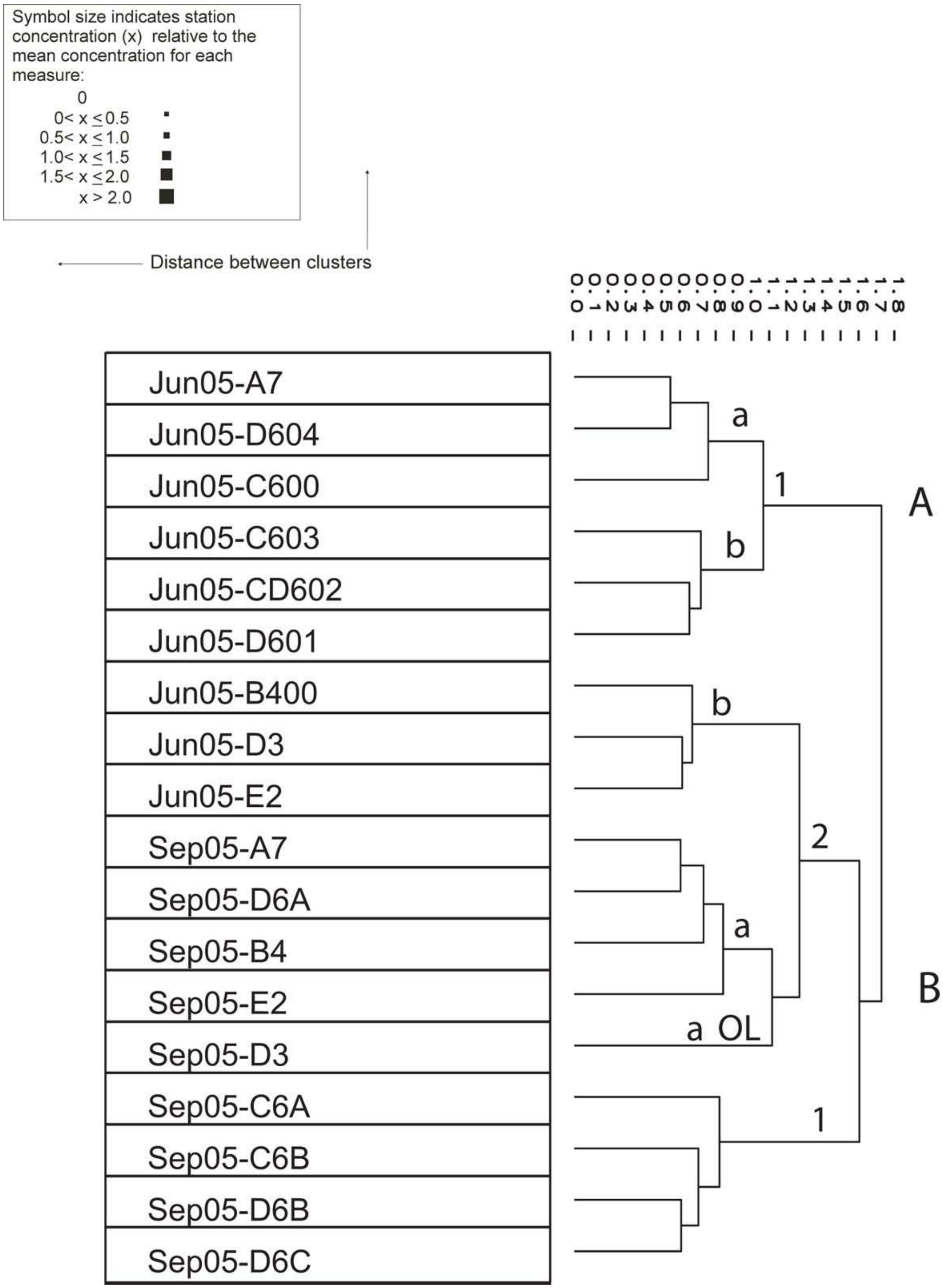

Figure 3-7b. Benthic Infauna Cluster Diagram

Table 3-6. Summary of Dominant Species Abundance for 70% of Individuals in June 2005

SPECIES	A7 (REF)			D6-04 (REF)			C6-00			Cluster A1a	
	1	2	3	1	2	3	1	2	3	Mean	Percent of Total
Axinopsida serricata	**45**	**30**	**39**	**10**	**18**	**23**	**7**	**4**	**39**	**22.0**	**17.9**
Euphilomedes carcharodonta	**11**	**13**	**24**	**30**	**27**	**22**	1	1	**14**	**16.3**	**13.3**
Euclymeninae sp A	**13**	11	16	7	9	**33**	0	2	**17**	**11.9**	**9.7**
Leitoscoloplos pugettensis	7	10	**23**	5	**14**	14	**4**	1	10	**10.0**	**8.2**
Scoletoma luti	9	**13**	6	0	12	7	0	0	5	**5.5**	**4.5**
Acila castrensis	10	3	8	5	4	6	0	**4**	7	**4.8**	**3.9**
Turbonilla sp	10	6	8	2	5	3	0	0	6	**3.9**	**3.2**
Ennucula tenuis	3	3	4	2	3	2	2	1	10	**3.4**	**2.7**
Galathowenia oculata	5	4	3	3	5	11	0	0	0	**3.3**	**2.7**
Maldanidae	1	2	1	**6**	9	2	0	1	1	**2.7**	**2.2**
Rhepoxynius daboius	4	3	4	5	5	2	0	0	1	**2.5**	**2.1**

SPECIES	C6-03			CD6-02			D6-01			Cluster A1b	
	1	2	3	1	2	3	1	2	3	Mean	Percent of Total
Axinopsida serricata	**11**	**12**	**11**	1	4	**26**	**29**	**41**	**15**	**15.6**	**17.4**
Spiophanes bombyx	0	**4**	**6**	**18**	**9**	11	10	**13**	5	**8.4**	**9.3**
Euclymeninae sp A	3	2	0	6	**10**	**28**	**11**	**10**	5	**8.3**	**9.2**
Leitoscoloplos pugettensis	5	**5**	**9**	2	3	**17**	10	8	**9**	**7.4**	**8.3**
Acila castrensis	**8**	**4**	2	3	**10**	5	**13**	8	7	**6.4**	**7.2**
Spio filicornis	0	2	0	**15**	**9**	9	4	5	1	**5.2**	**5.7**
Euphilomedes carcharodonta	1	1	0	4	2	16	8	7	**9**	**5.1**	**5.7**
Olivella pycna	**9**	2	1	**7**	6	4	5	6	0	**4.5**	**5.0**
Onuphis sp 1	1	1	1	3	2	12	3	5	4	**3.5**	**3.9**

SPECIES	D3			E2 (REF)	B4-00 (REF)	Cluster B2b	
	1	2	3	1	1	Mean	Percent of Total
Magelona sp.	**59**	**33**	**118**	**63**	**79**	**70.7**	**38.9**
Scoletoma luti	**21**	15	0	**18**	**41**	**23.7**	**13.0**
Maldane sarsi	0	0	2	**50**	0	**16.9**	**9.3**
Pectinaria californiensis	2	**16**	10	8	**20**	**12.4**	**6.8**
Acila castrensis	4	**16**	10	9	6	**8.3**	**4.6**
Euphilomedes carcharodonta	8	**16**	**15**	0	11	**8.0**	**4.4**
Pista estevanica	9	3	7	13	3	**7.4**	**4.1**
Rhepoxynius daboius	6	3	7	3	11	**6.4**	**3.5**
Notomastus sp. A	8	4	5	6	5	**5.6**	**3.1**
Amphiodia sp.	**10**	7	2	6	4	**5.4**	**3.0**
Prionospio jubata	2	2	**11**	2	9	**5.3**	**2.9**
Leitoscoloplos pugettensis	2	2	6	0	9	**4.1**	**2.3**
Cyclocardia crebricostata	3	1	3	8	2	**4.1**	**2.3**
Amphiodia periercta	4	4	8	0	5	**3.4**	**1.9**

Bold: Bold values in **red** indicate the top three species by abundance.
REF: reference location

Table 3-7. Summary of Dominant Species Abundance for 70% of Individuals in September 2005

SPECIES	C6-a			C6-b			D6-b			D6-c			Cluster B1	
	1	2	3	1	2	3	1	2	3	1	2	3	Mean	Percent of Total
Spiophanes bombyx	**26**	**10**	**10**	4	7	5	**18**	**16**	**8**	**25**	**15**	**32**	**15**	**14**
Olivella pycna	4	0	2	**13**	**21**	**22**	**10**	**16**	1	1	**21**	**29**	**12**	**11**
Spiophanes berkeleyorum	2	4	**6**	**26**	**11**	13	**8**	5	**13**	**12**	**14**	**22**	**11**	**11**
Leitoscoloplos pugettensis	**8**	**7**	1	12	**10**	**26**	2	5	6	**6**	8	8	**8**	**8**
Acila castrensis	4	3	**5**	8	8	8	5	6	6	5	12	8	**7**	**6**
Axinopsida serricata	0	0	0	**13**	5	**32**	1	0	3	2	**14**	4	**6**	**6**
Spio filicornis	4	2	2	2	3	3	6	**11**	5	5	5	16	**5**	**5**
Praxillella pacifica	0	3	0	4	6	16	2	6	**9**	3	3	5	**5**	**5**
Euphilomedes carcharodonta	1	0	0	8	2	12	3	3	0	0	7	12	**4**	**4**

SPECIES	A7 (REF)			D6-a (REF)			B4 (REF)	E2 (REF)	Cluster B2a	
	1	2	3	1	2	3	1	1	Mean	Percent of Total
Magelona sp.	1	2	6	2	2	1	**67**	**173**	**61**	**22**
Pectinaria californiensis	**82**	**66**	**65**	9	8	23	**84**	**39**	**52**	**18**
Axinopsida serricata	**111**	**33**	**28**	**54**	**42**	**36**	2	13	**29**	**10**
Galathowenia oculata	15	9	**27**	**32**	**19**	10	**41**	23	**25**	**9**
Scoletoma luti	11	9	24	9	15	6	39	23	**22**	**8**
Euphilomedes carcharodonta	**37**	19	21	**40**	**31**	**36**	24	0	**21**	**8**
Maldane sarsi	0	0	0	0	0	0	0	**63**	**16**	**6**
Spiophanes berkeleyorum	5	3	15	17	6	**28**	7	30	**15**	**5**
Acila castrensis	6	10	9	9	11	7	13	14	**11**	**4**
Amphiodia urtica/periercta	4	5	4	8	9	5	8	16	**9**	**3**
Dentaliida	11	11	4	8	3	6	12	6	**8**	**3**
Praxillella pacifica	0	0	16	18	13	22	7	2	**8**	**3**
Euclymene sp A	33	**23**	16	2	3	3	0	0	**7**	**2**
Leitoscoloplos pugettensis	14	11	12	18	12	8	2	0	**7**	**2**

SPECIES	D3			Cluster B2a OL	
	1	2	3	Mean	Percent of Total
Acila castrensis	**9**	**10**	**5**	**8**	**17**
Scoletoma luti	**6**	**5**	**5**	**5**	**12**
Magelona sp.	3	**4**	**8**	**5**	**11**
Leitoscoloplos pugettensis	**6**	3	3	**4**	**9**
Amphiodia urtica/periercta	5	2	3	**3**	**7**
Axinopsida serricata	3	2	4	**3**	**6**
Hemilamprops sp.	**7**	1	0	**3**	**6**
Euphilomedes carcharodonta	2	2	1	**2**	**4**

Bold: Bold values in **red** indicate the top three species by abundance.
REF: reference location

3.4 Dungeness Crab Results

This section presents the results of the 2005 DWS Dungeness crab monitoring survey conducted using commercial crab pots. The June crab sampling event took place over a three-day period from June 1 to June 4, 2005. The September crab sampling event took place over a two-day period from September 16 to September 18, 2005. The data results are presented for each location and sampling event with respect to relative abundance at the DWS, CPUE, sex, size class, and shell strength.

3.4.1 Dungeness Crab Catch per Unit Effort

A slight deviation from the sampling protocol for the Dungeness crab survey involved the soak time for commercial crab pots. The June 2005 sampling event included a replicate with an extended soak time of 48 hours for Replicate 1 due to adverse weather conditions, whereas the soak time for Replicate 2 remained at 24 hours. Two crab pots (both Replicate 2) were non-recoverable resulting in a 96% pot recovery for the June 2005 surveys, whereas three crab pots were unrecoverable (all Replicate 2) in September 2005, resulting in a 94% recovery. However, the total Dungeness crab catch increased from June to September 2005, despite the extended soak time for the one June replicate. The total June 2005 catch of 1,471 crabs, averaging 21.0 crabs/pot/day (Table 3-8)[2], was only slightly lower than the total September 2005 catch of 1,752 crabs, with an average of 38.9 crabs/pot/day (Table 3-9). The CPUE-based interpolated figures (Figure 3-8) are normalized to crabs caught per day based on crab pot soak time. The catch abundances for June 2005 take into account the extra day of crab pot soak time, thereby potentially underestimating the relative abundance of crabs present during the spring survey, as increased soak time is not linear with regard to CPUE (Briand et al. 2004; Zhou and Kruse 1999; Hankin et al. 1985). However, using a CPUE based on total crab pot drops (June 2005 = 46; September 2005 = 45), regardless of soak time, the total number of crabs/pot/drop would have still been lower in June 2005 (32.0) than during the September 2005 collection effort (38.9). Therefore, it is not believed that the additional soak time affects the overall data quality or usability of the Dungeness crab abundance data.

[2] The study design for the monitoring survey was to have equivalent soak times (i.e., one unit effort = 24 hours) for each crab pot deployment to normalize the level-of-effort for each pot. The monitoring study was not designed to determine the optimal soak time for a commercial crab pot, nor to determine the rate of catch based on the total number of hours of crab pot soak time.

Table 3-8. Summary of June 2005 Dungeness Crab Catch

STATION	Replicate 1		Replicate 2		June Totals	
	Catch	Soak Time (days)	Catch	Soak Time (days)	Total Catch	Catch / Day
DWS Locations outside of dredged material drop zones						
A6-00	48	2	LOST	0	48	24
B5-00	45	2	35	1	80	26.7
B6-00	32	2	20	1	52	17.3
C3-00	21	2	7	1	28	9.3
C7-00	31	2	42	1	73	24.3
D2-00	33	2	28	1	61	20.3
D4-00	40	2	15	1	55	18.3
D7-00	30	2	44	1	74	24.7
E2-00	52	2	22	1	74	24.7
E3-00	46	2	34	1	80	26.7
E5-00	27	2	26	1	53	17.7
E6-00	32	2	20	1	52	17.3
F1-00	36	2	30	1	66	22
F6-00	21	2	23	1	44	14.7
Mean:	**35.3**	**Mean:**	**26.6**	**Mean:**	**60.0**	**20.6**
MCR-DWS Drop Zone Locations						
C5-01	42	2	46	1	88	29.3
C6-00	28	2	26	1	54	18
C6-02	32	2	LOST	0	32	16
CD5-02	41	2	39	1	80	26.7
CD6-02	33	2	30	1	63	21
CD6-04	25	2	23	1	48	16
D5-01	24	2	32	1	56	18.7
D6-00	36	2	43	1	79	26.3
D6-03	30	2	41	1	71	23.7
Mean:	**32.3**	**Mean:**	**35.0**	**Subtotals:**	**63.4**	**21.7**
CR-DWS Drop Zone Locations						
D3-00	32	2	23	1	55	18.3
			DWS Total		**1471**	**503.7**
			Avg #/ Pot/Day	**70 pot days**		**21.0**

Table 3-9. Summary of September 2005 Dungeness Crab Catch

STATION	Replicate 1		Replicate 2		September Totals	
	Catch	Soak Time (days)	Catch	Soak Time (days)	Total Catch	Catch / Day
DWS Locations outside of dredged material drop zones						
A6-00	56	1	37	1	93	46.5
B5-00	34	1	22	1	56	28.0
B6-00	40	1	30	1	70	35.0
B7-00	50	1	17	1	67	33.5
C5-00	41	1	34	1	75	37.5
C6-01	38	1	34	1	72	36.0
C7-00	60	1	49	1	109	54.5
D5-00	34	1	24	1	58	29.0
D6-04	29	1	33	1	62	31.0
D7-00	14	1	LOST	0	14	14.0
E5-00	55	1	33	1	88	44.0
E6-00	45	1	LOST	0	45	45.0
E7-00	24	1	31	1	55	27.5
F5-00	60	1	46	1	106	53.0
F6-00	51	1	38	1	89	44.5
Mean:	42.1	**Mean:**	32.9	**Mean:**	70.6	37.3
MCR-DWS Drop Zone Locations						
C5-01	30	1	33	1	63	31.5
C6-02	43	1	36	1	79	39.5
C6-00	54	1	46	1	100	50.0
CD5-02	41	1	32	1	73	38.0
CD6-02	60	1	45	1	105	52.5
CD6-04	32	1	LOST	0	32	32.0
D5-01	39	1	33	1	72	36.0
D6-00	50	1	42	1	92	46.0
D6-03	42	1	32	1	74	37.0
Mean:	43.4	**Mean:**	37.4	**Mean:**	76.7	40.3
			Total		**1752**	**921.5**
			Avg #/ Pot/Day	**45 pot days**		**38.9**

Note: No crab pots were placed within the CR-DWS drop zone during the September sampling event due to ongoing dredged material placement.

