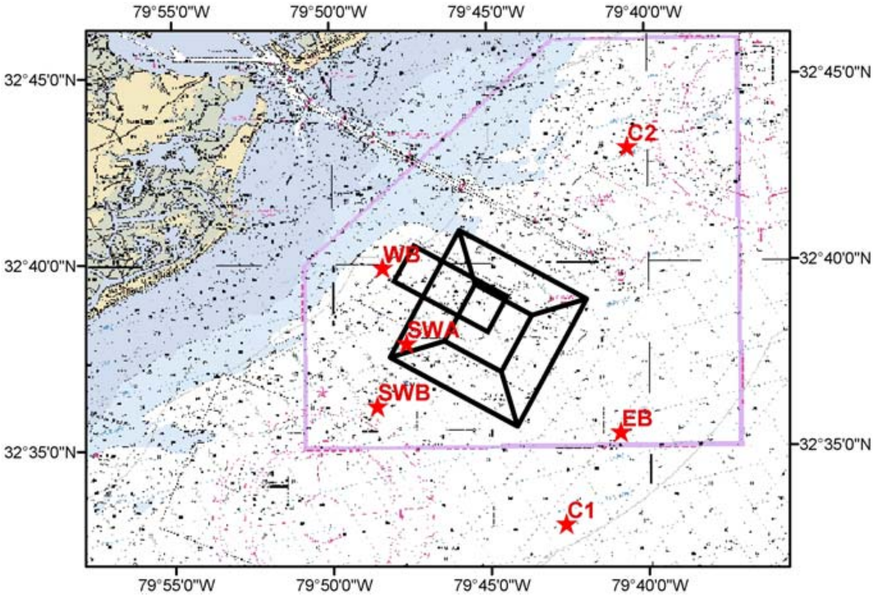
An Environmental Monitoring Study of Hard Bottom Reef Areas Near the Charleston Ocean Dredged Material Disposal Site



FINAL REPORT

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An Environmental Monitoring Study of Hard Bottom Reef Areas Near the Charleston Ocean Dredged Material Disposal Site

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CHAPTER 1: INTRODUCTION

The deepening of shipping channels throughout Charleston Harbor was completed in April 2002 and placed an estimated 22 million cubic yards (mcy) of material in the permitted disposal zone in the Charleston Ocean Dredged Material Disposal Site (ODMDS) located approximately seven miles from shore. The Charleston ODMDS is currently designated by the U.S. Environmental Protection Agency (USEPA) to receive both maintenance and deepening material and is located within a much larger ODMDS that was originally established for the Charleston area and surveyed in 1978 (SCWMRD 1979, Van Dolah *et al.* 1983). The current ODMDS overlaps another smaller ODMDS that was established for the placement of maintenance material.

Hard bottom reef habitats are present within 4 km to the west of the disposal area, and have been identified in many other areas offshore of Charleston, South Carolina (SEAMAP-SA 2001). Hard bottom reef habitats are naturally occurring hard or rocky formations that support dense assemblages of sponges, corals, and other invertebrates. These areas attract many recreationally and commercially important fishes such as black seas bass, porgies, snappers, and groupers (SCWMRD 1984). A baseline monitoring study initiated in 1987 discovered hard bottom reef habitats near the ODMDS area, and forced the smaller ODMDS to be de-designated and moved to the current location further offshore (Winn *et al.* 1989). Since then, additional hard bottom habitats in the areas surrounding the ODMDS have been reported (Jutte *et al.* 2003).

Due to the proximity of the Charleston ODMDS to hard bottom reef habitats, there is the potential for long-term loss of sessile biota and associated finfishes through burial by fine-grained sediments dispersed from the ODMDS. Even if the habitat is not buried, increased sedimentation can result in decreased productivity or death of sponges and corals. Burial of hard bottom habitats can also result in reductions in the number of fish species and individuals (Lindeman and Snyder 1999). Studies on corals in the vicinity of the disposal site have documented deleterious effects on long-term responsiveness and immediate short-term productivity rates following exposure to increased sediment concentrations (Porter 1993).

In an effort to minimize movement of dredged material from the ODMDS to nearby hard bottom sites, the U.S. Army Corps of Engineers (USACOE) constructed an "L" shaped berm comprised largely of cooper marl on the southern and western borders of the ODMDS. However, the efficacy of these mounds is unknown, especially as the fill volumes within the ODMDS approach the upper limits of the berm profile, and the berms slump and consolidate over time.

Sediment migration has been documented outside the designated disposal site using several techniques. The results of sediment analyses conducted on samples collected in the boundary areas surrounding the Charleston ODMDS in 2000 (Jutte *et al.* 2001, Zimmerman *et al.* 2002, 2003) indicated that disposal activities associated with the deepening project have resulted in changes in sediment composition outside the ODMDS. The sediment composition in the boundary areas to the west of the disposal site displayed, in most cases, higher silt/clay content than samples collected in 1993 and 1994. Areal mapping of sediment chemistry, conducted by the University of Georgia's Center for Applied Isotope Studies in October 2000 and 2002 (Noakes 2001, 2003), also identified dredged material outside the disposal area. Dredged material was clearly indicated in areas to the west and northwest of the disposal area based on isotopic signatures. These findings were further corroborated by side scan sonar surveys showing dredge trailings to the northwest of the disposal site and unauthorized dumps to the west and southwest of the disposal site (Gayes *et al.* 2002).

In order to monitor conditions in and around the Charleston ODMDS and its potential impact on surrounding hard bottom reef habitats a large monitoring effort has been ongoing. The current hard bottom reef monitoring study is part of a larger program to monitor conditions in and around the Charleston ODMDS. These efforts have included a baseline survey of conditions in and around the ODMDS in 1993-1994 (Van Dolah *et al.* 1996, 1997), an interim documentation of the same area during the current deepening project (Zimmerman *et al.* 2002), a post-disposal assessment (Jutte *et al.* 2005), and a planned three year post-assessment. Together these previous studies have evaluated changes in the composition of surficial sediments, bathymetry, sediment mobility and transport, surficial sediment chemistry, benthic macrofaunal assemblages, and contaminants in the ODMDS and surrounding areas.

Specific objectives of the current hard bottom reef monitoring project described here were to document any changes in sedimentation rates, sponge/coral density, sponge/coral condition, finfish assemblages, and areal extent of six hard bottom reef areas over a five year period. During the fourth and fifth year, isotopic signatures of the sediments collected at the reef sites were also evaluated to identify probable sources of the sediments.

This report includes three chapters. The first chapter describes results obtained from simultaneous underwater video tows and detailed side-scan sonar surveys of the six hard bottom reef sites completed by the Coastal Carolina University Center for Marine and Wetland Studies (CMWS). The second chapter describes the results of the hard bottom reef monitoring portion of the overall monitoring study, including results of visual and video surveys of study sites by divers and laboratory analysis of sediment composition and grain size conducted by the SCDNR Marine Resources Division. The third chapter describes the results of gamma isotopic analyses of sediments collected in sediment traps, surficial sediments from each hard bottom reef site, and sediments along a transect from Charleston Harbor conducted by the University of Georgia Center for Applied Isotope Studies (CAIS).

CHAPTER 2:

Geophysical Characterization of the Seafloor Charleston Ocean Dredged Material Disposal Site, 2004 and 2005

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2.1 INTRODUCTION

The Charleston Ocean Dredged Material Disposal Site (ODMDS) is located seven miles southeast of the Charleston, South Carolina, Harbor entrance, and receives material dredged from the harbor access channel periodically. Inner continental shelves are dynamic systems under constant reworking by effect of tides, bottom currents and waves. Free sediment therefore, has the potential to migrate as it adapts to the changing energy conditions imposed by these processes. Although the bulk of the material disposed at any ODMDS is likely to remain in place after disposal, the most mobile portion of the disposed sediment may eventually exit the site and migrate to adjacent areas.

The importance of benthic communities located on the inner shelf of South Carolina is far reaching. Many studies regarding the response of such reef areas to ocean dredged material disposal have been led and supported by the South Carolina Department of Natural Resources (SCDNR) and the US Army Corps of Engineers. Many studies referred to in previous reports have evaluated sedimentological characteristics, benthic biology, acoustic response, isotope tracers, and habitat distribution in areas within and around the ODMDS (e.g. Winn *et al.* 1989; Van Dolah *et al.* 1997; Gayes 2001; Noakes 2001). This study builds upon previous geophysical and bottom type characterizations of the six index reef sites in the vicinity of the Charleston ODMDS.

The Center for Marine and Wetland Studies at Coastal Carolina University (CMWS; www.coastal.edu/cmws), in close collaboration with the Marine Resources Research Institute of the South Carolina Department of Natural Resources (SCDNR; www.dnr.sc.gov/marine/mrri/mrri.htm), has been an active participant in gathering, processing and analyzing much of the data acquired for the purpose of monitoring reef areas that surround this ODMDS. A comprehensive evaluation of geophysical data mainly collected by the USGS – Woods Hole, in 2000 was the first in a series of CMWS studies that have investigated the spatial characteristics of the reef sites near the ODMDS, and provided a categorized map of hard bottoms over the entire surveyed area (Gayes 2001). Subsequent surveys and analyses have been performed on an annual basis.