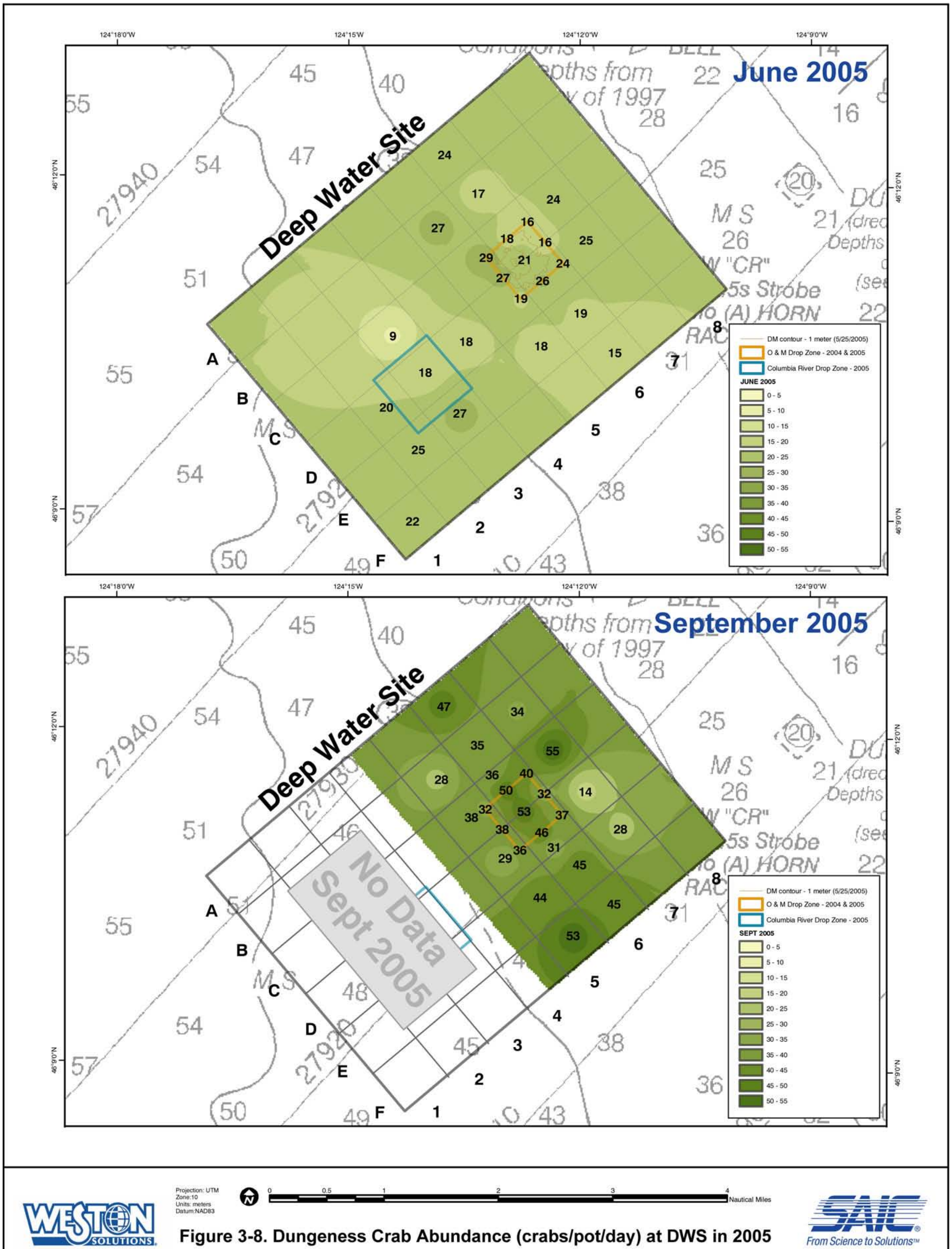

Figure 3-8. Dungeness Crab Abundance (crabs/pot/day) at DWS in 2005

3.4.2 Size Class

Size frequency distributions were created to provide a visual representation of the population structure of the catchable crabs present at the DWS during the two sampling events. Dungeness crab data were categorized into five size classes, similar to those assigned by McCabe and McConnell (1989), but revised to provide more even distribution for older crab populations: I (0–49 mm), II (50–99 mm), III (100–129 mm), IV (129–159 mm), and V (>159 mm). As discussed by McCabe and McConnell (1989) different age groups of Dungeness crabs often have overlapping carapace width distributions, particularly in the larger crabs, due to sampling during and immediately following molting periods. Since the DWS sampling occurred during the molting season, the crab data were separated into specific size classes, rather than age classes.

Crab pot data provided a relatively consistent pattern with regard to sexual representation in the surveys. The June 2005 catch was comprised of 80% males, and the September 2005 catch was comprised of 75% males. There was a slight increase in mean carapace width from 145.5 mm in June to 153.7 mm in September 2005 (Table 3-10). This was largely due to the relative absence of the larger, commercially harvestable, age class (>159 mm) in the June 2005 survey (5%) to being the second most prevalent age class in the September 2005 surveys (39%). The visual representation of the size frequency shift is presented in Figures 3-9 and 3-10. The commercially harvestable males comprise a small portion of the population in June 2005, prior to molting, followed by a greater abundance in September 2005. As further evidence of this summer molting, the softness of the crabs increased from 9% of the measured crabs in June 2005, to 66% of the measured crabs in September 2005.

3.4.3 Dungeness Crab Caught in Bottom Trawls

The total number of Dungeness crabs caught using the bottom trawl increased from 34 in June to 116 in September 2005 (Tables 3-11 and 3-12). Based on the trawl width (4.3 m) and transect lengths, the estimated density based on these trawls increased from 12.0 crabs/hectare in June to 38.9 crabs/hectare in September 2005. In both of these sampling events, the density distribution was consistent with the greatest density caught in Trawl A, followed by B, D, and then C.

Similar to the crab pot data, the trawl-caught crabs displayed an increase in mean carapace width from 137.2 mm in June to 145.4 in September 2005. This was largely due to the relative absence of the larger, commercially harvestable, age class (>159 mm) in June 2005 (9%) to being the second most prevalent age class in September 2005 (28%). The size frequencies are presented in Figures 3-11 and 3-12, where the commercially harvestable males shift from being a small portion of the population in June to a much larger post-molt population in September 2005.

3.4.4 Dungeness Crab Collection Method Comparison

A comparison between the crab collection techniques indicates that crab pot deployment, on average, caught more and slightly larger crabs than the bottom trawls (Table 3-13). For example, in the September 2005 sampling event the eight trawls (four sites, two replicates each) swept an area of nearly 3 hectares, capturing 116 crabs with a mean carapace width of 145.4 mm. However, the 45 retrievals of September 2005 crab pots captured 1,748 crabs (1,703 measured) with a mean carapace width of 153.7 mm. A similar pattern was observed during the June 2005 survey.

Multiple cohorts were present at both sites during each sampling event, regardless of collection method. Crab population structure at these two sites is primarily comprised of adult crabs (Size Class III, IV, and V), with almost no juvenile or sub-adult (Size Class I and II) crabs. Trawls on average caught smaller size classes of crabs than the crab pots. Crab pots, in general, were more efficient in total catch, provided a better sampling method for determining population structure, and provided a slightly larger range in size of crabs captured.

The difference in catch totals between the trawls and crab pots is likely due to active vs. passive fishing methods. The trawls only captured the crabs that were present on the bottom at the time the net swept across the transect. The crab pots were deployed for 24 hours at a time (for this study) and attracted any foraging crabs that passed through the odor corridor of the baited traps. It should also be noted that the sampling efficiency of the modified Willis otter trawl is unknown, and as noted in McCabe et al. (1985), sampling efficiencies for different size classes of crabs may also differ. Gotshall (1978) estimated the sampling efficiency for his 4.9 m bottom trawl in Humboldt Bay, CA, at about 50%.

Table 3-10. Crab Size Class Distribution and Shell Strength

Date	Method	Gender	Total Crabs Measured[1]	Min CW[1] (mm)	Max CW[1] (mm)	Mean CW[1] (mm)	Size Class Distribution Percentages (based on measured crabs)[1]					% Soft[1]
							I (<50 mm)	II (50-99 mm)	III (100-129 mm)	IV (130-159 mm)	V (>159 mm)	
June 2005	Pot	Female	289	113	158	137.3	0%	0%	18%	82%	0%	9%
		Male	1172	108	186	147.5	0%	0%	4%	90%	7%	10%
		Total	1461	108	186	145.5	0%	0%	6%	88%	5%	9%
	Trawl	Female	10	118	139	127.9	0%	0%	70%	30%	0%	na[2]
		Male	24	120	175	141.1	0%	0%	21%	67%	13%	na[2]
		Total	34	118	175	137.2	0%	0%	35%	56%	9%	na[2]
September 2005	Pot	Female	422	110	183	136.1	0%	0%	21%	78%	1%	37%
		Male	1281	111	190	159.5	0%	0%	2%	46%	52%	76%
		Total	1703	110	190	153.7	0%	0%	7%	54%	39%	66%
	Trawl	Female	20	116	157	131.4	0%	0%	45%	55%	0%	40%
		Male	96	99	183	148.3	0%	1%	22%	44%	33%	83%
		Total	116	99	183	145.4	0%	1%	26%	46%	28%	76%

1. Sampling protocol dictated that up to 50 randomly selected crabs were measured and sexed from each sampling location (i.e., crab pot); catches greater than 50 individuals were simply enumerated.
2. Shell strength data were not recorded for crab in June 2005 trawl samples.
CW: carapace width

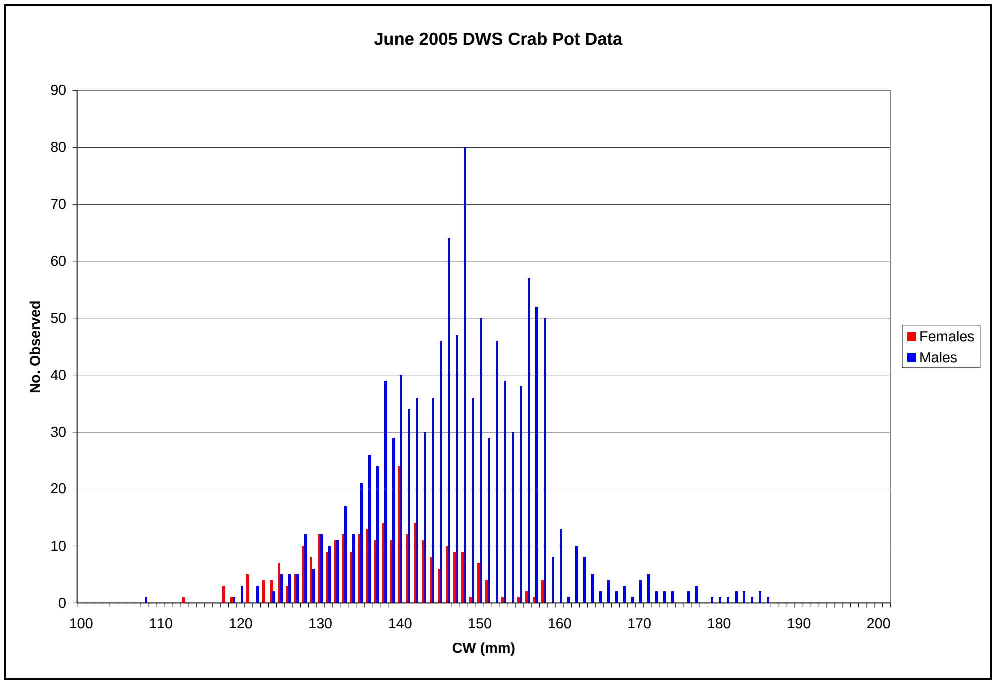

Figure 3-9. June 2005 Size Frequency Distribution for Dungeness Crabs (crab pots)

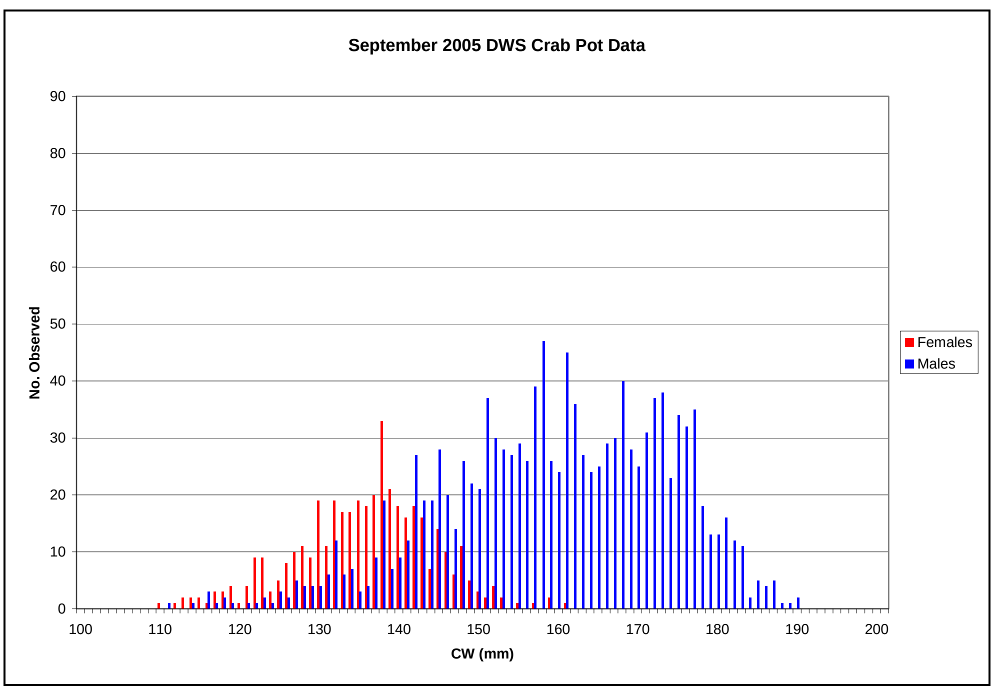

Figure 3-10. September 2005 Size Frequency Distribution for Dungeness Crabs (crab pots)

Table 3-11. Dungeness Crab Catch in June 2005 Trawls

Station	Date	Catch	Meters Trawled	Hectares Surveyed	Crabs / Hectare	Crabs / Trawl Area
A1	6/5/2005	5	746	0.34	14.7	25.0
A2	6/5/2005	12	744	0.34	35.3	
B1	6/6/2005	6	774	0.36	16.7	9.7
B2	6/6/2005	1	782	0.36	2.8	
C1	6/6/2005	3	711	0.33	9.1	4.6
C2	6/6/2005	0	695	0.32	0	
D1	6/6/2005	2	903	0.42	4.8	8.9
D2	6/6/2005	5	800	0.37	13.5	
Total		**34**	**6155**	**2.84**	**12**	

Table 3-12. Dungeness Crab Catch in September 2005 Trawls

Station	Date	Catch	Meters Trawled	Hectares Surveyed	Crabs / Hectare	Crabs / Trawl Area
A1	9/18/2005	36	759	0.35	102.9	88.4
A2	9/17/2005	25	742	0.34	73.5	
B1	9/18/2005	14	725	0.33	42.4	32
B2	9/18/2005	10	919	0.42	23.8	
C1	9/18/2005	4	904	0.42	9.5	13.8
C2	9/18/2005	7	829	0.38	18.4	
D1	9/17/2005	18	738	0.34	52.9	27
D2	9/17/2005	2	862	0.4	5	
Total		**116**	**6478**	**2.98**	**38.9**	

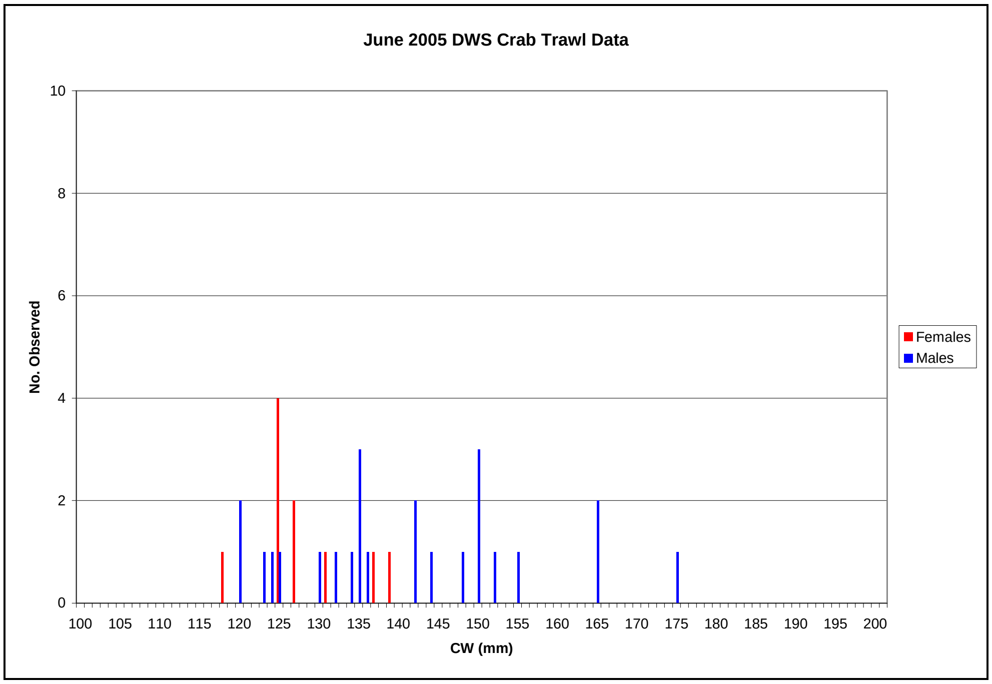

Figure 3-11. June 2005 Size Frequency Distribution for Dungeness Crabs (bottom trawls)

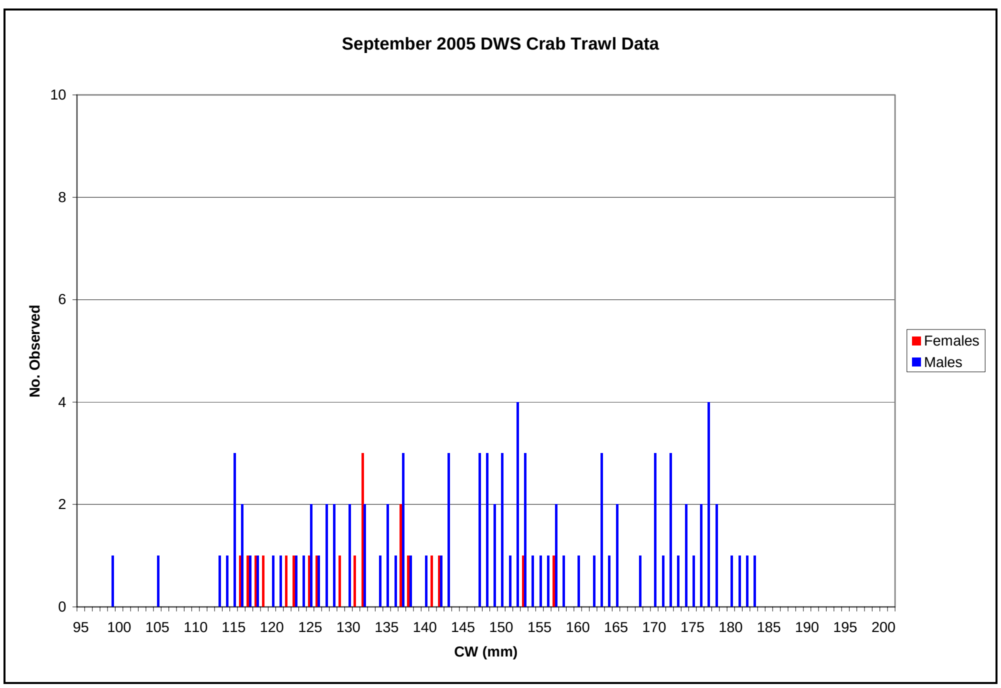

Figure 3-12. September 2005 Size Frequency Distribution for Dungeness Crabs (bottom trawls)

Table 3-13. Summary of the Total Dungeness Crab Catch (June and September 2005)

Date	Method of Capture	Males[1]	Females[1]	Total Measured[1]	Total Caught[2]	% Male[1]	# Legal Males[1]	% Legal Males[1,3]
June 2–5, 2005	Pot	1172	289	1461	1461	80%	80	5%
	Trawl	24	10	34	34	71%	16	47%
	Total	1196	299	1495	1495	80%	96	8%
September 16–18, 2005	Pot	1281	422	1703	1748	75%	692	39%
	Trawl	96	20	116	116	83%	32	28%
	Total	1377	442	1819	1864	76%	724	38%

Notes:
1. Sampling protocol dictated that up to 50 randomly selected crabs be measured and sexed from each sampling location (crab pot); catches greater than 50 crabs were simply enumerated. These statistics are based on those 50 measured individuals per location.
2. This column includes the total number of crabs caught (measured and unmeasured).
3. Percent of legal males relative to the total measured crabs.

3.5 Demersal Fish and Invertebrate Community Results

Demersal fish and invertebrates were sampled in the DWS during June and September 2005. Each sampling event consisted of two replicate transects at Trawls A, B, C, and D (formerly IV, III, II, and I in 2002 surveys). The locations of the trawls are indicated in Figure 2-4. All data for each of the trawls are located in Appendix F.

3.5.1 Demersal Fish Community Results

In June 2005, a total of 23 species were represented in the trawls with a total mean abundance of 6,645 ind./ha (Table 3-14). Species richness ranged from 10 species in Trawl C to 15 species at Trawl D. Among the trawls, Trawl A had the greatest abundance of fish, with an average of 2,859 ind./ha (43% of total catch). Trawl D also possessed a significant percentage of the total fish caught (26%), while Trawls C and B only comprised 16.5% and 14.5% of the total fish caught, respectively. Pacific sanddab was the dominant fish caught, comprising 47% of the total catch and 34–62% of the catch at each station. Rex sole was the second most abundant species during the June 2005 trawls, comprising 18% of the total catch and ranging between 11% and 20% of fish caught at each station. Blackbelly eelpout, Dover sole, English sole, Petrale sole, and Slender sole were also found in all trawls, collectively comprising 36% of the total catch.

In September 2005, a total of 20 species were represented in the trawls with a total mean abundance of 5,324 ind./ha (Table 3-15). Species richness ranged from 10 species at Trawl B to 12 species in Trawls C and A. Among the trawls, the highest abundance of fish occurred in Trawl B with 2,103 ind./ha (40% of total catch) and Trawl A with 2,055 ind./ha (39%). In contrast to June 2005, the total fish caught in Trawl D in September 2005 was only 528 ind./ha (10%). This decrease is primarily due to fewer Slender sole and Dover sole. Again, Pacific sanddab dominated the total catch (58%) and each trawl (46–70%), while Rex sole was the second most abundant species caught, comprising 19% of the total catch and 13–25% of the individual stations. Blackbelly eelpout, Dover sole, English sole, Petrale sole, and Slender sole were also represented in each trawl and collectively comprised 21% of the total catch.

Table 3-14. Average Fish Abundance and Percent Catch at the DWS (June 2005)

Species (#/ha)	Trawl A		Trawl B		Trawl C		Trawl D	
	Average	% Catch	Average	% Catch	Average	% Catch	Average	% Catch
Big Skate	0.0	0.0	0.0	0.0	1.6	0.1	1.4	0.1
Black Rockfish	2.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Blackbelly Eelpout	**316.2**	**11.1**	**20.8**	**2.2**	**38.6**	**3.5**	**126.0**	**7.3**
Bluespotted Poacher	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.1
Brown Irishlord	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.1
Dover Sole	**163.2**	**5.7**	**12.5**	**1.3**	**46.4**	**4.2**	**175.9**	**10.2**
English Sole	**358.8**	**12.6**	**195.8**	**20.4**	**114.1**	**10.4**	**45.9**	**2.7**
Eulachon	19.1	0.7	8.3	0.9	0.0	0.0	0.0	0.0
Northern anchovy	2.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Pacific Sanddab	**1345.6**	**47.1**	**500.0**	**52.0**	**682.9**	**62.1**	**579.5**	**33.6**
Petrale Sole	20.6	0.7	9.7	1.0	3.0	0.3	23.0	1.3
Rex Sole	**480.9**	**16.8**	**154.2**	**16.0**	**119.0**	**10.8**	**344.4**	**20.0**
Rockfish (juvenile)	0.0	0.0	0.0	0.0	0.0	0.0	6.8	0.4
Rockfish, Square Spot	2.9	0.1	1.4	0.1	0.0	0.0	1.2	0.1
Sablefish	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.1
Showey snailfish	0.0	0.0	1.4	0.1	0.0	0.0	0.0	0.0
Slender Sole	**132.4**	**4.6**	**44.4**	**4.6**	**66.0**	**6.0**	**377.4**	**21.9**
Slim Sculpin	0.0	0.0	2.8	0.3	26.0	2.4	38.1	2.2
Snailfish, UI	0.0	0.0	1.4	0.1	0.0	0.0	0.0	0.0
Speckled Sanddab	0.0	0.0	8.3	0.9	0.0	0.0	0.0	0.0
Staghorn Sculpin	8.8	0.3	0.0	0.0	1.6	0.1	0.0	0.0
True Cod	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.1
Warty Poacher	4.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total	**2858.8**	100.0	**961.1**	100.0	**1099.1**	100.0	**1725.7**	100.0

Bold: Numerically dominant species

Table 3-15. Average Fish Abundance and Percent Catch at the DWS (September 2005)

Species (#/ha)	Trawl A		Trawl B		Trawl C		Trawl D	
	Average	% Catch	Average	% Catch	Average	% Catch	Average	% Catch
Arrow Tooth Flounder	2.9	0.1	0.0	0.0	1.2	0.2	0.0	0.0
Big Skate	1.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Blackbelly Eelpout	**249.8**	**12.2**	**49.0**	**2.3**	**16.1**	**2.5**	**11.5**	**2.2**
Butter Sole	2.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Dover Sole	**197.4**	**9.6**	**47.2**	**2.2**	**23.1**	**3.6**	**23.9**	**4.5**
English Sole	**27.6**	**1.3**	**47.6**	**2.3**	**11.7**	**1.8**	**31.7**	**6.0**
Lingcod	1.5	0.1	1.2	0.1	0.0	0.0	0.0	0.0
Pacific hagfish	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.3
Pacific Sanddab	**944.9**	**46.0**	**1479.7**	**70.4**	**337.3**	**52.7**	**348.3**	**66.1**
Petrale Sole	17.5	0.9	3.6	0.2	3.9	0.6	1.5	0.3
Poacher, UI	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.2
Rex Sole	**503.1**	**24.5**	**278.9**	**13.3**	**138.2**	**21.6**	**83.2**	**15.8**
Rockfish (juvenile)	0.0	0.0	0.0	0.0	1.3	0.2	0.0	0.0
Rough Back Skate	0.0	0.0	1.5	0.1	0.0	0.0	0.0	0.0
Showey snailfish	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.6
Slender Sole	**104.7**	**5.1**	**184.1**	**8.8**	**95.2**	**14.9**	**17.0**	**3.2**
Slim Sculpin	0.0	0.0	10.3	0.5	7.6	1.2	4.0	0.8
Slimy Snailfish	0.0	0.0	0.0	0.0	2.6	0.4	0.0	0.0
Snailfish, UI	0.0	0.0	0.0	0.0	1.3	0.2	0.0	0.0
Staghorn Sculpin	1.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total	**2055.0**	**100.0**	**2103.0**	**100.0**	**639.7**	**100.0**	**526.7**	**100.0**

Bold: Numerically dominant species

3.5.2 Invertebrate Community Results

Mean total invertebrate abundance in June 2005 ranged from 182 ind./ha in Trawl B to 1,964 ind./ha in Trawl D, while species richness ranged from 8 in Trawl C to 14 in Trawl D (Table 3-16). All trawls were dominated by *Crangon* species, comprising 96% of the catch at Trawls C and D, 93% in Trawl A, and 87% in Trawl B. The next most abundant species was *Cancer magister*, comprising 6% of the total individuals caught in Trawl B, 4% in Trawl A, and 0.5% in Trawls C and D. Mean total biomass ranged from 4.2 kg/ha in Trawl C to 9.9 kg/ha in Trawl A. Mean biomass was dominated by *Cancer magister* and *Dermasterias imbricate*.

In September 2005, mean total invertebrate abundance was lower than that observed in June 2005, ranging from 75 ind./ha at Trawl B to 338 ind./ha at Trawl A (Table 3-17). The change in species abundance is primarily due to a decrease in *Crangon* species abundance. Species richness was also lower, ranging from 4 to 8 species. Trawls A and B were dominated by *Crangon* species and *Cancer magister*. Although Trawl C had predominantly *Crangon* species (1.5%), *Metridium senile* also had a considerable presence, comprising 16% of that trawl's total catch. Trawl D had only a small percentage of *Crangon* species, and was mostly comprised of *Cancer magister, Luidia folioata*, and *Metriduim senile*. Mean total biomass ranged from 10.4 kg/ha in Trawl C to 41.5 kg/ha in Trawl A. Biomass was dominated by *Cancer magister*, followed by *Metridium senile, Pycnopodia helianthoides,* and *Luidia foliolata*.

Table 3-16. Mean Abundance and Percent Catch of Invertebrates at the DWS (June 2005)

Species (#/ha)	Trawl A		Trawl B		Trawl C		Trawl D	
	Average	% Catch	Average	% Catch	Average	% Catch	Average	% Catch
Cancer magister	25.0	3.7	11.0	6.0	4.5	0.5	9.1	0.5
Crangon sp.	**633.8**	**93.5**	**158.3**	**87.1**	**839.8**	**95.8**	**1884.7**	**96.0**
Cuttlefish	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.2
Dermasterias imbricata	0.0	0.0	0.0	0.0	18.8	2.1	29.2	1.5
Hermissenda crassicornis	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.1
Hermit crab	5.9	0.9	2.8	1.5	0.0	0.0	0.0	0.0
Luidia foliolata	1.5	0.2	4.2	2.3	0.0	0.0	10.0	0.5
Macoma nasuta	0.0	0.0	0.0	0.0	3.0	0.3	0.0	0.0
Metridium senile	0.0	0.0	0.0	0.0	1.6	0.2	4.9	0.3
Nassarius mendicus	2.9	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Nassarius perpinquis	1.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Nucula sp.	1.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Nudibranch, UI	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.1
Octopus	0.0	0.0	0.0	0.0	1.5	0.2	0.0	0.0
Olivella sp	0.0	0.0	1.4	0.8	0.0	0.0	0.0	0.0
Ophiura lutkeni	0.0	0.0	0.0	0.0	3.0	0.3	1.4	0.1
Pagurus armatus	0.0	0.0	1.4	0.8	0.0	0.0	0.0	0.0
Pisaster brevispinus	1.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Pycnopodia helianthoides	1.5	0.2	1.4	0.8	0.0	0.0	0.0	0.0
Pycnopodia, pink	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.1
Scale Worm	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.1
Sea Whips	0.0	0.0	0.0	0.0	0.0	0.0	6.8	0.3
Spirontocaris lamellicornis	2.9	0.4	1.4	0.8	4.6	0.5	4.1	0.2
Tritonia diomedia	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.1
Grand Total	**677.9**	**100.0**	**181.8**	**100.0**	**876.8**	**100.0**	**1963.7**	**100.0**

Bold: Numerically dominant species

Table 3-17. Mean Abundance and Percent Catch of Invertebrates at the DWS (September 2005)

Species (#/ha)	Trawl A		Trawl B		Trawl C		Trawl D	
	Average	% Catch	Average	% Catch	Average	% Catch	Average	% Catch
Argis	0.0	0.0	0.0	0.0	2.5	0.9	0.0	0.0
Cancer magister	**88.2**	**26.1**	**33.1**	**44.1**	14.0	4.9	**29.0**	**35.6**
Crangon communis	1.5	0.4	0.0	0.0	**59.2**	**20.6**	0.0	0.0
Crangon sp.	**218.6**	**64.6**	**29.9**	**39.8**	**146.8**	**51.1**	1.3	1.5
Luidia foliolata	21.6	6.4	9.1	12.1	13.0	4.5	**18.5**	**22.7**
Macoma	0.0	0.0	0.0	0.0	0.0	0.0	2.5	3.1
Metridium senile	0.0	0.0	1.5	2.0	45.2	15.7	8.4	10.3
Nassarius mendicus	1.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Octopus	1.4	0.4	0.0	0.0	0.0	0.0	1.3	1.5
Pisaster brevispinus	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.8
Pycnopodia helianthoides	1.4	0.4	1.5	2.0	3.9	1.4	0.0	0.0
Rossia pacifica	2.9	0.8	0.0	0.0	1.3	0.5	0.0	0.0
Scleroplax sp.	1.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Sea Whips	0.0	0.0	0.0	0.0	0.0	0.0	**17.9**	**22.0**
Spirontocaris prionota	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.5
Spirontocaris sp.	0.0	0.0	0.0	0.0	1.3	0.5	0.0	0.0
Grand Total	**338.4**	**100.0**	**75.1**	**100.0**	**287.3**	**100.0**	**81.5**	**100.0**

Bold: Numerically dominant species

4.0 DISCUSSION

This section discusses the 2005 data results relative to seasonal changes and previous surveys. In addition, data are evaluated relative to the effects dredged material disposal has on localized communities near the drop zones. Two previous surveys conducted by SAIC and Weston Solutions (formerly MEC) included a baseline biological survey of the DWS (MEC and SAIC 2003) and a bottom trawl comparison survey (MEC 2004).

4.1 Sediment Profile Images

The results of the 2005 SPI survey were similar in many respects to the SPI survey conducted in 2002, prior to the disposal of any dredged material at the DWS. For comparative purposes, only stations occupied in both 2002 and 2005 were evaluated. In 2002, the DWS was dominated by fine to very fine sand, providing a SA.F benthic habitat and a Stage I benthic community. The OSI averaged 3.36 in the July 2002 survey, increasing to an average of 4.57 in September 2002 mainly due to a seasonal increase in the RPD mean (from 1.08 cm in July to 1.85 cm in September 2002; Tables 4-1 and 4-2).