This report provides new results from the most recent two years (2004 and 2005) of surveying at the six index reef sites. In addition, comparisons are made between the new data and data from prior years. In general, backscatter intensity distribution from sidescan-sonar surveys is very similar from year to year at the index sites. Textural analysis of these sonar mosaics provides computed categorization of seafloor in the survey areas as either hard bottom or sand covered. Results from this quantitative habitat mapping algorithm are compared with video and audio data collected in tandem with the sidescan-sonar. Changes in bottom type at each site through time are quantified by comparison of habitat maps from any two different years throughout the duration of the survey history.

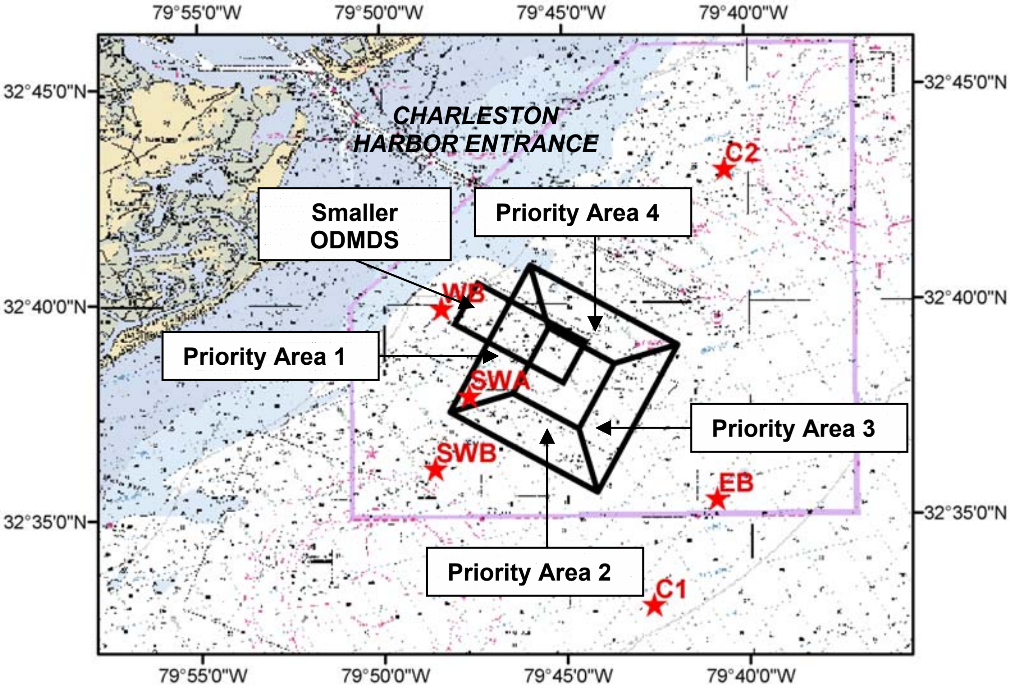

Figure 2.1. Location of the six reef sites surveyed in this study in relation to the Charleston Harbor entrance and ODMDS.

2.2 METHODS

Data from the 2004 and 2005 Ocean Dredged Material Disposal Site (ODMDS) surveys have not previously been presented. These data were collected during two cruises on board the R/V Coastal II and the NOAA ship Nancy Foster respectively. The 2004 survey was conducted in February and the 2005 surveys were conducted between March 27th and April 4th.

Six 1 km^2 seafloor sites (Figure 2.1) were surveyed along 11 N-S and 2 E-W trending tracklines each year. Trackline data included: sidescan-sonar, bottom video, audio, and position. The sidescan system used for all surveys was a Klein 595 dual-frequency analog system provided by Coastal Carolina University's Center for Marine and

Wetland Studies (CMWS). This system is capable of collecting continuous backscatter data of the seafloor at frequencies of 100 kHz and 384 kHz. A swath of ~200 m in the athwart ship direction is ensonified with each pulse of the system's transducers. By mosaicking the sidescan data along all shiptracks over each site, complete coverage of each square-kilometer was achieved, with significant data overlap (as much as 50%) between lines.

Bottom video data were collected simultaneously and along the same track lines as the sidescan-sonar using CCU's towed video array collection system. This custom-designed system consists of four components: (1) an aluminum sled, designed to slide on the bottom in an upright position at all times; (2) a water proof capsule containing two small surveillance cameras (black-and-white and color), mounted on the sled and pointed at the bottom at a ~30° angle with the horizontal; (3) a cable that transmits the video information from the cameras to the laboratory onboard; and (4) two sets of standard video cassette recorders for collection of data onto video tapes, one of which is fed with a time stamp for further geo-rectification.

Table 2.1. Data collected during the 2000, 2001, 2002, 2004, and 2005 reef studies.

INDEX REEF SITE		Aug 2000	Jul/Aug 2001	Oct/Nov 2002	Oct 2004	Mar/Apr 2005
SWA	1.9 km SW (inshore)	Video Mar 2000 Side scan	Video Side scan	Video Side scan Audio	Video Side scan Audio	Video Side scan Audio
WB	4.4 km NW (inshore)	Video	Video Side scan	Video Side scan Audio	Video Side scan Audio	Video Side scan Audio
SWB	4.6 km SW (inshore)	Video	Video Side scan	Video Side scan Audio	Video Side scan Audio	Video Side scan Audio
EB	6.7 km E/SE (offshore)	Video	Video Side scan	Video Side scan Audio	Video Side scan Audio	Video Side scan Audio
C1	8.2 km E/SE (offshore) reference area	Not Surveyed	Video Side scan	Video Side scan Audio	Video Side scan Audio	Video Side scan Audio
C2	9.6 km N/NE (offshore) reference area	Not Surveyed	Video Side scan	Video Side scan Audio	Video Side scan Audio	Video Side scan Audio
E1	0.4 km SE	Side Scan/Video	Not Surveyed	Not Surveyed	Not Surveyed	Not Surveyed
W1	0.5 km SW	Side Scan/Video	Not Surveyed	Not Surveyed	Not Surveyed	Not Surveyed

For this study, sidescan-sonar and bottom video track lines were spaced 100 meters on average. The shiptrack deviated from a straight line in the center of each survey site in order to avoid collision of the video sled with anchored bottom benthic sampling gear placed by SCDNR at these sites. The position of the ship's GPS antenna was logged at all times using HYPACK navigation software, at rates of approximately 2 Hz. These positions were further corrected for the layback between the GPS antenna and the positions of the sidescan-sonar vehicle and video sled.

2.3 LABORATORY PROCESSING

Sidescan-sonar Processing

Raw sidescan sonar data were processed following the protocols in Danforth (1997). Each line was demultiplexed, applied a running window filter for stripe removal, corrected for beam pattern, and linearly stretched to distribute the digital values over a Gaussian scale of gray values. Once processed in this manner, individual lines collected over each reef site were pieced together to produce sidescan-sonar ‘mosaics’, which are equivalent to top-view images of the seafloor. The mosaics were sampled at a 2 by 2 meter cell size. The digital file format of these mosaics was TIFF, which was registered to UTM coordinates by means of an associated world file and displayed as a GIS with ESRI software (e.g. ArcMap).

Video Coding

Collected black-and-white and color videotapes were coded using the protocols described in Ojeda *et al.* (2001). The method consists in characterizing the visible portions of the seafloor from videotapes based on bottom visibility, bottom type and presence and abundance of emergent growth, which for the study area consists mainly of coral colonies (Table 2.2).

Videos were coded by stopping the video tape every 5 seconds and describing the field of view captured in the frame according to the codes in Table 2.2. Because ship speeds ranged between 4 and 5 knots (~2 to 2.6 m/sec) during data acquisition, the spacing between coded points ranged between 10 and 13 meters.

To compare video data from all surveys, only video points that fell inside a 1-km^2 box centered on each reef site were considered and counted for each code. Point counts were performed using built-in functions in ArcGIS software and Excel spreadsheet software.

Table 2.2. Classification scheme used to interpret video and audio data from the area surrounding the Charleston ODMDS. The bottom classification was coded for each 5-second length of video collected, merged with navigation from HYPACK and overlain on sidescan-sonar mosaics using ArcMap.

Bottom Classification	Video Characteristics	Audio Characteristics
Bottom Visible: Sand with no growth	Continuous sand veneer visible on the video	Low noise or constant abrasive noise
Bottom Visible: Hard bottom that does not support soft corals and sponges	Clear outcrop of rocky substrate evident on the video but no visible invertebrate growth.	Mixture of sound of sand abrading sled and distinct collisions of sled on rocky substrate
Bottom visible: Patchy emergent growth	Rocky substrate clearly visible on the video. Soft corals and sponges evident but less than 10 individual clusters observed per 10 second length of video.	Mixture of sound of sand abrading sled and distinct collisions of sled on rocky substrate
Bottom visible: Heavy emergent growth	Rocky substrate clearly visible on the video. Soft corals and sponges evident and more than 10 individual clusters observed per 10 second length of video.	Mixture of sound of sand abrading sled and distinct collisions of sled on rocky substrate

Table 2.2 cont. Classification scheme used to interpret video and audio data from the area surrounding the Charleston ODMDS. The bottom classification was coded for each 5-second length of video collected, merged with navigation from HYPACK and overlain on sidescan-sonar mosaics using ArcMap.