The July 2002 and June 2005 SPI parameter measurements for benthic stage, RPD mean, and OSI were similar; however, slightly coarser grain size was observed within the MCR-DWS in 2005. This indicates that, despite the placement of dredged material in 2004 resulting in a slightly coarser substrate, the seasonal condition of the benthic habitat at the DWS is comparable between 2002 and 2005.

The September 2002 and 2005 SPI parameter measurements for benthic stage, RPD mean, and OSI were higher, on average, for the DWS in 2005. The site-wide seasonal increase in benthic stage was greater outside the drop zones, but within the drop zones the benthic stage was the same as baseline (September 2002) conditions. The OSI within the drop zones was also very similar in September 2005 as observed in September 2002. This indicates that despite the placement of dredged material, the conditions within the drop zones are within the range of seasonal conditions, relative to the baseline survey, that occur at the DWS.

In June 2005, the DWS was also dominated by fine to very fine sand (SA.F benthic habitat), with the exception of areas in the vicinity of the MCR-DWS drop zone, where the substrate consisted of medium sand (SA.M benthic habitat). The change in bottom substrate was due to the disposal of coarser grained sandy dredged material from the MCR navigational channel. In June 2005, the DWS consisted primarily of a Stage I benthic community, an average RPD of 1.4 cm and average OSI of 3.28 (see Section 3.1, Table 3-1), conditions very similar to 2002. However, the 2005 data demonstrated a greater seasonal shift in bottom characteristics than observed in 2002. The average OSI in September 2005 was 6.29, which was largely due to an increase in the benthic successional stage (primarily Stage I on III), and a modest increase in average RPD depth (average 1.61 cm; see Section 3.1, Table 3-2).

The most notable seasonal shift in the 2005 dataset, or lack thereof at the drop zone sub-areas, was with respect to the OSI. As noted above, the overall average OSI increased at the DWS, with the exception of the sampling locations within the CR-DWS (n =1) and MCR-DWS (n = 13)[3]. Since the OSI integrates several SPI analytical parameters, it provides a greater contrast relative to subtle differences observed in a single parameter. The OSI value in the dredged material drop zones generally decreased slightly between June and September 2005 (Figure 4-1).

[3] It should be noted that the primary focus of the 2005 monitoring effort was on the MCR-DWS, but the SPI sampling location within the CR-DWS tracked similarly (i.e., seasonal reduction in OSI). The greater seasonal change between June and September at the CR-DWS is likely due to the fact that the drop zone had not yet been utilized in June (i.e., pre-disposal condition), whereas dredged material had been placed at the MCR-DWS in 2004.

This is not unexpected, as the ongoing input of additional dredged material would inhibit the seasonal shift in benthic successional stages observed elsewhere at the site and in the 2002 data. As indicated in Figure 4-2, in 2002 the OSI seasonal change generally remained the same or increased across the DWS. However, the overall 2002 seasonal shift was much less than what was observed in the 2005 data. It should also be noted that this does not necessarily indicate a degradation of benthic habitat. Rather, the anthropogenic disturbances have the same effect as natural seasonal disturbances (i.e., winter storms) that appear to keep the site in a constant state of benthic re-colonization (i.e., benthic Successional Stage I). The September 2005 benthic successional stage (Stage I), RPD (0.54 to 5.03 cm), and corresponding OSI values (2 to 7) within the MCR-DWS drop zone were comparable to benthic conditions observed throughout the site in June 2005.

Table 4-1. Summary of Key Comparative SPI Parameters between July 2002 and June 2005

Station[1]	Location[2]	July 2002 SPI Data				June 2005 SPI Data			
		Grain Size Major Mode	Benthic Stage	RPD mean (cm)	OSI	Grain Size Major Mode	Benthic Stage	RPD mean (cm)	OSI
A5-00	DWS	3 to 2 phi; 4 to 3 phi	ST I	1.28	3	3 to 2 phi	ST I	0.98	3
A8-00	DWS	3 to 2 phi	ST I on III	0.71	4.5	4 to 3 phi	ST I	1.28	3
B5-00	DWS	3 to 2 phi	ST I	0.63	2	3 to 2 phi	ST I	2.14	4
B6-00	DWS	3 to 2 phi	ST I	1.67	4	4 to 3 phi	ST I	1.68	4
B7-00	DWS	3 to 2 phi; 4 to 3 phi	ST I	1.32	3	3 to 2 phi	ST I	2.67	5
C2-00	DWS	4 to 3 phi	ST I on III	0.98	7	4 to 3 phi	ST I	1.61	4
C3-00	DWS	3 to 2 phi; 4 to 3 phi	ST I on III	1.26	5	3 to 2 phi	ST I	1.73	4
C5-00	DWS	3 to 2 phi	ST I	1.25	3	3 to 2 phi	ST I	1.58	4
C6-00	MCR-DWS	3 to 2 phi	ST I	0.53	2.00	2 to 1 phi	ST I	1.31	3
C6-02	MCR-DWS	na	na	Na	Na	2 to 1 phi	ST I	1.18	3
C6-03	MCR-DWS	na	na	Na	Na	2 to 1 phi	ST I	2.98	na
C7-00	DWS	3 to 2 phi	ST I	1.08	3	3 to 2 phi	ST I	1.10	3
CD5-02	MCR-DWS	na	na	Na	Na	2 to 1 phi	ST I	0.79	3
CD6-01	MCR-DWS	na	na	Na	Na	2 to 1 phi	INDET	4.45	na
CD6-02	MCR-DWS	na	na	Na	Na	2 to 1 phi	ST I	0.73	2
CD6-03	MCR-DWS	na	na	Na	Na	2 to 1 phi	ST I	0.37	2
CD6-04	MCR-DWS	na	na	Na	Na	2 to 1 phi	ST I	0.57	2
D2-00	DWS	4 to 3 phi	ST I	1.28	3	4 to 3 phi	ST I	1.94	4
D3-00	CR-DWS	3 to 2 phi	ST I	1.95	4	4 to 3 phi	ST I on III	2.20	8
D5-00	DWS	3 to 2 phi	ST I	1.23	3	3 to 2 phi	ST I	0.65	2
D5-01	MCR-DWS	na	na	Na	Na	3 to 2 phi	INDET	1.21	na
D6-00	MCR-DWS	3 to 2 phi	ST I	1.12	3	3 to 2 phi	ST I	1.19	3
D6-01	MCR-DWS	na	na	Na	Na	3 to 2 phi	ST I	0.88	3
D6-03	MCR-DWS	na	na	Na	Na	3 to 2 phi	ST I	0.46	2
D7-00	DWS	3 to 2 phi	ST I	0.94	3	3 to 2 phi	ST I	0.95	3
E2-00	DWS	4 to 3 phi	ST I to II	1.14	3.5	4 to 3 phi	ST I to II	1.75	5
E3-00	DWS	4 to 3 phi	ST I	1.57	4	3 to 2 phi	ST I	0.86	3
E5-00	DWS	3 to 2 phi	ST I	0.57	2.	3 to 2 phi	ST I	1.06	3
E6-00	DWS	4 to 3 phi	ST I	0.91	3	3 to 2 phi	ST I	0.88	3
E7-00	DWS	3 to 2 phi	ST I	0.51	2	3 to 2 phi	ST I	0.79	3
F7-00	DWS	3 to 2 phi	ST I	0.76	3	3 to 2 phi	ST I	0.97	3
AVG		-	-	1.08	3.36	-	-	1.39	3.36
MAX		-	-	1.95	7.00	-	-	4.45	8.00
MIN		-	-	0.51	2.00	-	-	0.37	2.00

1. Stations that were occupied in both 2002 and 2005; and new stations located within the MCR-DWS drop zone.
2. Designates station as being within the CR-DWS drop zone, MCR-DWS drop zone, or the DWS where no dredge material disposal has taken place.

Table 4-2. Summary of Key Comparative SPI Parameters between September 2002 and September 2005

Station[1]	Location[2]	September 2002 SPI Data				September 2005 SPI Data			
		Grain Size Major Mode	Benthic Stage	RPD mean (cm)	OSI	Grain Size Major Mode	Benthic Stage	RPD mean (cm)	OSI
A5-00	DWS	3 to 2 phi	ST I	1.02	3	3 to 2 phi	ST I on III	1.60	8
A8-00	DWS	3 to 2 phi	ST I	2.32	5	3 to 2 phi	ST I on III	2.62	9
B5-00	DWS	3 to 2 phi	ST I	2.34	5	3 to 2 phi	ST I on III	1.93	8
B6-00	DWS	3 to 2 phi	ST I	1.31	3	4 to 3 phi	ST I on III	1.77	8
B7-00	DWS	3 to 2 phi	ST I	1.65	4	4 to 3 phi	ST I on III	1.75	8
C2-00	DWS	4 to 3 phi	ST I on III	3.00	9	4 to 3 phi	ST I	2.31	5
C3-00	DWS	4 to 3 phi	ST I on III	2.52	9	4 to 3 phi	ST I on III	2.05	8
C5-00	DWS	3 to 2 phi	ST I	1.29	3	2 to 1 phi	ST I on III	1.67	8
C6-00	MCR-DWS	3 to 2 phi	ST I	2.11	4	3 to 2 phi	ST I	1.48	3
C6-02	MCR-DWS	na	na	Na	Na	3 to 2 phi	ST I on III	0.76	7
C6-03	MCR-DWS	na	na	Na	Na	3 to 2 phi	ST I on III	0.96	7
C7-00	DWS	3 to 2 phi	ST I	1.63	4	3 to 2 phi	ST I on III	1.24	7
CD5-02	MCR-DWS	na	na	Na	Na	3 to 2 phi	ST I	0.75	2
CD6-01	MCR-DWS	na	na	Na	Na	3 to 2 phi	ST I	1.07	3
CD6-02	MCR-DWS	na	na	Na	Na	3 to 2 phi	ST I	1.46	3
CD6-03	MCR-DWS	na	na	Na	Na	3 to 2 phi	ST I	1.11	3
CD6-04	MCR-DWS	na	na	Na	Na	3 to 2 phi	ST I	0.54	2
D2-00	DWS	> 4 phi	ST I	2.34	5	4 to 3 phi	INDET	1.90	3
D3-00	CR-DWS	3 to 2 phi	ST I	1.58	4	3 to 2 phi	ST I	1.30	3
D5-00	DWS	3 to 2 phi	ST I	2.40	5	3 to 2 phi	ST I on III	1.98	8
D5-01	MCR-DWS	na	na	Na	Na	3 to 2 phi	ST I on III	0.71	6
D6-00	MCR-DWS	4 to 3 phi	ST I	2.00	4	2 to 1 phi	ST I	0.74	2
D6-01	MCR-DWS	na	na	Na	Na	2 to 1 phi	ST I	5.03	na
D6-03	MCR-DWS					3 to 2 phi	ST I on III	1.08	7
D7-00	DWS	3 to 2 phi	ST I	1.06	3	4 to 3 phi	ST I on III	1.82	8
E2-00	DWS	3 to 2 phi	ST I	2.11	4	4 to 3 phi	ST I on III	2.17	8
E3-00	DWS	3 to 2 phi	ST I	2.17	4	4 to 3 phi	ST I on III	2.02	8
E5-00	DWS	4 to 3 phi	ST I on III	1.83	8	4 to 3 phi	ST I on III	1.32	7
E6-00	DWS	3 to 2 phi	ST I	2.17	4	4 to 3 phi	ST I on III	1.53	8
E7-00	DWS	3 to 2 phi	ST I	1.20	3	4 to 3 phi	ST I on III	1.90	8
F7-00	DWS	3 to 2 phi	ST I	0.78	3	4 to 3 phi	ST I on III	1.13	7
AVG		-	-	1.85	4.57	-	-	1.60	6.07
MAX		-	-	3.00	9.00	-	-	5.03	9.00
MIN		-	-	0.78	3.00	-	-	0.54	2.00

1. Stations that were occupied in both 2002 and 2005; and new stations located within the MCR-DWS drop zone.
2. Designates station as being within the CR-DWS drop zone, MCR-DWS drop zone, or the DWS where no dredge material disposal has taken place.

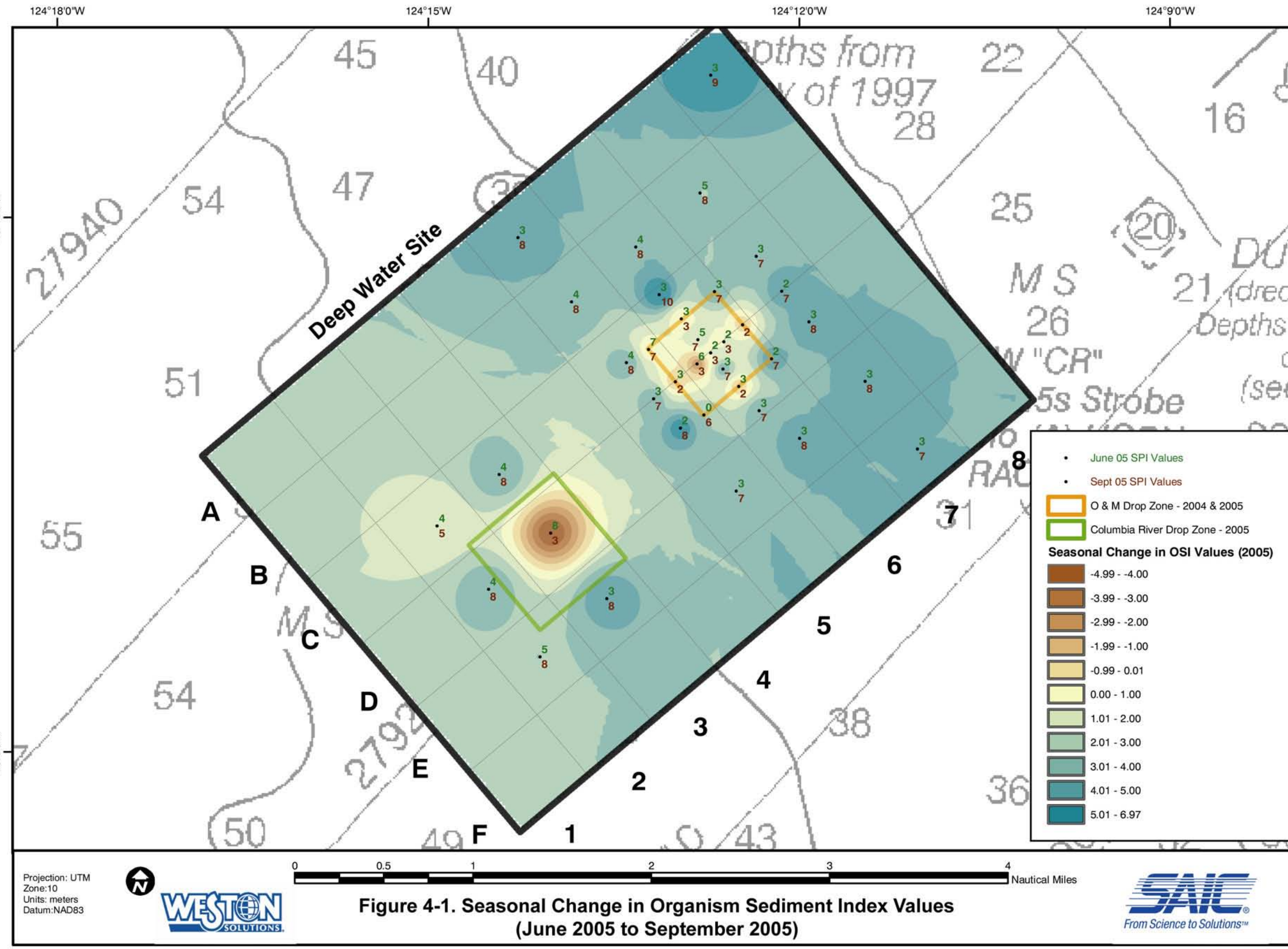

Figure 4-1. Seasonal Change in Organism Sediment Index Values (June 2005 to September 2005)