Bottom Classification	Video Characteristics	Audio Characteristics
Bottom not visible: no emergent growth	The sea floor was not visible but suspended sediment and materials in the water column were still resolvable. No invertebrates observed within the field of view per 10-second length of video.	Low noise or constant abrasive noise
Bottom not visible: Patchy emergent growth	The sea floor was not visible but suspended sediment and materials in the water column were still resolvable. Less than ten clusters of invertebrates were observed within the field of view per 10-second length of video	Mixture of sound of sand abrading sled and distinct collisions of sled on rocky substrate
Bottom not visible: Heavy emergent growth	The sea floor was not visible but suspended sediment and materials in the water column were still resolvable. More than ten clusters of invertebrates were observed within the field of view per 10-second length of video	Mixture of sound of sand abrading sled and distinct collisions of sled on rocky substrate
No visibility	Neither the bottom nor material in the water column is visible	Audio is classified as 1) low noise, 2) sound of sand abrading the sled, 3) mixture of sound of sand abrading sled and distinct collisions of sled on rocky substrate or 4) extensive collision of sled on rocky substrate

Textural Analysis Mapping of Habitat

A methodology for thematic mapping of seafloor habitats based on sidescan-sonar mosaics was implemented by the CMWS during a study of nearshore reef sites adjacent to the Grand Strand Nourishment Project (Ojeda *et al.* 2001). A complete discussion of this methodology can be found in Ojeda *et al.* (2004). The method is based on a combination of textural analysis of images and a neural network classifier. A series of parameters representing diverse relationships between neighboring pixels within a small (i.e. 5 by 5 pixel or 10 m^2) window are first calculated for areas where ground control information exists. These parameters are then used as a training set and fed to a neural network classifier, which learns the parameters that represent each of the input classes. Once trained, a network is capable of deciding what class best resembles the input features calculated over portions of the image where ground control data do not exist.

This technique has worked well in previous studies of nearshore habitats and presents one among few alternatives for the problem of generating spatially comprehensive, thematic maps of the seafloor (Ojeda *et al.* 2001; Gayes *et al.* 2002; Ojeda *et al.* 2004).

For this study, the algorithm implemented for the Grand Strand study (Ojeda *et al.* 2001) was utilized. This algorithm produces only two possible outcomes from a given sidescan-sonar image or image window: sand, and hard bottom. Because this algorithm was developed based on a high-quality mosaic and simultaneously acquired bottom video, it was deemed appropriate to continue employing this algorithm for consistency with the 2001 study (Gayes *et al.* 2001). Future developments of this technique will revisit the spectrum of sonar and video data available at CMWS for training of a new algorithm.

Preparation of Change Maps

Interpretive raster maps obtained with the textural analysis routine are useful to evaluate the distribution of bottom change by allowing comparisons to be made on a pixel by pixel basis between two different survey years. The values of these maps depend on four possible combinations, depending on whether a pixel (1) remained as sand, (2) remained as hard bottom, (3) changed from hard bottom to sand, or (4) changed from sand to hard bottom. The extent of a change map is limited to the overlapping area of the two input maps and thus contains values only on areas where both input maps hold data. Consequently, a fifth “no data” outcome is possible, which results from those areas of no data on either input map.

Survey Areas

The six 1-km^2 areas surveyed in this study are the same as those surveyed in 2001 and reported by Gayes *et al*. (2002). These areas correspond to the 1 km^2 window centered on the six reef sites SWA, SWB, WB, EB, C1 and C2 as per nomenclature by SCDNR. These reef sites are located between 1.9 and 9.6 km from the perimeter of the Charleston ODMDS current disposal area (Figure 2.1). Since the beginning of the monitoring program in 2001, SCDNR divers have collected sediment composition data, surficial sediment thickness, sediment deposition rates and abundance and composition of fish and invertebrate communities biannually on each site (Jutte *et al*. 2003).

2.4 RESULTS: HABITAT CHANGE: 2002-2004, 2004-2005, and 2001- 2005

Changes that occurred in bottom habitat during the periods October/November 2002 to February 2004, February 2004 to March/April 2005, and July 2001 to March/April 2005 were characterized in two different manners: by comparing coded video points from the two survey seasons, and by applying the textural analysis technique described in Ojeda *et al.* (2004). The textural analysis technique is entirely raster-based and allows comparisons to be made at a pixel basis over the entire survey area. While the spatial coverage is complete with this technique, many bottom characteristics can affect backscatter intensity. It is possible, for example, to have a thin veneer of sand over an area, yet still have high backscatter intensity values. Ground truthing with audio and video data provides a higher level of confidence in bottom type classification relevant to benthic habitat condition. The audio and video data are, however, limited spatially to the relatively narrow field of view along the survey transects. It is best, therefore, to employ a combination of these methods for the most complete, accurate, and bottom type detailed characterization.

Site SWA

SWA is the site closest to the disposal area (1.9 km inshore of the perimeter, Figure 2.1). In the 2000 survey site SWA was interpreted to include abundant hard bottom based on the absence of surficial sediment cover interpreted from CHIRP subbottom profiles and the high backscatter values on sidescan-sonar mosaics (Gayes 2001).

Site SWA has been imaged five times by sidescan-sonar and bottom video systems: March 2000, July 2001, October 2002, February 2004, and March/April 2005 (Gayes 2001; Gayes *et al.* 2002). Coded points from bottom video are overlain on the sidescan mosaics for 2004 and 2005 (Figures 2.2a and 2.3a). The two most recent surveys indicate that ~20 % of the seafloor in the 1 km^2 survey area is hard bottom (Table 2.3). This is not too different from the values reported for the 2002 and 2004 surveys. While the 2000 survey reports 100 % hard bottom, is important to recognize that almost all of the video was coded as ‘no visibility’. The interpretation of 100 % hard bottom cover for 2000 is likely skewed since that percentage is based on interpretation of only 15 video clips for a total of 75 seconds of visible data over the entire square kilometer.

Table 2.3. Habitat distribution on site SWA based on coded video points within a 1-km2 box centered on reef site. 1 = No visibility, 2 = Bottom visible: sand with no growth, 3 = Bottom visible: hard bottom no growth, 4 = Bottom visible: patchy emergent growth, 5 = Bottom visible: heavy emergent growth, 6 = Bottom not visible: no emergent growth, 7 = Bottom not visible: patchy emergent growth, 8 = Bottom not visible: heavy emergent growth. Percentages are in term of total points.

SWA	**2000**		**2001**		**2002**		**2004**		**2005**	
	total points coded	%	total points coded	%	total points coded	%	total points coded	%	total points coded	%
1	99	**87**	0	**0**	0	**0**	0	**0**	2	**0.1**
2	0	**0**	1071	**73.7**	1108	**76**	665	**81.5**	1067	**78.1**
3	0	**0**	8	**0.6**	0	**0**	0	**0**	1	**0.1**
4	0	**0**	114	**7.8**	173	**11.9**	50	**6.1**	232	**17**
5	12	**10.5**	154	**10.6**	176	**12.1**	101	**12.4**	65	**4.8**
6	0	**0**	93	**6.4**	0	**0**	0	**0**	0	**0**
7	3	**2.6**	9	**0.6**	0	**0**	0	**0**	0	**0**
8	0	**0**	4	**0.3**	0	**0**	0	**0**	0	**0**
TOTALS										
Hard bottom	15	**13.2**	289	**19.9**	349	**24 .0**	151	**18.5**	298	**21.8**
Sand	0	**0**	1071	**73.7**	1108	**76.0**	665	**81.5**	1067	**78.1**
No Visibility	99	**86.8**	93	**6.4**	0	**0**	0	**0**	2	**0.1**
Total video collected	114	**100**	1453	**100**	1457	**100**	816	**100**	1367	**100**

The mosaics from 2004 and 2005 are similar in terms of backscatter intensity distribution (Figures 2.2a and 2.3a). While most of the southern half of these images is dominated by a region of high backscatter (light gray tones), the northern third and southwestern corner are characterized by low backscatter. Despite the difference in survey platforms from year to year (e.g. R/V Coastal II vs. R/V Anderson vs. R/V Foster), visual inspection of the backscatter intensity data between 2001 and 2005 suggests little change in the shape and location of high backscatter regions at site SWA.

Results of the textural classification algorithm are reported as color-coded habitat maps, with hard bottom classification represented by the darker shade and sand as the lighter (Figures 2.2b, 2.2c, 2.3b and 2.3c). Site SWA was classified as 68.1 % hard bottom in 2004 and 59.3 % in 2005 (Table 2.4). While these values differ by a few percent, they are consistent with values reported for 2001 and 2002. The value reported for 2000 is inconsistent with all of the subsequent four years. The 2000 sidescan mosaic was not collected with site SWA as a specific target, and was clipped from a much larger image. The visual appearance of this image is very similar to the subsequent surveys with respect to the distribution and extent of high backscatter intensity seafloor. Differences in the textural analysis results may reflect artifacts from lower contrast values in the 2000 image.