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M.Goff, SAIC, October 2005

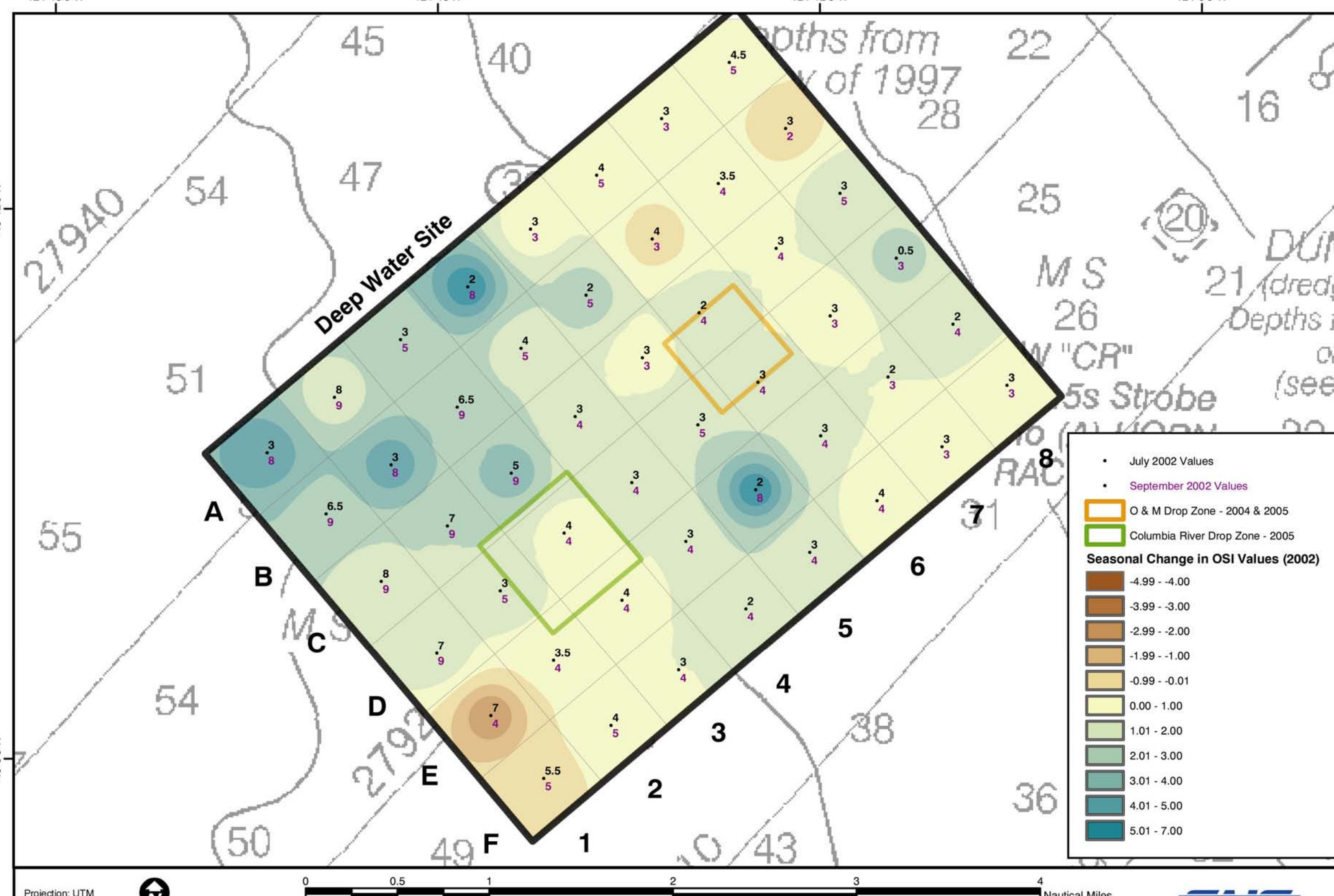

Figure 4-2. Seasonal Change in Organism Sediment Index Values (July 2002 to September 2002)

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M.Goff, SAIC, February 2006

4.2 Sediment Conventionals

Sediment grain size and TOC were evaluated to provide an indication of habitat type in the drop zones and the corresponding reference stations. In order to better understand the trends that were observed in 2005, TOC content and percent sand for each sample was plotted alongside the baseline sediments collected in 2002. Sediment collected throughout the DWS in 2002 showed a close relationship between percentage sand and TOC (R^2= 0.83), with the TOC decreasing with increasing percentage sand (Figures 4-3 and 4-4). Based on this relationship, the sand and TOC content of sediment in 2005 reference locations is generally similar to that of 2002. TOC content in June 2005 was slightly higher than expected (based on the percentage sand) at Station A7 and each of the stations in the area of the CR-DWS drop zone (B4, D3, and E2). The cause of this increased TOC content is unclear, but it may be related to a relatively calm winter season in 2005. It is unlikely that this is related to disposal activities since no disposal had occurred at the CR-DWS prior to the June 2005 sampling events.

Grain size and TOC at stations in the MCR-DWS drop zone indicate increased sand and decreased TOC with disposal activity (Figure 4-3). Relative to 2002, the relationship between percentage sand and TOC was consistent with 2005; however, the 2005 is shifted towards sandier, lower organic sediment in both June and September 2005.

In June 2005, percentage sand and TOC at Station D3 was similar to that of the reference stations B4 and E2 (Figure 4-4). However, in September 2005, the percentage sand and TOC were more similar to the sediments at the MCR-DWS disposal sites, with higher percentage sand and lower organic carbon. As with the MCR-DWS stations, the relationship between percentage sand and TOC was similar to baseline, however, the nature of the habitat shifted to sandier, lower TOC sediment following disposal.

The relationship between the changes in habitat and the benthic community are discussed in the following section.

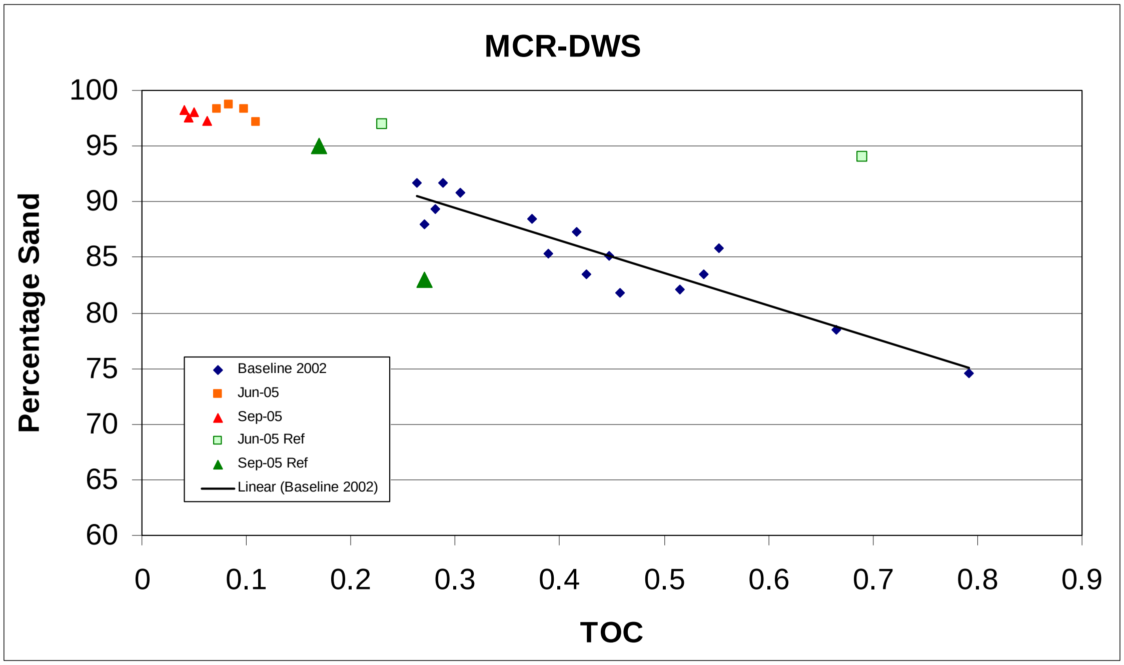


Figure 4-3. Relationship of Total Organic Carbon and Grain Size at the MCR-DWS Drop Zone in 2002 and 2005

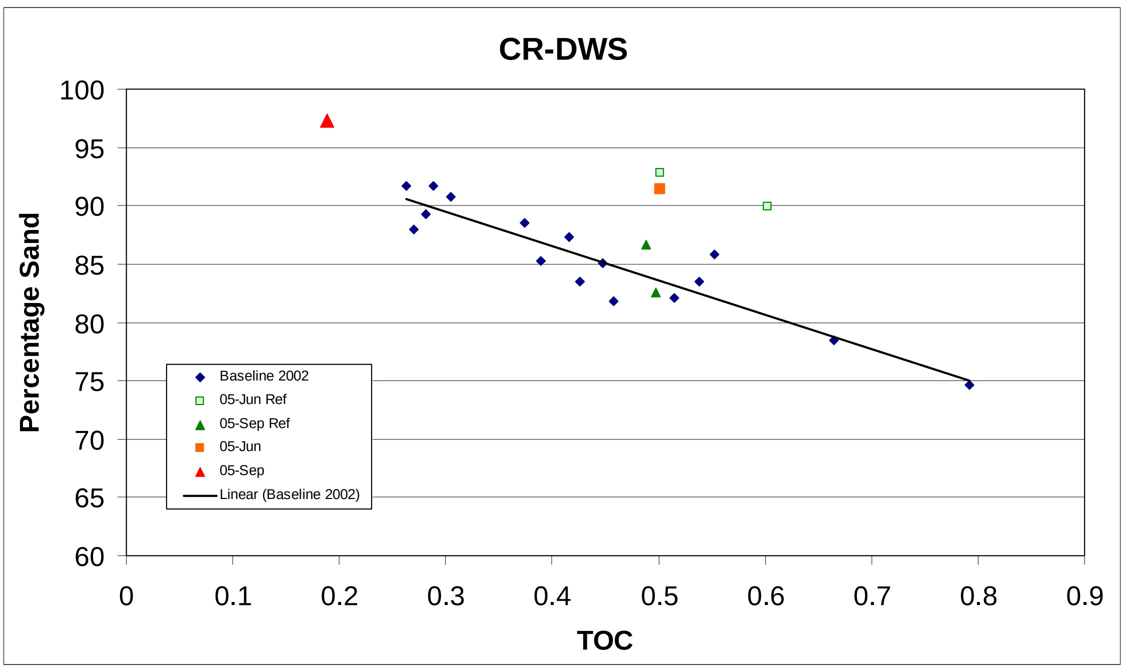


Figure 4-4. Relationship of Total Organic Carbon and Grain Size at the CR-DWS Drop Zone in 2002 and 2005

4.3 Benthic Habitat and Community Structure

The mouth of the Columbia River is a dynamic system, subject to strong winter storms and calmer summer periods. The benthic habitat across the DWS is influenced by these seasonal changes, with sand dominating in the winter and early spring and an organically enriched, fine-sediment layer overlying the sand during the summer calm periods. The benthic community structure responds to these seasonal shifts in sediment grain size and organic enrichment. In addition, portions of the DWS behave differently from other areas, such that the benthic habitat and resulting benthic community is not homogenous across the site or throughout the year.

In order to evaluate the potential impacts of dredged-material disposal on the benthic habitat and benthic communities in the DWS, baseline data were collected in 2002 to establish areas within the DWS that have similar benthic communities and would be expected to respond similarly to seasonal shifts. This assumption was then used to establish reference stations for each of the disposal sites.

Three general areas were defined across the DWS during the 2002 baseline surveys. The shallower portion of the DWS was characterized by sandy, less organically enriched sediment that featured a community with lower abundance and species diversity. The benthic community was a typical sand-dominated community for the northeastern Pacific and was dominated by *A. serricata*, *G. oculata*, and *E. carcharodonta*. The deeper portion of the DWS was more typical of a sand-silt community, with higher amounts of organically enriched sediment. The community in this area had higher abundance and was dominated by the polychaete, *Magelona* sp. The third area was represented by the middle portion of the DWS and was a transitional area. In the July 2002 survey, the middle portions of the DWS were more similar to the shallow portion of the DWS, with less organic material, lower abundance, and lower species diversity. In September 2005, following the summer calm period, this area was characterized by higher percent TOC, higher abundance, and higher species diversity.

Sampling efforts in 2005 focused on those portions of the site that had disposal activity. Dredged material from the mouth of the Columbia River operations and maintenance program were placed in the shallower portion of the site, at the MCR-DWS drop zone. Stations from the 2002 survey that correspond to the MCR-DWS include Stations A7, C6, and D7. The Columbia River deepening program placed dredged material in the deeper portion of the site, at the CR-DWS drop zone. Benthic stations from 2002 that correspond to the CR-DWS include A3, B4, and E2.

4.3.1 Benthic Habitat at the MCR-DWS Drop Zone

Dredged material placement at the MCR-DWS drop zone occurred in the summer of 2004 prior to the June 2005 sampling event. Approximately 2.74 MCY (1.7 MCY in 2004 and 1.04 MCY in 2005) of dredged material from the MCR navigational channel were disposed of in the MCR-DWS drop zone. Therefore, in order to evaluate the potential impacts of disposal to the benthic habitat and community structure, sediment grain size, TOC, and species composition in 2005 were compared to that of 2002 and 2005 reference areas.

The benthic habitat at the MCR-DWS reference stations (A7 and D6-03), based on the sand-TOC relationship, was generally similar to that of 2002 (Figure 4-3). The organic carbon content at reference station A7 was slightly higher than expected in June 2005, but fell within the expected range in September 2005. The cause in this increased TOC content is speculated to be a result of the mild winter of 2004–2005. The stations located within the MCR-DWS showed a considerable increase in percent sand and decrease in organic carbon content, compared to the baseline samples collected in 2002. This trend towards sandier, lower TOC sediment continued between June and September 2005 during active placement of dredged material.

Based on the 2002 survey, the benthic community in the shallow portion of the site was characterized by modest abundance (190 to 380 ind./0.1 m^2) and species diversity (Table 4-3). The dominant species are typical of shallower sandy environments along the Washington and Oregon coasts. The community was dominated by the clam *A. serricata*, the ostracod *E. carcharodonta*, and the polychaete, *G. oculata*. *Axinopsida* is a common clam that can settle in large densities in sandy environments. *Euphilomedes* is an opportunistic ostracod and can quickly move into disturbed environments and would be well suited to a dynamic benthic habitat. *Galathowenia* is common along the continental shelf at moderate depths.

In 2005, the benthic community at the reference stations was generally similar to that of 2002. Mean abundance was slightly lower than in 2002 (152 to 310 ind./m^2) and diversity was slightly higher in both June and September 2005. The dominant species were also similar to those observed during the baseline surveys, with *A. serricata* and *Euphilomedes* among the most numerous. There was a shift from *G. oculata* to two other polychaetes common in sandy California shelf sediments: Euclymeninae sp A in June 2005 and *P. californiensis* in September 2005.

The benthic community in stations representing the MCR-DWS disposal site was characterized by substantially lower abundance (87 to 103 ind./m^2) and diversity, relative to the 2002 baseline survey and the 2005 reference stations. Abundance was one-half to one-third that of the reference stations. The species dominance appeared to shift from the clam-ostacod dominated community towards a polychaete-snail dominated community, with *Spiophanes* spp. and the snail *Olivella pycna* among the most numerous species. Both of these species are common in the DWS area. Based on the abundance and species composition, it appears that the benthic communities in the MCR-DWS are behaving differently from those of the reference sites.

It is interesting to note that Station C6-00 (C6-b) at the northern edge of the drop zone clustered with the reference stations in June 2005, indicating that the benthic community was more similar to the reference stations than to the other MCR-DWS stations. Based on the SPI images for Station C6-00 (shown on page 62), it appears this location did receive dredged material in 2004. The June SPI image shows a coarse sandy substrate, with little overlying organic material. The benthic community at this location appears to be recruiting new organisms, indicating that the benthic community is able to respond to habitat modifications following disposal at the MCR-DWS drop zone. This may indicate that the benthic community is resilient enough to resemble a baseline community in a relatively short period of recovery.

4.3.2 Benthic Habitat at the CR-DWS Drop Zone

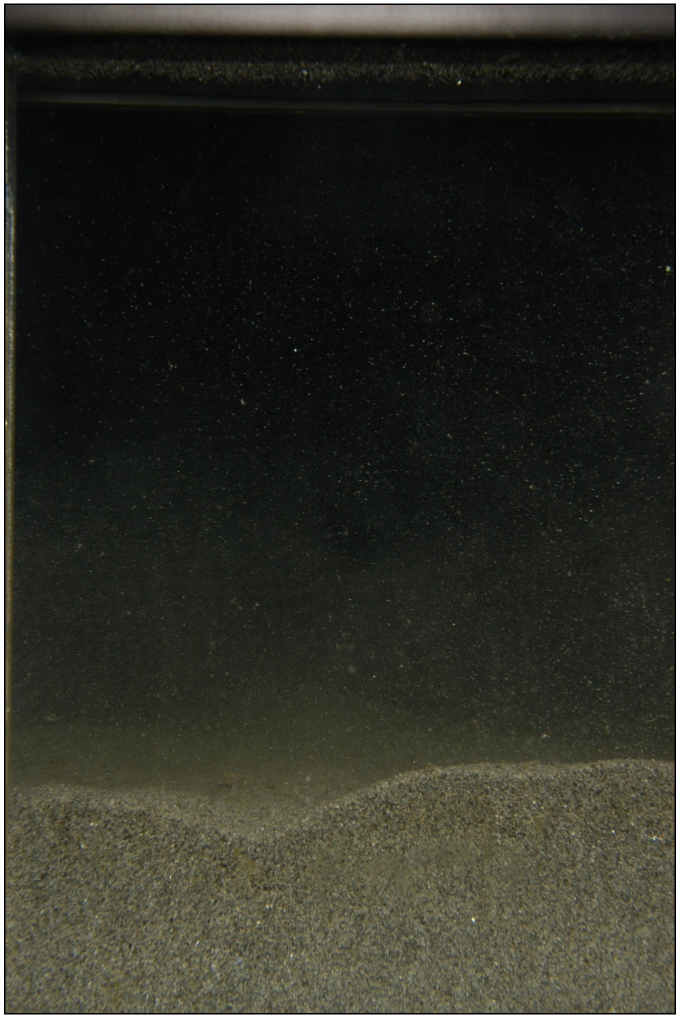
Disposal activity at the CR-DWS drop zone did not begin until after the June 2005 survey. Approximately 1.32 MCY of dredged material from the Columbia River Channel Improvement Project were disposed of in the CR-DWS drop zone during 2005. Therefore, potential impacts at the CR-DWS were evaluated based on a comparison of June 2005 with September 2005 data, using 2002 data as a guide to indicate what to expect between the seasons.