Table 2.4. Habitat distribution on site SWA based on interpretive textural analysis of the sidescan-sonar mosaic. Areas are in units of 10^5 m^2.

	2000		**2001**		**2002**		**2004**		**2005**	
	area	%	area	%	area	%	area	%	area	%
Hard bottom	9.64	**96.4**	6.678	**66.8**	6.937	**69.4**	6.805	**68.1**	5.931	**59.3**
Sand	0.36	**3.6**	3.274	**32.7**	2.92	**29.2**	3.188	**31.9**	3.652	**36.5**
No Data	0	**0**	0.048	**0.5**	0.143	**1.4**	0.007	**0.07**	0.417	**4.2**
Total area	10	**100**	10	**100**	10	**100**	10	**100**	10	**100**

Habitat change maps were produced from pixel by pixel comparisons between two habitat maps from different years (Table 2.5; Figures 2.2d, 2.3d, and 2.3e). The two most recent intervals are the 2002-2004 and 2004-2005 inter-survey periods. A net hard bottom loss of 2.1 % was calculated for the 2002-2004 interval, and a net loss of 7.1 % was calculated for the 2004-2005 interval. Previous surveys result in a 3.4 % hard bottom net gain during the 2001-2002 inter-survey period. An alarming 29.3 % net loss of hard bottom was calculated for the 2000-2001 interval. The sidescan mosaics, however, are very similar in appearance for those two years. Again, it is possible that poor contrast in the 2000 image resulted in output of questionable accuracy from the textural analysis routine.

Table 2.5. Spatial analysis of change, site SWA. Values are number of square meters.

	2000 to 2001	2001 to 2002	2002 to 2004	2004 to 2005	2000 to 2005
from sand to sand	20,800	157,800	168,400	169,100	24,600
from hard bottom to hard bottom	650,600	524,700	549,600	465,500	564,900
from hard bottom to sand	306,000	132,500	144,000	195,600	340,000
from sand to hard bottom	15,000	166,100	123,100	127,400	24,100
Total area of analysis	992,400	981,100	985,100	957,600	953,600
Area of no change (%)	67.7 %	69.6 %	72.9%	66.3 %	61.8 %
Area of change (%)	32.3 %	30.4 %	27.1%	33.7 %	38.2 %
Net hard bottom change * (%)	-29.3 %	3.4 %	-2.1%	-7.1 %	-33.1 %

* Positive values indicate net gain; negative values indicate net loss.

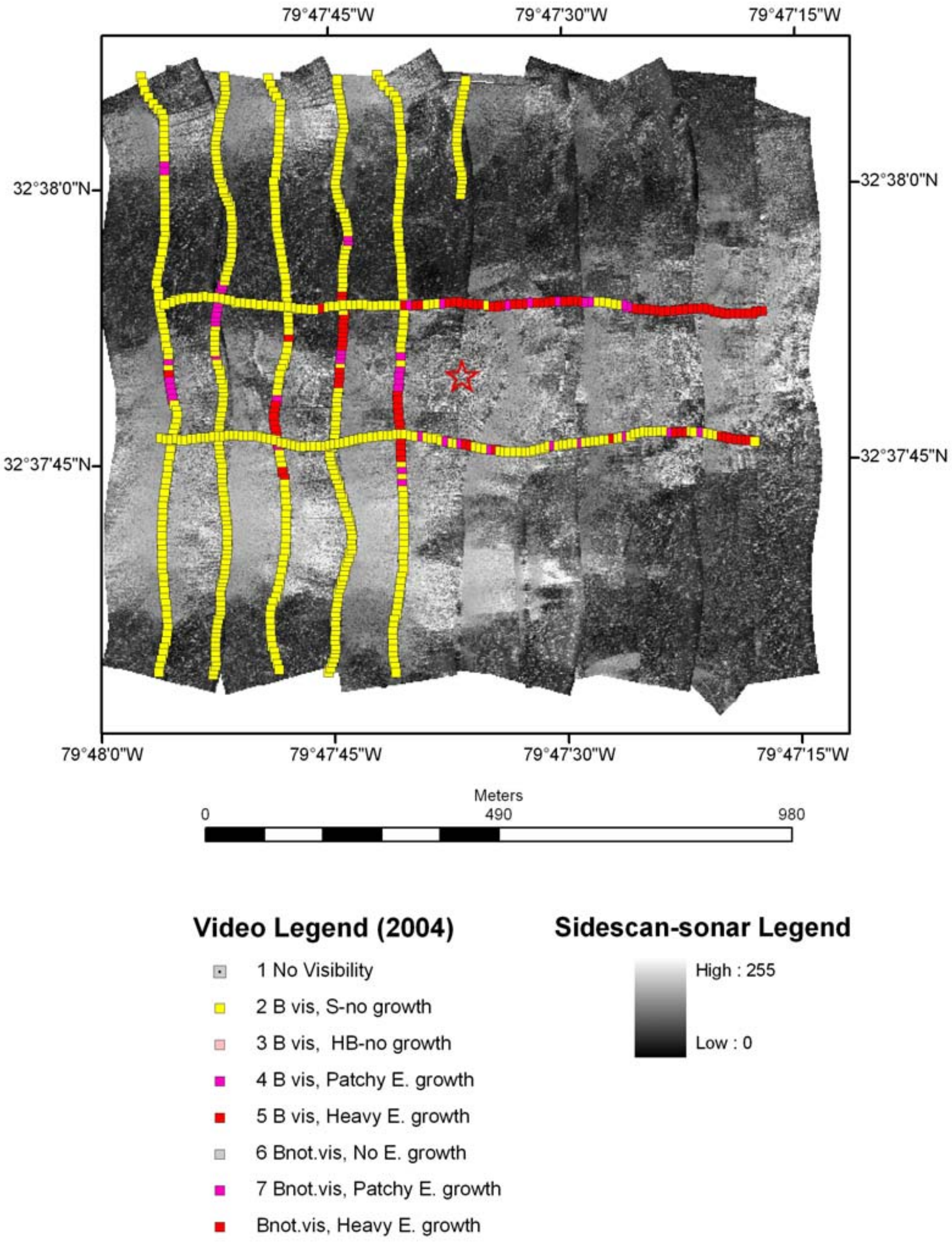

Figure 2.2a. Sidescan-sonar and coded video data collected over site SWA during the 2004 field season.

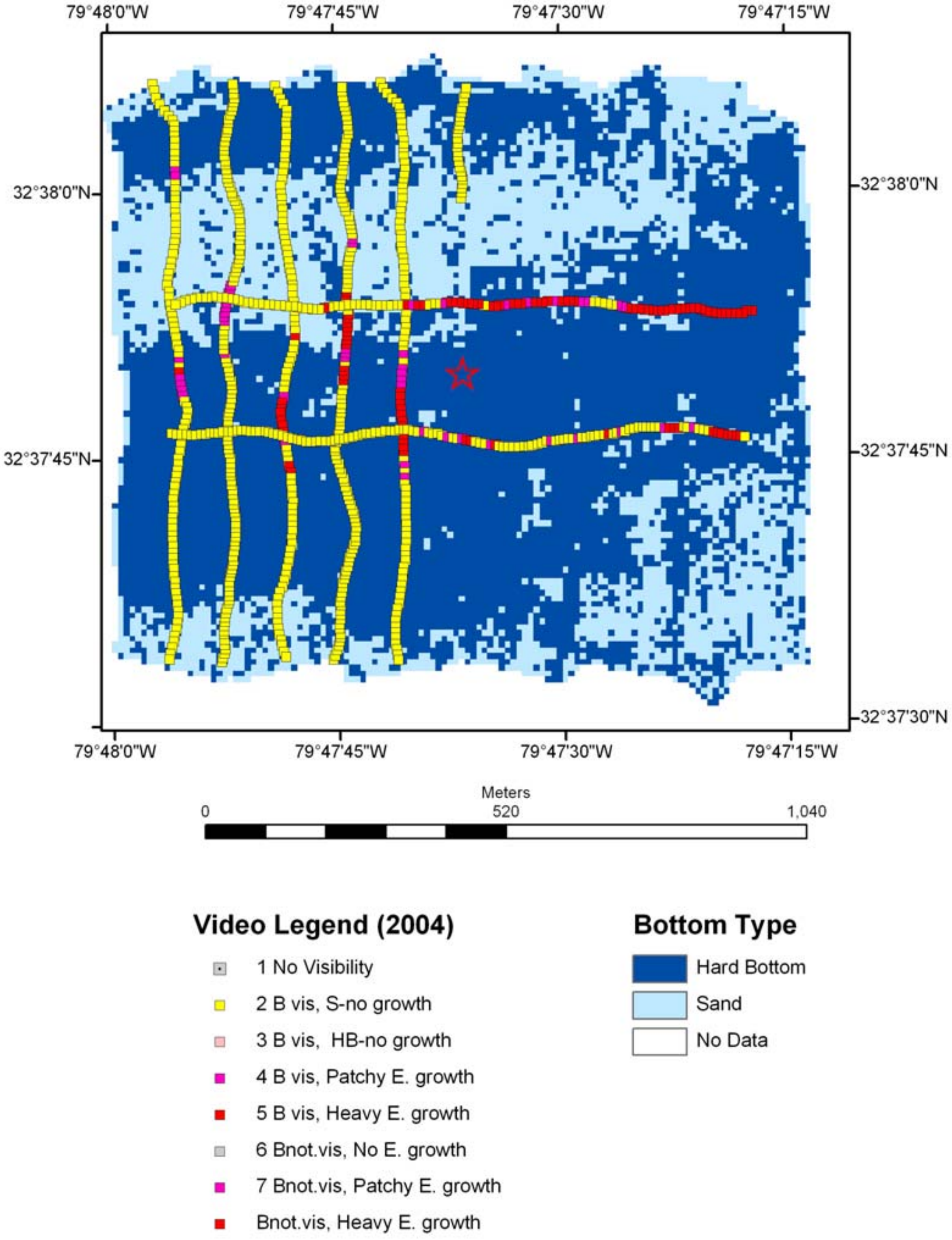

Figure 2.2b. Habitat mapping and coded video points of site SWA based on the sidescan-sonar mosaic from field season 2004.

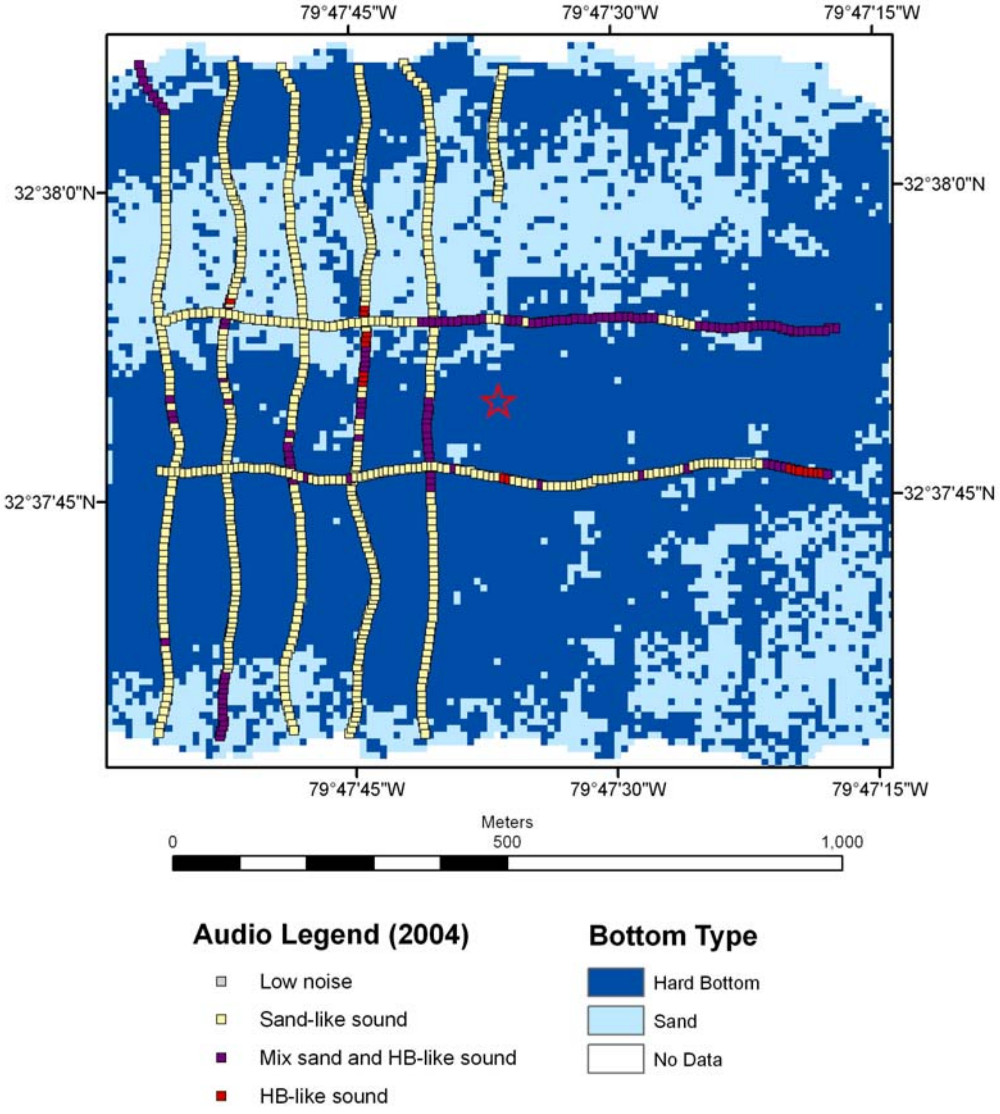

Figure 2.2c. Habitat mapping and coded audio points of site SWA based on the sidescan-sonar mosaic from field season 2004.

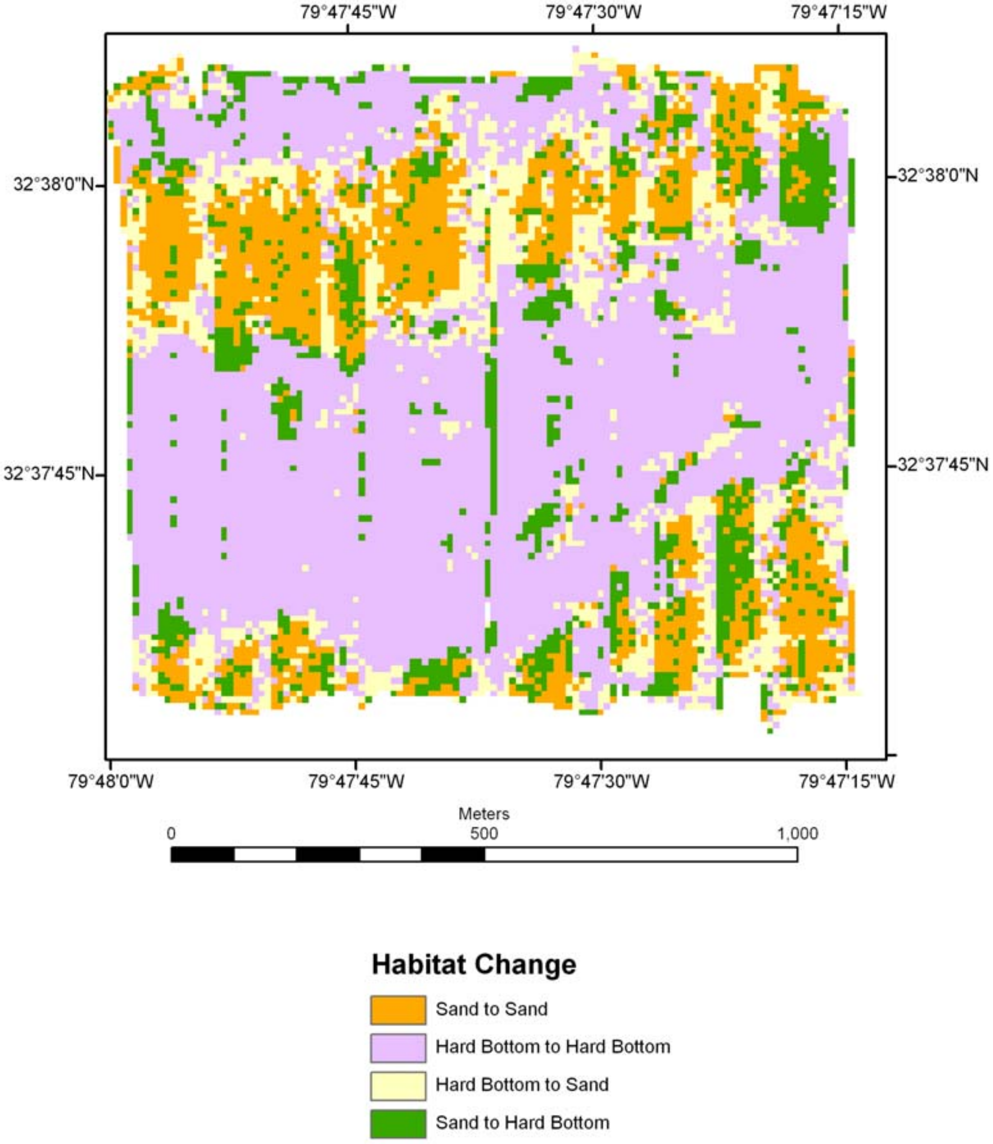

Figure 2.2d. Map of habitat change at site SWA during the inter-survey period 2002-2004.