In June 2005 the benthic habitat at the CR-DWS disposal site and the corresponding reference stations (B4 and E2), based on the sand-TOC relationship, was generally similar to that of 2002 (Figure 4-4). As in the MCR-DWS reference stations, TOC content was slightly higher than predicted in June 2005; however, in September 2005 the TOC content was more similar to that observed in 2002. Station D3 in the CR-DWS showed a considerable increase in percent sand and decrease in organic carbon content.

The deeper portion of the DWS was characterized as a sand-silt community, reflecting the thin layer of fine-grained, organically enriched sediment overlying the sandy bottom. During the baseline survey, this area was characterized by higher abundance (403 to 627 ind./0.1 m^2) and higher species diversity (Table 4-4). However, evenness was lower at this community than in the shallower portions of the DWS, with one polychaete species (*Magelona* sp.) accounting for approximately 40% of the individuals observed. Magelonids build loose tube structures, can move through the sediment, and are common on sandy bottoms.

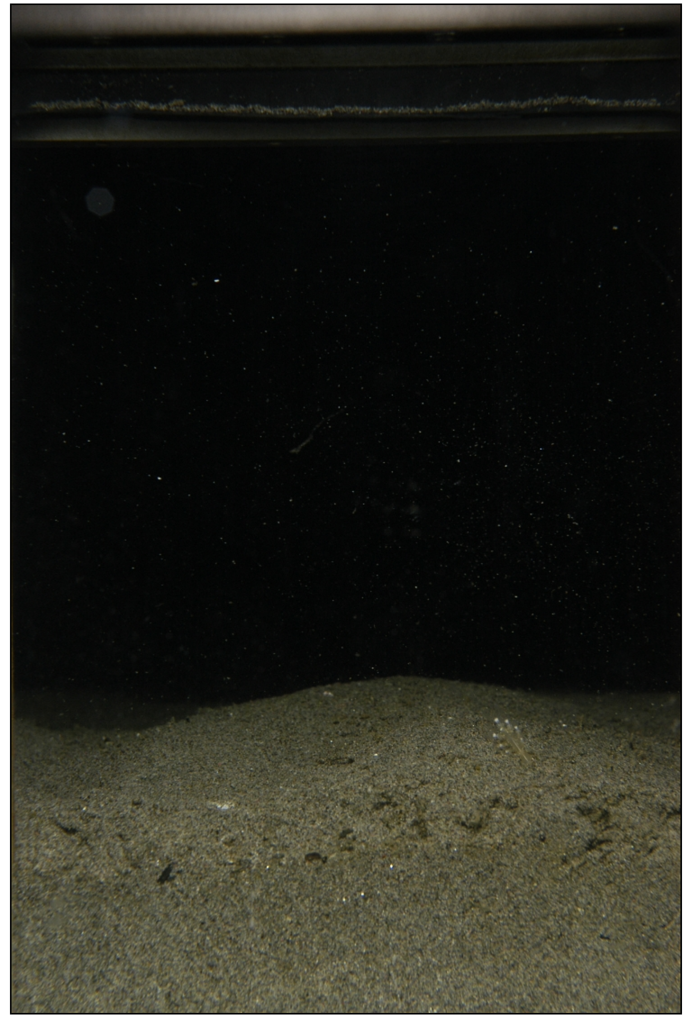
In June 2005, the benthic communities at the CR-DWS and the reference stations (B4 and E2) were similar to each other. Mean abundance and species diversity were slightly lower than that observed in 2002. Magelonids were common but were less dominant than in 2002, comprising approximately 25% of the population observed at these stations. Other polychaetes common to the continental shelf (*M. sarsi*, *S. luti*, and *P. californiensis*) comprised a slightly larger portion of the benthic community.

The benthic community observed at the reference stations in September 2005 was similar to that of June 2005. As in 2002, abundance and diversity increased during the summer; however, the dominance by Magelona sp. persisted. In contrast, the mean abundance at the CR-DWS disposal site decreased significantly, with mean abundance of 46 ind./m^2, represented by only 31 species. While Magelona was still among the dominant species, the polychaete *S. luti* and the clam *A. cartensis* were more common. This change in dominance was primarily a result of the dramatic decrease in the density of Magelona, from 70 ind./m^2 in June 2005 to 5 ind./m^2 in September 2005.



Station C6-00 Replicate 1

June 2, 2005



Station C6-00 Replicate 2

September 13, 2005

Table 4-3. Summary of Benthic Community Observed at the MCR-DWS

	2002		2005			
	Stations A7, C6, D7		MCR-DWS Ref		MCR-DWS	
	July	Sept	June	Sept	June	Sept
Mean abundance	**190**	**380**	**152**	**310**	**87**	**103**
Diversity (No. of species)	**44**	**60**	**61**	**79**	**45**	**45**
Dominant Species (percent of total)						
Axinopsida serricata	27	25	18	16	16	
Galathowenia oculata	14	13				
Euphilimedes carcharodonta	6	6	13	10		
Euclymeninae sp A			10		9	
Spiophanes bombyx/berkeleyorum					9	25*
Pectinaria californiensis				12		
Olivella pycna						11

Includes all *Spiophanes* species

Table 4-4. Summary of Benthic Community Observed at the CR-DWS

	2002		2005			
	Stations A3, E3, C2		CR-DWS Ref		CR-DWS	
	July	Sept	June	Sept	June	Sept
Mean abundance	**423**	**607**	**281**	**473**	**220**	**46**
Diversity (No. of species)	**67**	**79**	**59**	**64**	**89**	**31**
Dominant Species (percent of total)						
Magelona sp.	40	36	26	24	32	11
Maldane sarsi	6	5	10	7		
Acila cartensis	6	4			5	17
Pectinaria californiensis				14		
Scoletoma luti			10		5	12

4.4 Dungeness Crab

This section provides a discussion of the Dungeness crab life history, an interpretation of the data results of the crab survey, and conclusions based on the findings of the crab studies at the DWS.

4.4.1 Dungeness Crab Life History

Dungeness crabs inhabit a wide variety of habitats and environmental conditions, extending from Pt. Conception, CA, north to Prince William Sound, and west to Amchitka Island in the Aleutians (Jensen and Armstrong 1987). Adult Dungeness crabs commonly occur subtidally to 90 m (295 ft) on sandy bottoms, but have been found as deep as 230 m (750 ft; Jensen 1995). Male Dungeness crabs can reach a maximum carapace width of 230 mm (immediately anterior of the tenth anterolateral spine) and weights of over 2 lbs. Female Dungeness crabs are typically smaller, with a maximum size of 165 mm resulting from more energy devoted to egg-production rather than growth.

Under constant conditions, molting rates and frequencies decrease with age (Hankin et al. 1985). Adult female Dungeness crab molting probabilities have been shown to decrease after reaching a relatively distinct size, with molt probabilities going from near 0.90 at 131 mm CW to 0.08 at 143.5 mm CW (Xue and Hankin 2002). Adult female crabs are known to exhibit a well-defined molting season from mid-February through mid-May, just prior to mating (MacKay 1942, Cleaver 1949, Butler 1960, Hankin et al. 1985, Gilbert et al. 1989). On the other hand, male Dungeness crabs tend to molt from June through August. This ensures that male crabs will have hard shells and therefore will be able to compete for, and successfully mate with, molting female crabs in the spring. Gravid female Dungeness crab generally extrude eggs in October and November (Cleaver 1949, Reilly 1983, McConnaughey et al. 1992), at which time they become more frequently and more strongly aggregated than male or non-ovigerous female Dungeness crab (O'Clair et al. 1996). Ovigerous (i.e., egg-bearing) female Dungeness crab aggregations almost always occur at depths of less than 10 m, where they remain partially to completely buried in the sediment and occasionally are observed stacked on top of each other (O'Clair et al. 1996). Dungeness crab larvae are released between January and March off the Washington State coastline (Cleaver 1949, Reilly 1983, McConnaughey et al. 1992).

Juvenile estuarine and coastal settlement generally occurs from May to June (Stevens and Armstrong 1984, Gunderson et al. 1990). Young crabs have been observed to molt multiple times a year and can experience molt increment increases as large as 25–30% per molt, whereas mature crabs tend to molt less frequently (one or fewer) (Schultz et al. 1996), and at a reduced molt increment rate of 10–15% per molt (Hankin et al. 1985). Juvenile Dungeness crab in general move out into oceanic waters from estuaries following their second summer, having reached an average carapace width of 100 mm for females and 116 mm for males (Butler 1960, 1961). Dungeness crab generally reach market size (159 mm) by about four years of age (Cleaver 1949, Butler 1960, Gilbert et al. 1989).

4.4.2 Dungeness Crab Data Interpretation

Due to continuous growth patterns and necessary assumptions concerning molting rates, frequency, and cohort overlap, it is difficult to accurately determine chronological age of crustaceans captured in the field using modal analysis (Rothschild et al. 1992). Crustaceans molt their exoskeleton to accommodate future growth and, as a result, abandon any external evidence of age or previous size. While size frequency distributions allow for a visual representation of the abundance and size trend in measured crabs, they are not able to determine the number of crabs that have reached their terminal molt (maximum size), whether they have skipped a molt, or molted more frequently than the cohort trend. As a result, older populations of crabs have a varying degree of age class overlap, making age class determination for older populations less reliable than for newer cohorts.

In 2002, Dungeness crabs were collected at the DWS in the months of July and September as part of a baseline biological survey. In 2005, Dungeness crabs were collected during the months of June and September. Due to life history pattern, there is a significant difference between the 2002 (July) and the 2005 (June) "spring/summer" surveys. By July, most of the males have already mated with the female crabs and are undergoing, or recently have undergone, molting. To minimize the risk of predation from other crabs, these very soft-shelled crabs will not enter crab pots, and as a result would not be present in the 2002 July survey catch data. However, when the sampling occurred in June 2005 many of these crabs were in a pre-molt state and entered the crab pots. Due to this timing difference, only general comparisons can be made between the two "spring/summer" surveys.

During the 2005 survey, the number of crabs captured at the DWS increased from a catch of 1,471 (21.0 crabs/pot/day) in June 2005 to a catch of 1,752 (38.9 crabs/pot/day) in September 2005. There was a slight difference in site coverage between sampling events, as six locations were moved for the September 2005 survey to avoid the operation of the Dredge Sugar Island, which was actively disposing of dredged material at the CR-DWS drop zone. However, the increasing crab abundance trend from June to September 2005 was consistent with the findings of the trawl surveys (34 caught in June 2005, 116 caught in September 2005), which were generally constant with regard to survey locations between the two seasons. These findings were consistent with the 2002 survey, which found that the number of crabs caught in the July 2002 surveys was much lower than the number caught in September 2002, both for trawls and crab pot surveys (MEC and SAIC 2003). This finding is also consistent with the life history patterns of Dungeness crabs, with male crabs molting immediately after mating with female crabs in the spring.

Dungeness crab populations exhibited a relatively consistent pattern with regard to sexual representation in the total crab pot catch, with the male crabs representing only 5% fewer of the total catch in September 2005 than in June 2005. Due to the summer molting and corresponding growth, the average size of both male and female crabs increased 8 mm from June 2005 to September 2005 in crab pots (the same increase seen in 2002). This was indicative of the relative absence of commercially legal male crabs in June 2005 (7%) to September 2005 (52%). The mean carapace width for male crab increased from 147.5 mm in June 2005 to 159.5 mm (commercially legal) in September 2005, consistent with the one molt increase in size prediction of pre-molt to post-molt linear regressions (Hankin et al. 1985). Similarly, the proportion of soft crabs increased from 9% of the total catch to 66%, and the proportion of males from 10% to 76% from September 2005 to June 2005, clearly defining the summer molt.

As with the 2002 survey, no gravid female crabs were caught in the crab pots or bottom trawls during this survey. This finding was not unexpected, as ovigerous female Dungeness crabs in this region are most frequently captured in commercial pots during the months of December and January (Hankin et al. 1985). Additionally, ovigerous female crabs generally remain closer to the shoreline than the disposal site (P. Dinnel pers. comm. 2002), rarely occurring in habitat greater than 30 m in depth (O'Clair et al. 1996).

Based on the distribution of crab pots stations in 2005, and a comparison with the 2002 survey data, it appears that the Dungeness crab population at the MCR DWS drop zone exhibited a very consistent pattern with regard to relative abundance, average size, sexual representation, and molting cycle between seasons. Due to the absence of southwest crab pot station locations in September 2005, it was not possible to make a seasonal comparison near the CR-DWS drop zone; however, it is likely that, with the high mobility of the adult crab populations, it was similar to the patterns displayed by the remainder of the site. The trawl surveys displayed consistent abundance patterns between June and September 2005, with the greatest densities of crabs in the northeast (shallowest) portion of the site and lower densities in the deeper southwest portion of the DWS.

The data demonstrate that the local crab population structure is affected primarily by the commercial crab industry, with the harvest of the larger, commercially legal male crabs. The larger male crabs remain relatively absent from the population until after the spring/summer molt, when their numbers rebound following seasonal growth. The changes in male crab average carapace width/age class suggest that the crab population structure and relative abundance are greatly affected by commercial harvest. There does not appear to be discernable changes in population structure and relative abundance as a result of disposal activities, when comparisons are made between the un-utilized portions of the DWS and the drop zones. As no gravid females were captured during either the 2002 or the 2005 surveys, it can be assumed that future Dungeness crab cohorts will not be affected by the seasonal dredged material disposal activities at the DWS. In both the June and September 2005 surveys, approximately 9 percent more crabs were captured in the MCR-DWS zone than in areas outside the dredged material drop zone, suggesting that disposal activities did not result in reductions in the relative abundance of crab. Consequently, there is no indication from these data that the 2004 or 2005 disposal of dredged material affected the relative abundance of Dungeness crab in the DWS or the MCR-DWS drop zone.

4.5 Demersal Fish and Invertebrate Community

The demersal fish and invertebrate community at the mouth of the Columbia River is variable, both in species distribution as well as in abundance and biomass. Community structure varies both seasonally and annually. In addition, the demersal community varies across the DWS, with differences in species occurrence and abundance between different portions of the site. Because the demersal community shifts by location, season, and year, an approach similar to that of the benthic community analysis was used to evaluate the potential impacts of dredged-material disposal. Cluster analysis was conducted to characterize the demersal fish and invertebrate communities at the DWS. The results of the Bray-Curtis cluster analysis provided an indication of the relative importance of each species at each of the trawl locations and determined which trawl locations were most similar to each other.

Although the results of the cluster analysis are discussed in terms of trawl similarity, the Bray-Curtis cluster analysis actually provides a measure of dissimilarity. Three ranges of dissimilarities were used to indicate cluster groups. Dissimilarity values in excess of 2 indicated those groups that were most dissimilar. Dissimilarity values between 1 and 2 identified those subgroups that were considered somewhat similar. A few subgroups had dissimilarity values that were less than 1, representing those stations with the greatest degree of similarity. The Bray-Curtis dissimilarity values permitted a comparison of the trawl catches by using the relative abundance of species as the primary grouping criterion. While the Bray-Curtis cluster analysis provides an indication of similarity based on relative species importance, it is not based on absolute abundance. Therefore, the potential impacts of dredged material disposal were examined by comparing community structure patterns and key species abundance in trawls from the baseline surveys (2002 and 2003) and following dredged-material disposal (2005).

4.5.1 Demersal Fish Community at the DWS

Baseline trawl surveys were conducted in 2002. Additional trawl surveys were conducted in 2003, as part of a comparison study of trawl gear. Because both surveys were conducted in a similar manner and occurred prior to disposal activity at the site, they provide an indication of the demersal fish community patterns at the DWS.

Based on the cluster analysis, the patterns observed in the demersal fish community structure were generally similar in 2002 and 2003 (Figures 4-5 and 4-6). In the "summer" period (July 2002 and August 2003), the shallower portions of the DWS, represented by Trawls A and B, were most similar to each other. Those stations representing the deeper portions of the site were also similar to each other, with Trawls C, D, and E as the second subgroup. Trawl groupings in September 2002 and 2003 were similar to those of July/August, with Trawls A and B grouping similarly and Trawls C, D, and E grouping together. These groupings are summarized in Figure 4-7.

The demersal fish community across the DWS was generally dominated by flatfish species, in particular Pacific sanddab, Rex sole, Dover sole, and English sole (Table 4-7). Other important species were Slender sole, Blackbelly eelpout, Eulachon (September 2002 only) and Sablefish (August 2003 only).

Mean total abundance and biomass were substantially higher in 2003 compared to 2002, demonstrating the inter-annual variability of the site (Table 4-5). It is also important to note that certain species were relatively more abundant in one year than the other. For example, Pacfic tomcod and Eulachon were among the top five species caught in 2002 and were less abundant in 2003 (Table 4-7). Likewise, Sablefish were common at Trawl C in 2003, but were not common in 2002. This may be due in part to the different timing of the trawl surveys (July 11 versus August 4).

Although the overall abundance and biomass differed between years, patterns between Trawls were similar (Table 4-5). In both 2002 and 2003, the mean total abundance in Trawl A was 2 to 3.5 times higher than that of Trawl B. Mean total abundance in Trawls A and B were more similar in September. Patterns in the center of the DWS were more variable. In 2002, Trawl C had higher mean total abundance than that of Trawls D or E for both July and September. In 2003, Trawl C was more similar to Trawls D and E. Trends in mean total biomass were similar to those of abundance.