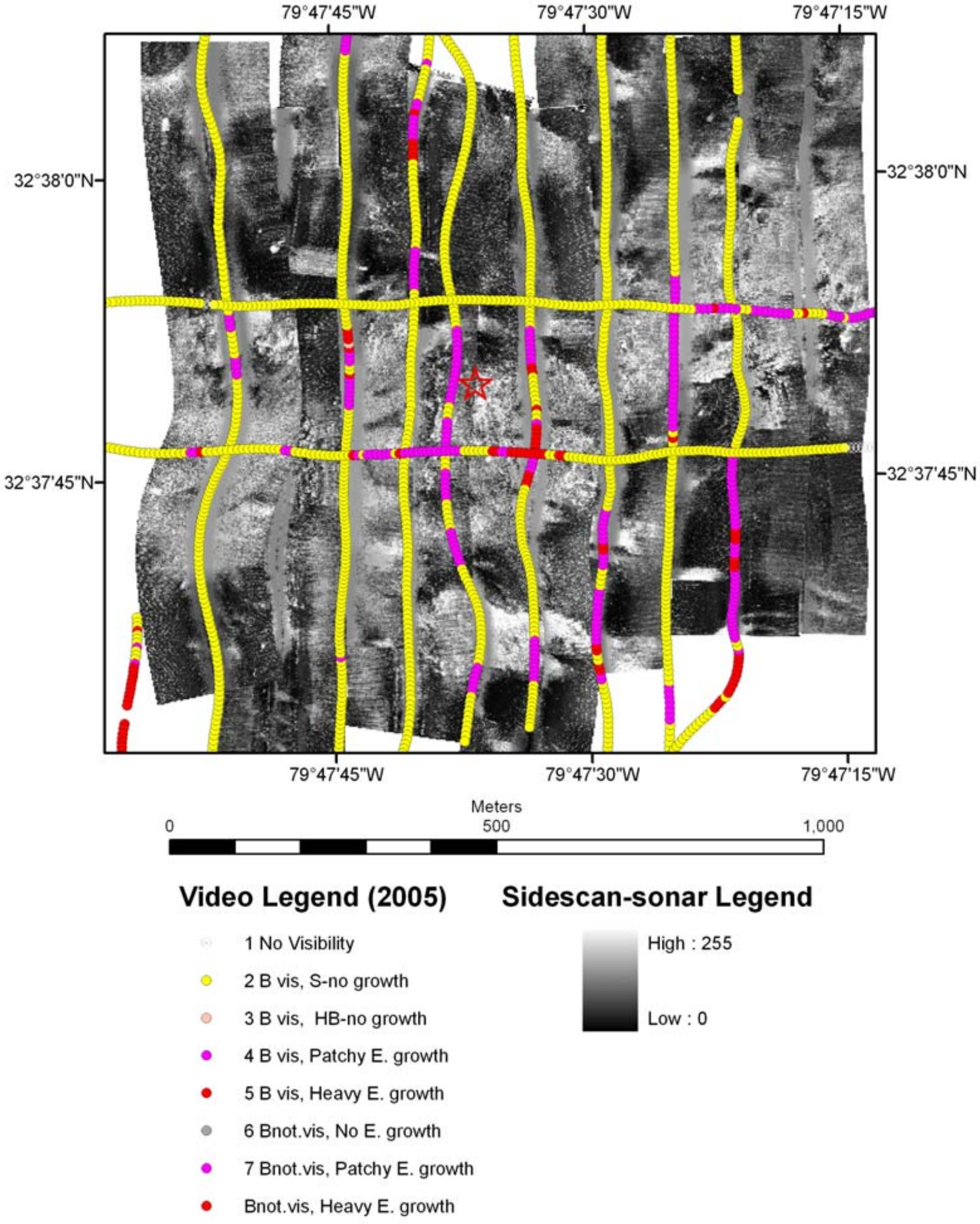

Figure 2.3a. Sidescan-sonar and coded video data collected over site SWA during the 2005 field season.

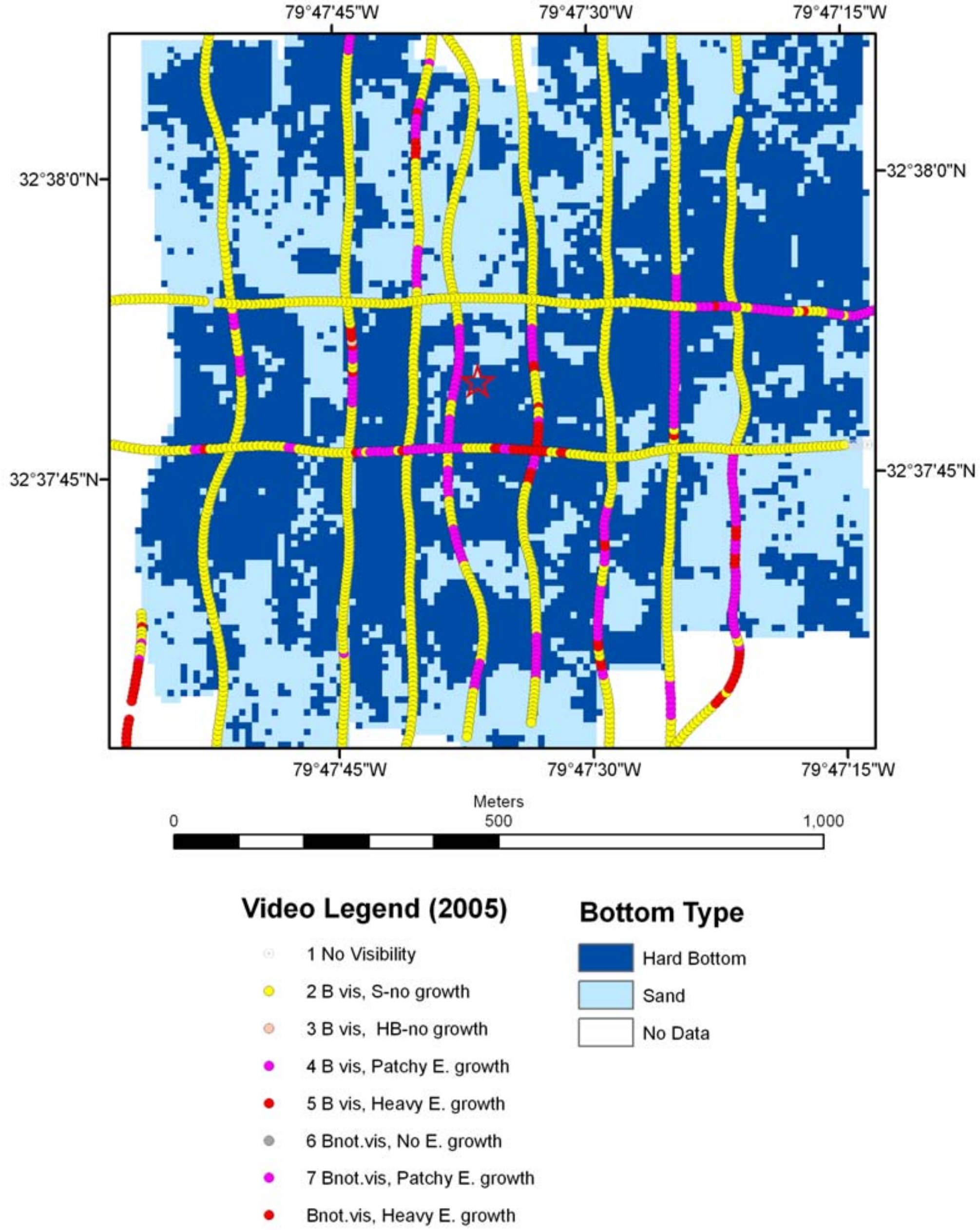

Figure 2.3b. Habitat mapping and coded video points of site SWA based on the sidescan-sonar mosaic from field season 2005.