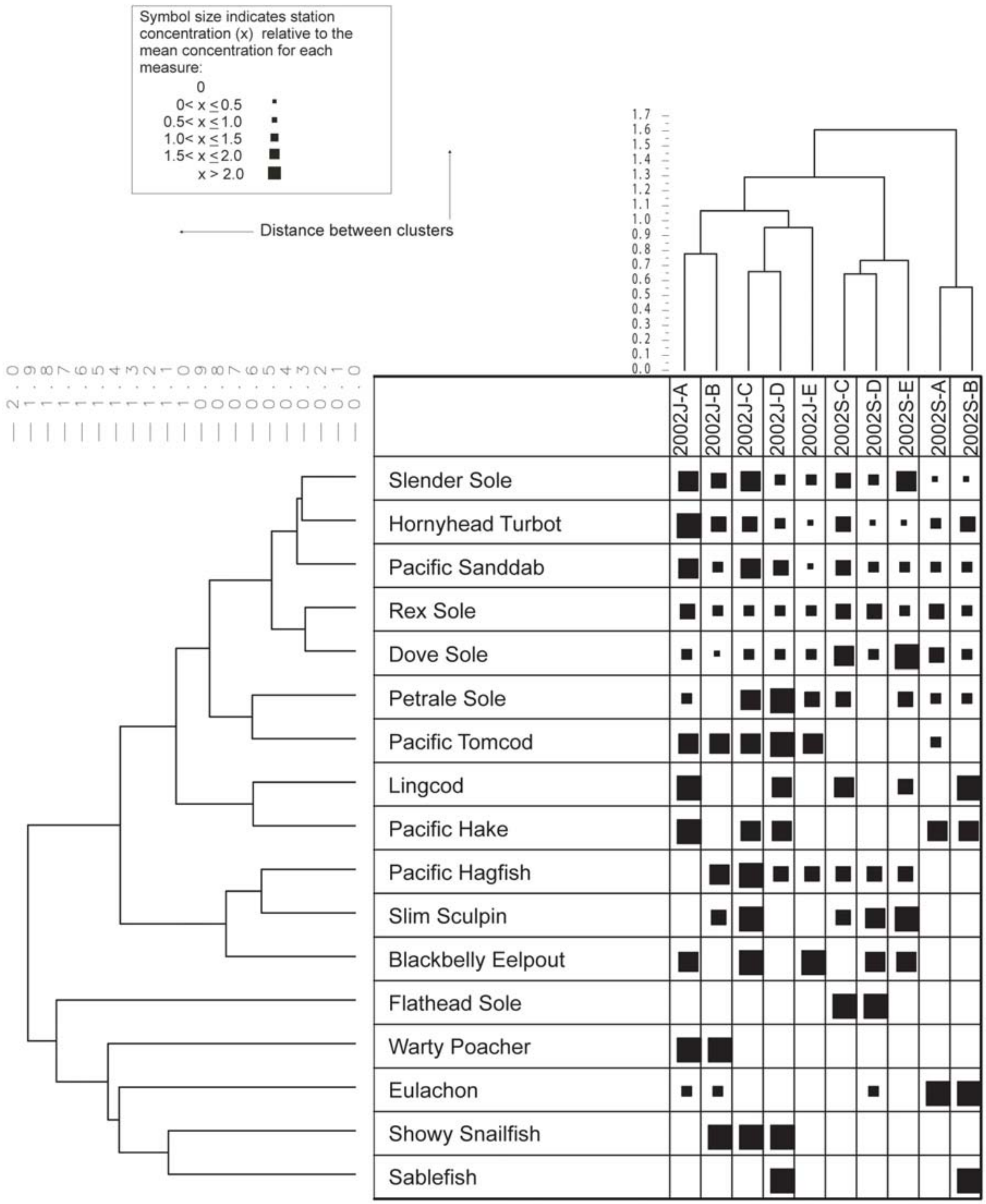


Figure 4-5. 2002 Demersal Fish Cluster Analysis (July and September 2002)

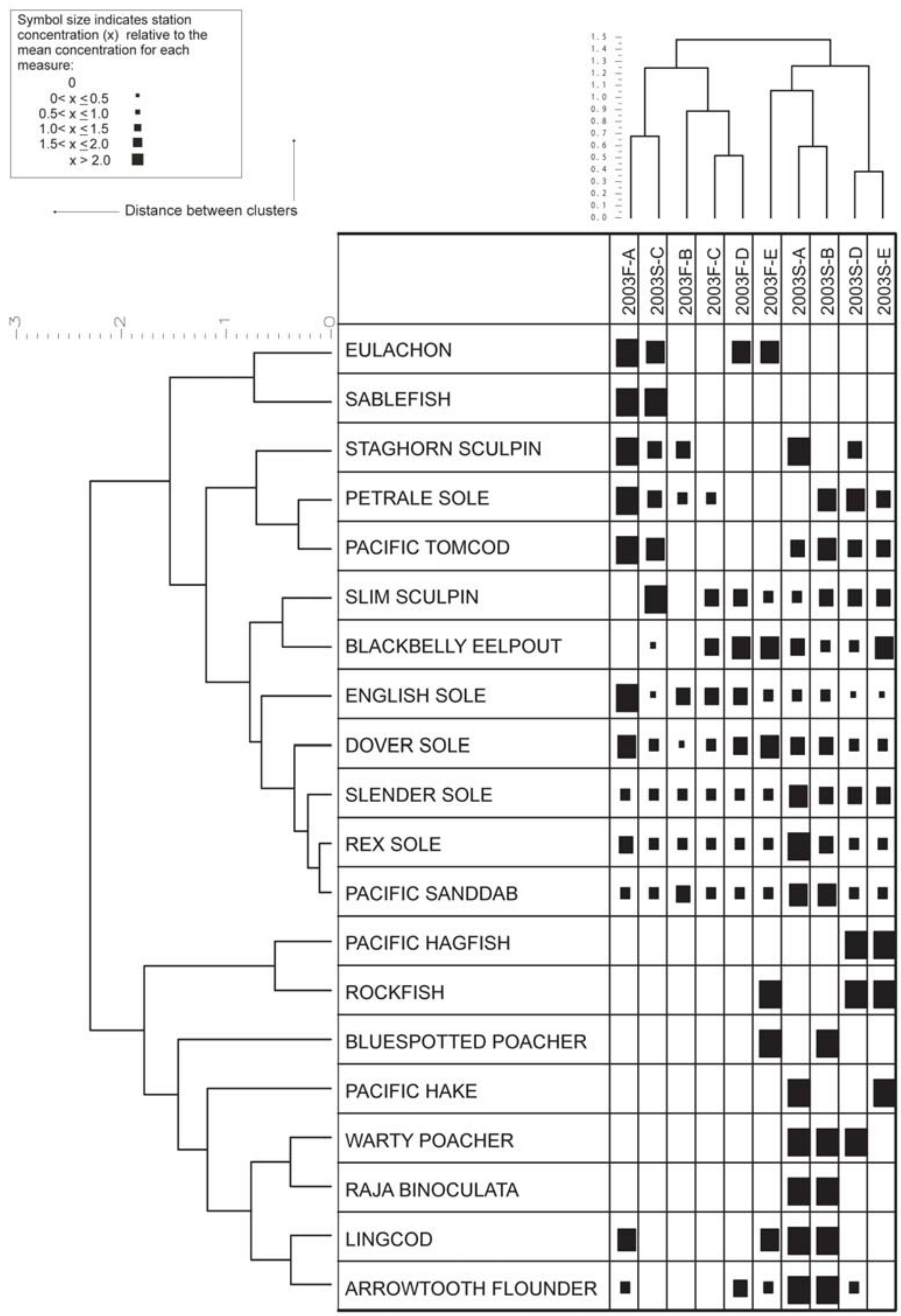


Figure 4-6. 2003 Demersal Fish Cluster Analysis (August and September 2003)

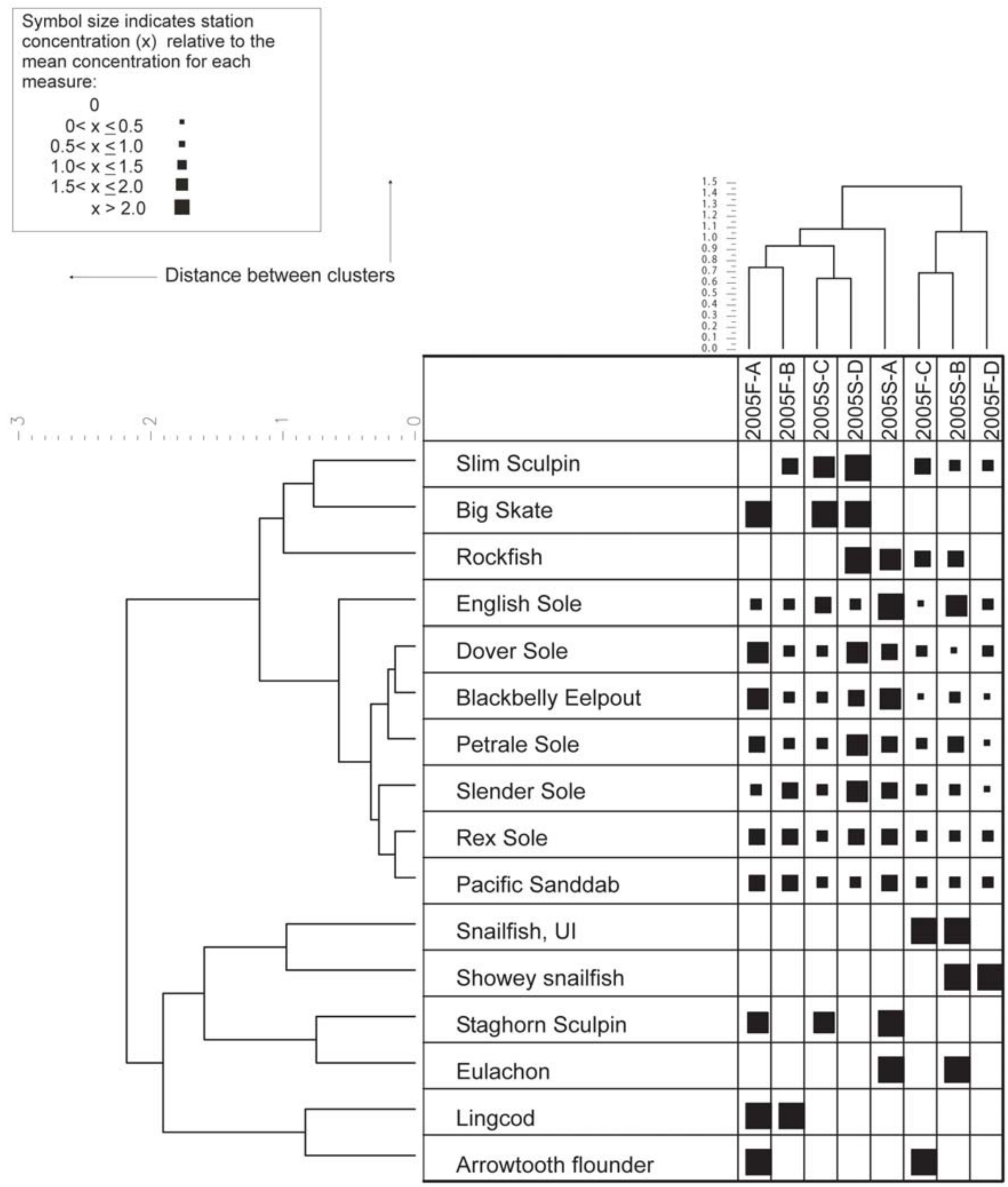


Figure 4-7. 2005 Demersal Fish Cluster Analysis (June and September 2005)

4.5.2 Demersal Fish Community in 2005

Based on the cluster analysis of 2005 data, the demersal fish community was comprised of similar species across the DWS (Figure 4-7). None of the trawl comparisons exceeded the dissimilarity index of 2. This was primarily due to the dominance of flatfish, with relatively high abundance of Pacific sanddab throughout the DWS.

There were four subgroups that were distinguished by having a greater degree of similarity (<1). These groups were:

Group 1A: September Trawls A, B, and C

Group 1B: June Trawls A and B

Group 2A: September Trawl D

Group 2B: June Trawls C and D

Overall, fish abundance and species richness in the DWS in 2005 are similar to those observed in previous years (Table 4-5; MEC 2004, MEC and SAIC 2003). The demersal fish assemblage caught within the DWS is typical of fish assemblages found along Washington State's coastlines (NOAA 2001, MEC and SAIC 2003, MEC 2004). This assemblage is composed primarily of flatfish, blackbelly eelpout, and several other minor species. Between June and September 2005, a decrease in fish abundance, biomass, and species richness occurred across most of the DWS, although the relative composition of the fish assemblage remained similar (Table 4-6). This is consistent with trends in abundance observed in 2002 and 2003.

Demersal Fish near the MCR-DWS Drop Zone

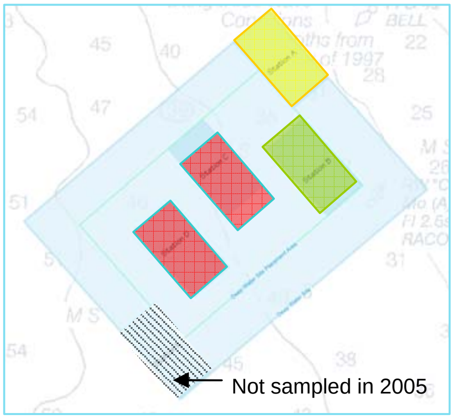
Inter-annual variation of fish abundance was considerable at the MCR-DWS drop zone. Dredge disposal had already occurred prior to 2005 at this site, making both seasonal and inter-annual, pre-disposal and post-disposal comparisons possible. No discernable trend in fish abundance or composition occurred at MCR-DWS in 2002 or 2003. In addition, seasonal changes in fish abundance did not follow any particular pattern. Between seasonal sampling events, the fish abundance increased from July to September in 2002, decreased from August to September in 2003, and increased again between June and September in 2005. If dredge disposal had an effect on fish populations, this effect was masked by these variables.

Cluster analysis was used to determine potential changes in fish assemblage at the MCR-DWS. The 2002, 2003, and 2005 data were analyzed by the seasonal sampling events, summer (July 2002, August 2003, and June 2005), and fall (September) (Figures 4-8 and 4-9). The summer data indicated that the demersal fish community at the MCR-DWS drop zone and the reference station were similar. It also appeared that 2003 and 2005 trawls clustered separately. This suggests that a shift in fish assemblage may have occurred between the years, although the flatfish continued to dominate abundance at all stations for both years (Table 4-5).

Demersal Fish CR-DWS Drop Zone

Demersal fish abundance and species richness decreased at CR-DWS drop zone between June and September 2005. Two factors are likely contributing to the observed decrease. First, the previous years' data for this site reveal a similar trend, where fish abundance and richness declines between summer and fall. Secondly, dredge disposal was being deposited at the same time as when the September 2005 trawls occurred. It is reasonable to assume that a portion of the shift in fish abundance was due to the deposition of dredge material. Further research is required to determine to what extent the decline was caused by seasonal migrations or dredge deposition.

Although the fish population decreased between June 2005 and September 2005, the relative abundance appears to have remained the same (Table 4-6). Flatfish dominate in both mean abundance and total mean biomass at all sites (Table 4-5). Further analysis of changes in fish assemblages were conducted using cluster analysis (Figure 4-9). This analysis yielded four distinct clusters: Group 1A (September A, B, and C); Group 1B (June A and B); Group 2A (September D); and Group 2B (June C and D). For the most part, these clusters were defined by a few of the minor fish species and crangonid shrimp. Similar to the MCR-DWS, the shallow trawls were distinguished from the deeper trawls during the summer, while in the fall, the CR-DWS (the deepest location sampled) clustered separately from the other sites. The dredge disposal that occurred between the June 2005 and September 2005 sampling events may have been responsible for isolating CR-DWS from other trawls. However, in 2003 Trawl C initially clustered with the deeper trawls in August but shifted to the shallower trawls in September (Figure 4-8). Since Trawl E was not sampled this year, it is uncertain whether this response is seasonal or whether the dredge disposal is driving the isolation of CR-DWS. Again, future surveys at this site are needed to distinguish between these two factors.



June 2005

2005 – Summer (June)	Mean Abundance of Key Species			
Species	I	II	III	
	A	B	C	D
Arrowtooth flounder	0	0	0	0
Big Skate	0	0	2	1
Blackbelly eelpout	316	21	39	126
Dover sole	163	13	46	176
English sole	359	196	114	46
Lingcod	0	0	0	0
Pacific sanddab	1346	500	683	580
Petrale sole	21	10	3	23
Rex sole	481	154	119	344
Rockfish	3	1	0	8
Slender sole	132	44	66	377
Slim sole	0	3	26	38

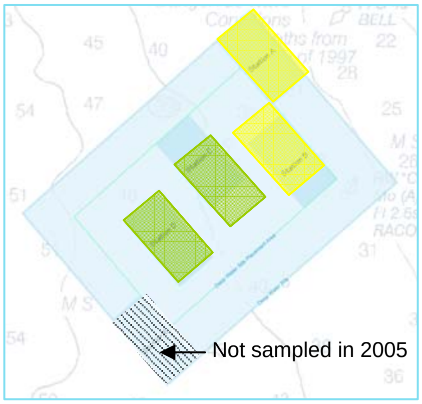
August 2003

2003 – Summer (August)	Mean Abundance of Key Species				
Species	I		II	III	
	A	B	C	D	E
Arrowtooth flounder	29	12	0	2	0
Blackbelly eelpout	19	5	2	10	36
Dover sole	307	252	62	171	131
English sole	38	24	6	2	2
Pacific sanddab	3524	2517	615	645	491
Rex sole	3810	1674	428	643	429
Slender sole	45	79	21	126	210
Slim sculpin	5	17	38	17	12

July 2002

2002 – Summer (July)	Mean Abundance of Key Species				
Species	I		II		III
	A	B	C	D	E
Dover sole	21	4	25	23	11
English sole	58	23	15	8	1
Eulachon	0	1	0	0	0
Pacific sanddab	381	56	644	363	21
Pacific tomcod	5	7	6	8	7
Petrale sole	49	19	31	9	4
Rex sole	184	80	89	44	46
Slender sole	1	0	9	15	5

Figure 4-8. Cluster Analysis Comparison of Key Species Caught in Trawls between July 2002, August 2003, and June 2005



September 2005

2005 – September	Mean Abundance of Key Species			
Species	I		II	
	A	B	C	D
Arrowtooth flounder	3	0	1	0
Big Skate	1	0	0	0
Blackbelly eelpout	250	49	16	11
Dover sole	197	47	23	24
English sole	28	48	12	32
Lingcod	1	1	0	0
Pacific sanddab	945	1480	337	348
Petrale sole	17	4	4	1
Rex sole	503	279	138	83
Rockfish	0	0	1	0
Slender sole	105	184	95	17
Slim sole	0	0	0	0

September 2003

2003 – September	Mean Abundance of Key Species				
Species	I	II			III
	A	B	C	D	E
Arrowtooth flounder	3	0	0	6	3
Blackbelly eelpout	0	0	18	50	32
Dover sole	473	43	179	277	603
English sole	470	82	77	59	29
Pacific sanddab	843	1177	518	444	344
Rex sole	1847	763	671	527	327
Slender sole	77	42	59	112	97
Slim sculpin	0	0	24	21	9

September 2002

2002 – September	Mean Abundance of Key Species				
Species	I		II		
	A	B	C	D	E
Dover sole	34	10	6	19	122
English sole	4	20	24	3	3
Eulachon	39	45	0	12	0
Pacific sanddab	57	102	256	94	64
Petrale sole	2	1	19	5	34
Rex sole	215	100	187	169	72
Slender sole	3	1	19	5	4

Figure 4-9. Cluster Analysis Comparison of Key Species Caught in Trawls between September 2002, 2003, and 2005

Table 4-5. Comparison of Demersal Fish Abundance, Richness, and Biomass Sampled in 2002, 2003, and 2005

Station	Mean Total Abundance			Mean Total No. Species			Mean Total Biomass		
	July 2002	August 2003	June 2005	July 2002	August 2003	June 2005	July 2002	August 2003	June 2005
A	700	8,202	2,859	13	12	13	63.0	688	176
B	196	4,714	961	11	11	13	14.4	265	57.4
C	822	1,229	1,099	13	10	10	71.0	92	48.1
D	462	1,643	1,726	13	12	15	43.0	108	61.1
E	96.5	1,295	ns	9	10	ns	6.6	67	ns
Station	**Mean Total Abundance**			**Mean Total No. Species**			**Mean Total Biomass**		
	Sep. 2002	**Sept. 2003**	**Sept. 2005**	**Sept. 2002**	**Sept. 2003**	**Sept.2005**	**Sept. 2002**	**Sept.2003**	**Sept. 2005**
A	353	3,780	2,055	10	10	12	27.9	427	108
B	283	2,113	2,103	11	6	10	21.5	133	69.4
C	545	1,547	640	9	7	12	53.4	120	27.9
D	294	1,497	527	9	8	11	20.3	91.9	29.8
E	301	1,465	ns	11	10	ns	25.8	88.8	ns

Table 4-6. Relative Percent Abundance of the Top Five Species Caught in the DWS, June and September 2005

Fish	A			B			C			D		
	June	Sept.	RPD	June	Sept.	RPD	June	Sept.	RPD	June	Sept.	RPD
Pacific Sanddab	47%	46%	2%	52%	70%	-30%	62%	53%	16%	34%	66%	-65%
Rex Sole	17%	24%	-37%	16%	13%	19%	11%	22%	-66%	20%	16%	23%
Slender Sole	5%	5%	-10%	5%	9%	-62%	6%	15%	-85%	22%	3%	149%
English Sole	13%	1%	161%	20%	2%	160%	10%	2%	140%	3%	6%	-77%
Blackbelly Eelpout	11%	12%	-9%	2%	2%	-7%	4%	3%	33%	7%	2%	108%
Dover Sole	6%	10%	-51%	1%	2%	-53%	4%	4%	16%	10%	5%	77%

Table 4-7. Top Five Species Caught in the DWS

SUMMER			FALL		
July 2002	August 2003	June 2005	September 2002	September 2003	September 2005
Station A			***Station A***		
Pacific sanddab	Pacific sanddab	Pacific sanddab	Pacific sanddab	Rex sole	Pacific sanddab
Rex sole	Rex sole	Rex sole	Rex sole	Pacific sanddab	Rex sole
English sole	Dover sole	English sole	Eulachon	Dover sole	Blackbelly eelpout
Slender sole	Slender sole	Blackbelly eelpout	English sole	English sole	Dover sole
Dover sole	English sole	Dover sole	Dover sole	Slender sole	Slender sole
Station B			***Station B***		
Rex sole	Pacific sanddab	Pacific sanddab	Pacific sanddab	Pacific sanddab	Pacific sanddab
Pacific sanddab	Rex sole	English sole	Rex sole	Rex sole	Rex sole
English sole	Dover sole	Rex sole	Dover sole	English sole	Slender sole
Slender sole	Slender sole	Slender sole	English sole	Dover sole	Blackbelly eelpout
Pacific tomcod	English sole	Blackbelly eelpout	Slender sole	Slender sole	English sole
Station C			***Station C***		
Pacific sanddab	Pacific sanddab	Pacific sanddab	Rex sole	Rex sole	Pacific sanddab
Rex sole	Rex sole	Rex sole	Pacific sanddab	Pacific sanddab	Rex sole
Slender sole	Dover sole	English sole	Dover sole	Dover sole	Slender sole
Dover sole	Sablefish	Slender sole	Slender sole	English sole	Dover sole
English sole	Petrale sole	Dover sole	English sole	Slender sole	Blackbelly eelpout
Station D			***Station D***		
Pacific sanddab	Pacific sanddab	Pacific sanddab	Dover sole	Rex sole	Pacific sanddab
Rex sole	Rex sole	Slender sole	Rex sole	Pacific sanddab	Rex sole
Petrale sole	Dover sole	Rex sole	Pacific sanddab	Dover sole	English sole
Dover sole	Petrale sole	Dover sole	Slender sole	Slender sole	Dover sole
Slender sole	Slender sole	Blackbelly eelpout	Petrale sole	English sole	Slender sole

4.5.3 Invertebrate Community Cluster Analysis

Overall invertebrate abundance and species richness in the DWS were greater than those observed in previous years, primarily due to the strong *Crangon sp*. presence (Table C8; MEC and SAIC 2003). The invertebrate assemblage, however, remained fairly similar (MEC and SAIC 2003, MEC 2004). Some of the more prominent species caught were *Crangon sp*. *Luidida folioata*, *Metridium senile*, and *Pycnopodia helianthoides* (see Section 3.5.2; Table 3-16 and 3-17). These epifaunal species are dominant along the Oregon and southern Washington coasts (Carey 1972, McCauley 1972). Between June and September 2005, a decrease in invertebrate abundance and species richness occurred in all trawls sampled within the DWS. This general decrease in invertebrate abundance between seasons was also observed in both the 2002 and 2003 surveys (Table 4-8). As in previous years, invertebrate biomass increased in the fall. In this instance, the increase in biomass is predominately attributable to *C. magister*.

MCR-DWS Drop Zone

Total invertebrate abundance was higher in 2005 compared to previous years. This is due to the number of *Crangon* species caught during the June 2005 trawls and *C. magister* caught in the September 2005 trawls. Despite the higher number of organisms collected, biomass remained similar to that observed in 2003 (Table 4-8). There was no indication that dredged material disposal has had an impact on the abundance or biomass of the resident macro-invertebrates.

CR-DWS Drop Zone

In order to evaluate the invertebrate demersal community at the CR-DWS drop zone, the September catch from Trawl D was compared to the September catch in Trawl C. Mean total abundance was lower at the CR-DWS (Table 4-8). This was primarily a result of the substantial number of Crangonid shrimp (*Crangon alaskensis*, *C. communis*, *Crangon* unidentified) observed in Trawl C and a lack of *Crangon* spp. in Trawl D. The abundance of *C. magister* in Trawl D was similar to that of Trawl C. It is important to note that active disposal was occurring at the time of trawling though Trawl D. It is quite likely that the decrease in *Crangon* spp. was temporary, and that the action of dredged material settling on the bottom was responsible for the decrease in this very mobile species. Crangonid shrimp likely will reoccupy the area after disposal ceases.

Table 4-8. Comparison of Invertebrate Abundance, Richness, and Biomass Sampled at the DWS in 2002, 2003, and 2005

Station	Mean Total Abundance			Mean Total No. Species			Mean Total Biomass		
	2002	2003	2005	2002	2003	2005	2002	2003	2005
SUMMER									
A	63	45	678	8	8	10	1.1	11.5	9.9
B	81	81	182	7	4	8	1.6	10.9	6.3
C	130	168	877	12	8	8	2.4	20.6	4.2
D	136	167	1964	12	10	14	2.8	16.9	9.7
E	84	510	ns	13	7	ns	0.4	18.0	ns
FALL									
A	33	147	338	4	10	9	12.2	55.3	41.5
B	24	62	75	3	6	5	4.0	19.8	18.1
C	29	79	287	4	7	10	7.8	27.5	10.4
D	40	94	81	3	8	9	12.9	25.7	20.9
E	83	94	ns	3	10	ns	2.8	27.6	ns

4.6 Bathymetric Data

Bathymetric data provided by the USACE-Portland District for the MCR-DWS drop zone provide a visual depiction of the cumulative dredged material footprint (Figure 4-10). Bathymetric surveys conducted in early 2004 and late 2005 provide topographic detail of the DWS topography both prior to and subsequent to the disposal of dredged material at the site. The dredged material accumulation of 2.74 MCY over the two-year period exhibits a relief of 4.5 m above the seafloor following placement. This provides further evidence of the localized changes at the DWS. No bathymetric data were available for the CR-DWS drop zone for this report.

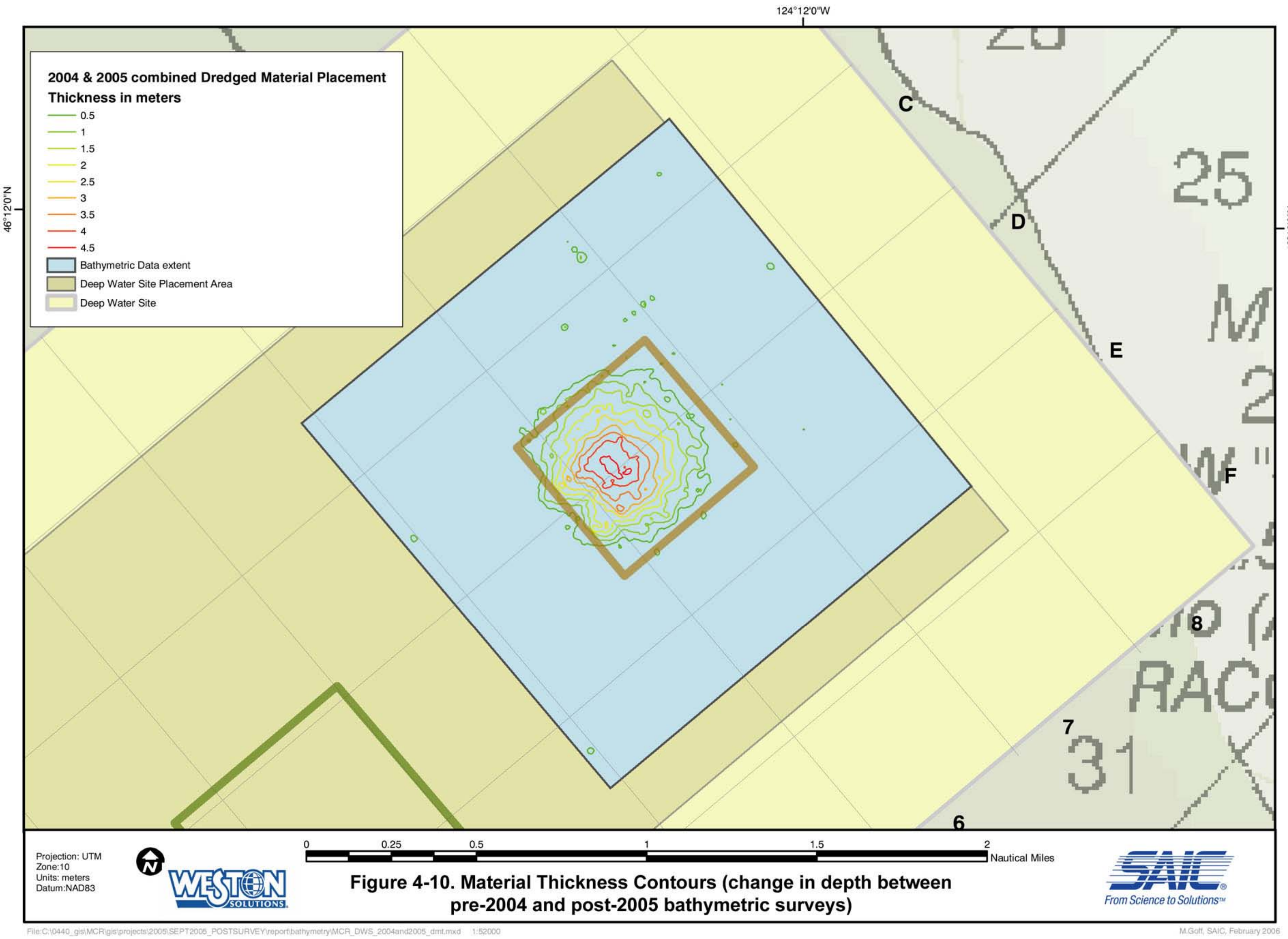


Figure 4-10. Material Thickness Contours (change in depth between pre-2004 and post-2005 bathymetric surveys)

5.0 CONCLUSION

Slight physical changes to the seafloor conditions at DWS were evident in the SPI imagery, sediment conventional analysis, and bathymetry. The SPI imagery indicated that the grain size mode within the MCR-DWS was coarser on average than the rest of the DWS following dredged material disposal. The sediment analysis also indicated that the drop zones shifted towards s higher percentage of sand and lower TOC. At reference locations in the DWS, trends in sediment grain size and TOC were similar to those of the 2002 baseline survey. The bathymetric surveys of the MCR-DWS drop zone indicated dredged material accumulation of up to 4.5 m above the seafloor following disposal.

The OSI rank based on SPI parameters increases site-wide seasonally (increased RPD; Stage I improved to Stage I on III) with the exception of the drop zones, where OSI values remained unchanged (at successional Stage I). The ongoing input of additional dredged material would inhibit the seasonal shift in benthic successional stages observed elsewhere at the DWS. It should also be noted that this does not necessarily indicate a degradation of benthic habitat, rather the anthropogenic disturbances have the same effect as natural seasonal disturbances (i.e., winter storms). The overall benthic habitat types and successional stage remain similar to those observed in June 2005 and baseline conditions observed in July and September 2002. The benthic community analyses indicated that the reference locations in 2005 were similar in abundance, species diversity, and community structure, relative to the 2002 baseline surveys. In both the MCR-DWS and CR-DWS, species abundance has decreased and community structure has changed immediately following dredged material disposal; however, this is primarily due to the loss of the dominant species rather than a re-colonization of the area by new, more opportunistic species.

The relative abundance of Dungeness crab was largely unaffected by dredged material disposal at the DWS. The data demonstrate that the local crab population structure is affected primarily by the commercial crab industry, with the harvest of the larger, commercially legal male crabs. The larger male crabs remain relatively absent from the population until after the spring/summer molt, when their numbers rebound following seasonal growth.

Trends in the demersal fish and invertebrate community between summer and fall were similar between 2002, 2003, and 2005. The demersal fish community was dominated by flatfish, particularly Pacific sanddab and eelpouts, and the invertebrate community was dominated by *Crangon* spp. and *C. magister*. Disposal at the MCR-DWS drop zone did not result in significant changes in community structure or abundance relative to the DWS reference stations. Following disposal at the CR-DWS, the demersal community differed from the other areas. However, this trend was also observed in the 2002 baseline survey and it is uncertain whether the differences observed in CR-DWS in September 2005 were related to disposal activities or inter-annual population shifts at the site. The mean abundance and diversity of species observed in September 2005 in both the DWS and drop zones were within the range of seasonal variation observed during the baseline surveys of 2002 and 2003.

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