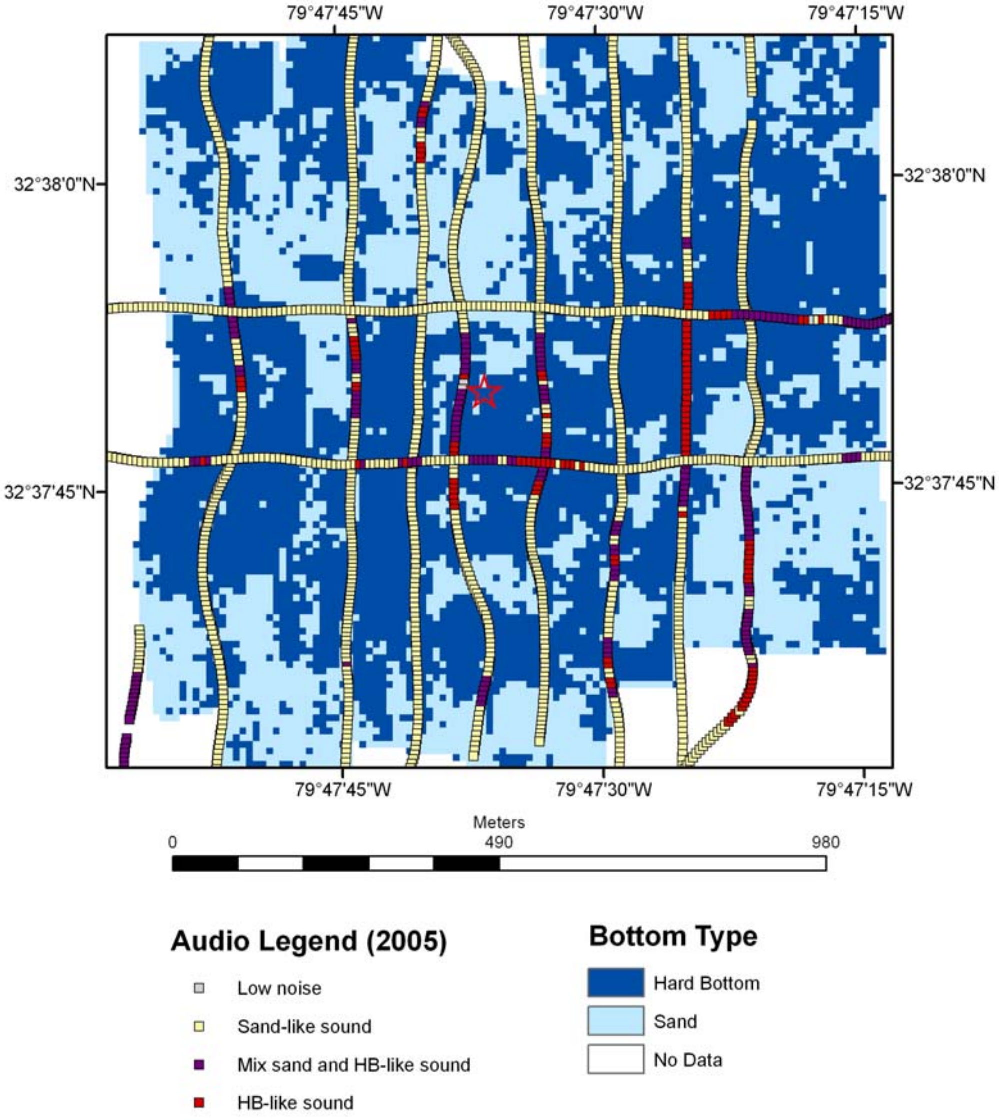

Figure 2.3c. Habitat mapping and coded audio points of site SWA based on the sidescan-sonar mosaic from field season 2005.

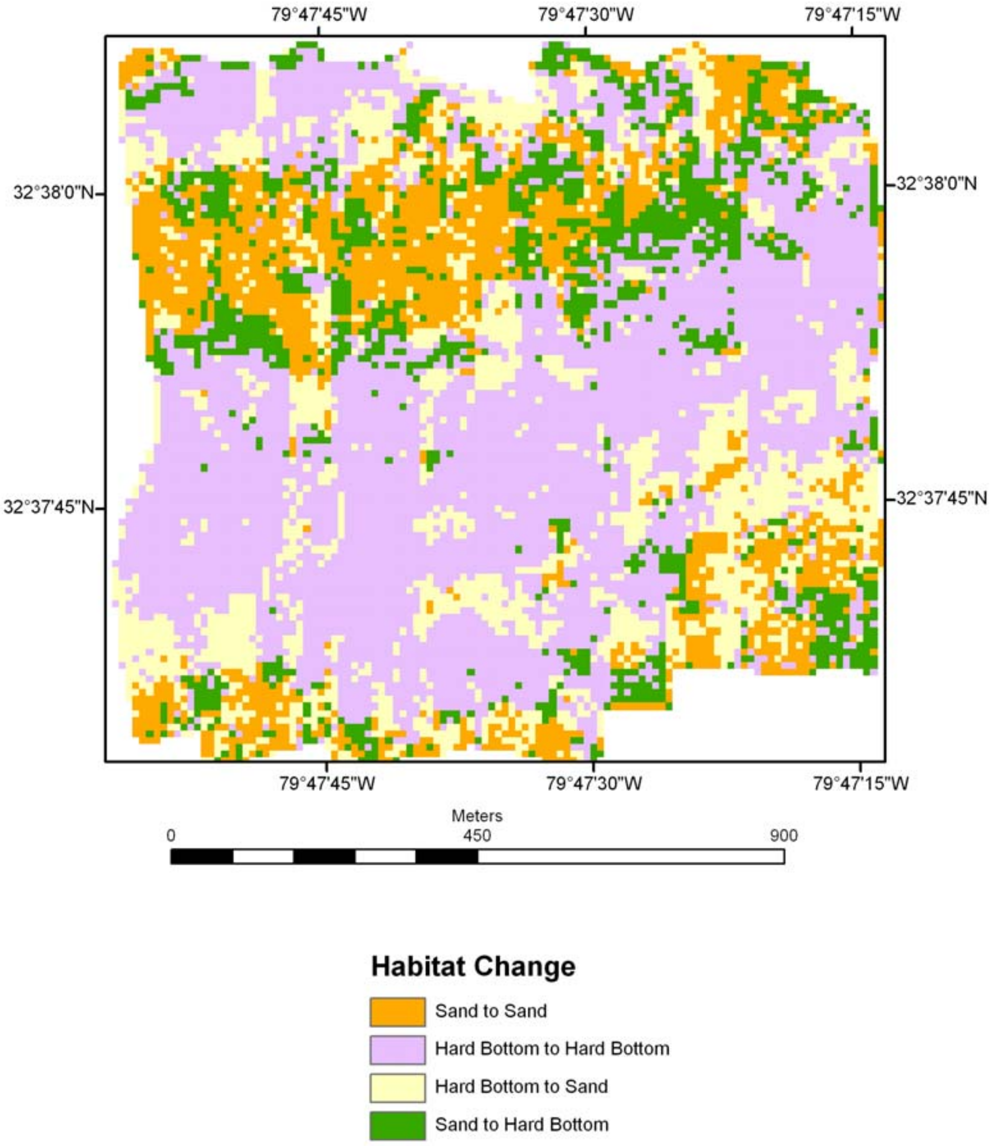

Figure 2.3d. Map of habitat change at site SWA during the inter-survey period 2004-2005.

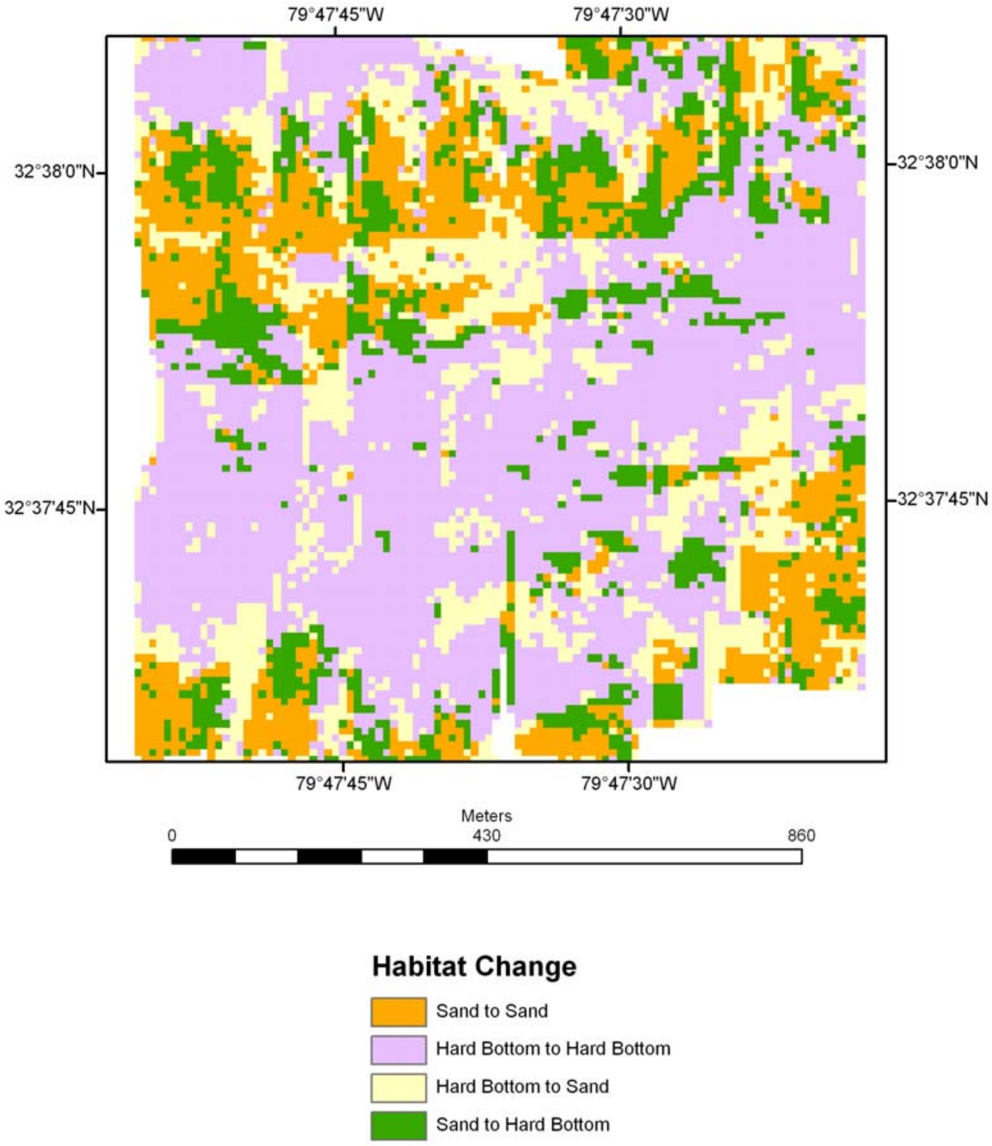

Figure 2.3e. Map of habitat change at site SWA during the inter-survey period 2001-2005.

Site WB

Site WB is located 4.4 kilometers northwest of the disposal site and shoreward of Priority Area 1, and is the most inshore of the six sites surveyed (Figure 2.1). Site WB has been surveyed with sidescan-sonar and bottom video data annually from 2001 to 2005, in addition to a video survey in 2000. During the 2004 survey, the video data was largely not visible. Of the small percentage of coded video points that were interpretable, all indicated some degree of emergent growth (Table 2.6). Visibility conditions were better during the 2005 survey and most of the visible bottom was covered with some degree of growth. With the exception of 2004, the results from which are skewed due to visibility conditions, percentages of hard ground and sand are fairly consistent throughout the five-year history of the survey.

Table 2.6. Habitat distribution on site WB based on coded video points within a 1-km2 box centered on reef site. 1 = No visibility, 2 = Bottom visible: sand with no growth, 3 = Bottom visible: hard bottom no growth, 4 = Bottom visible: patchy emergent growth, 5 = Bottom visible: heavy emergent growth, 6 = Bottom not visible: no emergent growth, 7 = Bottom not visible: patchy emergent growth, 8 = Bottom not visible: heavy emergent growth. Percentages are in term of total points.

WB	**2000**		**2001**		**2002**		**2004**		**2005**	
	total points coded	%	total points coded	%	total points coded	%	total points coded	%	total points coded	%
1	113	**27**	0	**0**	4	**0.3**	1293	**92.8**	64	**4**
2	173	**31.7**	336	**23.5**	753	**50**	0	**0**	483	**30.3**
3	36	**6.6**	0	**0**	0	**0**	0	**0**	15	**0.9**
4	142	**26**	176	**12.3**	422	**28**	0	**0**	833	**52.3**
5	43	**7.9**	31	**2.2**	327	**21.7**	0	**0**	31	**1.9**
6	1	**0.2**	444	**31.1**	0	**0**	45	**3.2**	142	**8.9**
7	21	**3.8**	408	**28.6**	0	**0**	40	**2.9**	25	**1.6**
8	17	**3.1**	33	**2.3**	0	**0**	15	**1.1**	0	**0**
TOTALS										
Hard bottom	259	**47.4**	336	**23.4**	749	**49.7**	55	**4**	879	**55.2**
Sand	173	**31.7**	648	**45.4**	753	**50**	0	**0**	483	**30.3**
No Visibility	114	**20.9**	444	**31.1**	4	**0.3**	1338	**96**	231	**14.5**
Total video collected	546	**100**	1428	**100**	1506	**100**	1393	**100**	1593	**100**

The sidescan mosaics for site WB have complicated distributions of high and low backscatter intensity. While in site SWA, there is a relatively well-defined band of high backscatter intensity area in the lower portion of the survey area, high and low backscatter values are commingled throughout site WB. The 2004 mosaic is highly speckled, making visual delineation of features difficult (Figure 2.4a). This speckling may be related to complications during data collection or processing steps.

Results from the textural analysis routine characterize the site as ~87 % hard bottom in 2004 and ~68 % hard bottom in 2005 (Table 2.7; Figures 2.4b and 2.5b). Site WB does not exhibit any obvious pattern of hard bottom that is consistent through time.

Table 2.7. Habitat distribution on site WB based on interpretive textural analysis of the sidescan-sonar mosaic. Areas are in units of 10^5 m^2.

	2000		**2001**		**2002**		**2004**		**2005**	
	area	%	area	%	area	%	area	%	area	%
Hard bottom	-	**-**	6.12	**61.2**	8.102	**81**	8.685	**86.9**	6.772	**67.7**
Sand	-	**-**	3.054	**30.5**	1.827	**18.3**	1.307	**13.1**	3.062	**30.6**
No Data	-	**-**	0.826	**8.3**	0.071	**0.7**	0.008	**0.08**	.166	**1.7**
Total area	-	**-**	10	**100**	10	**100**	10	**100**	10	**100**

Comparison of habitat maps between different survey years provides a quantitative estimation of change in bottom type. Between 2001 and 2002, a net gain of ~5.5 % of the hard bottom area is calculated. A significant net loss of ~18 % of hard bottom area is calculated for the following inter-survey period. These numbers suggest a rather dynamic sediment transport at site WB. During the 4 year history of this site, however, there is very little net change in total hard bottom area (Table 2.8). Due to the very high percentage of video data coded as 'no visibility' during the 2004 survey, further comments regarding extent of bottom type change from 2002-2004 and 2004-2005 cannot be made with confidence.

Table 2.8. Spatial analysis of change, site WB. Values are numbers of m^2.

	2000 to 2001	2001 to 2002	2002 to 2004	2004 to 2005
from sand to sand	106,400	39,500	42,000	105,400
from hard bottom to hard bottom	541,000	720,800	590,300	436,800
from hard bottom to sand	60,100	88,800	263,900	170,100
from sand to hard bottom	192,200	143,000	86,700	195,500
Total area of analysis	899,700	992,100	982,900	907,800
Area of no change (%)	72.0 %	76.6 %	64.3 %	59.7 %
Area of change (%)	28.0 %	23.4 %	35.7 %	40.3 %
Net hard bottom change * (%)	14.7 %	5.5 %	-18 %	2.8 %

* positive values indicate net gain; negative values indicate net loss.

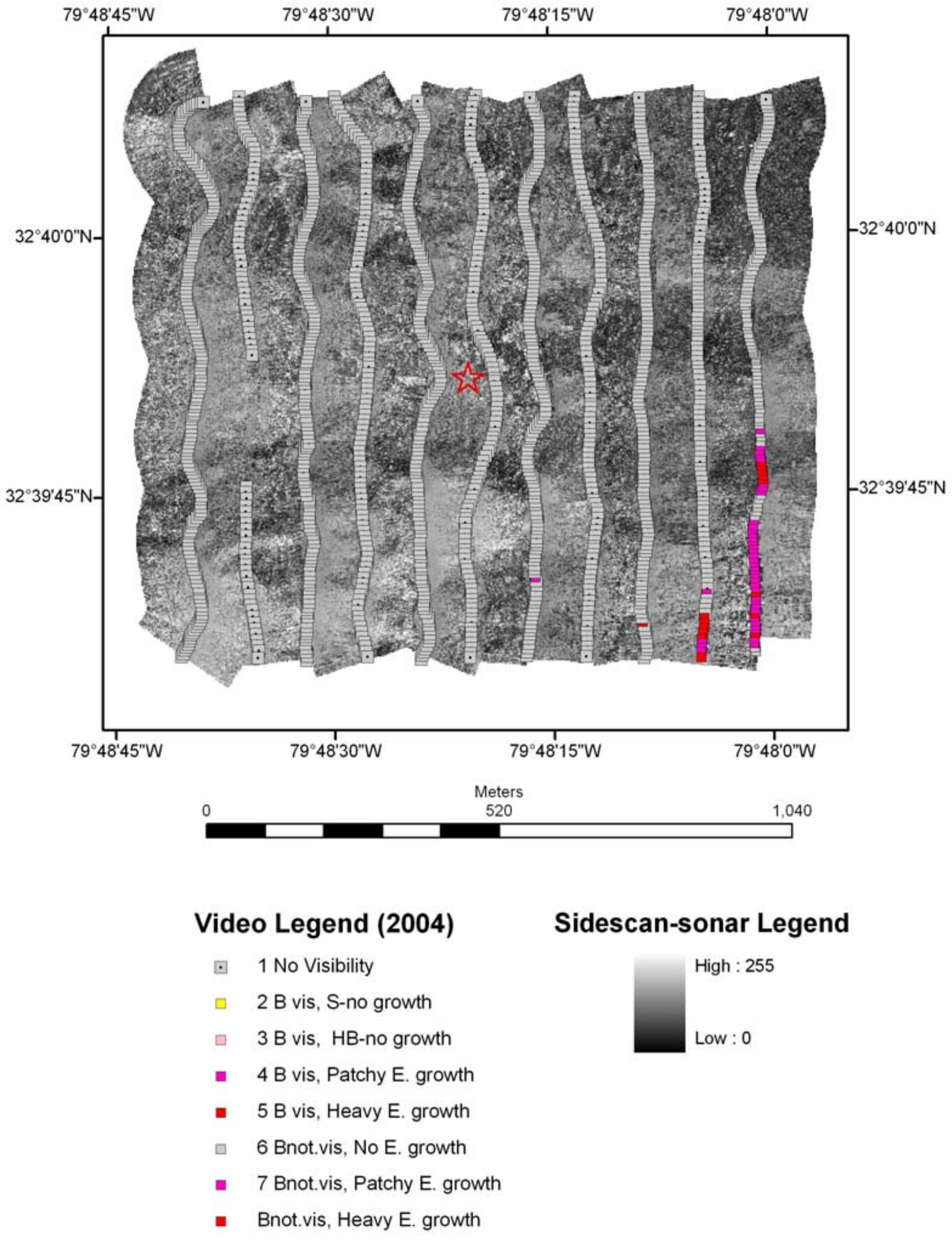

Figure 2.4a. Sidescan-sonar and coded video data collected over site WB during the 2004 field season.

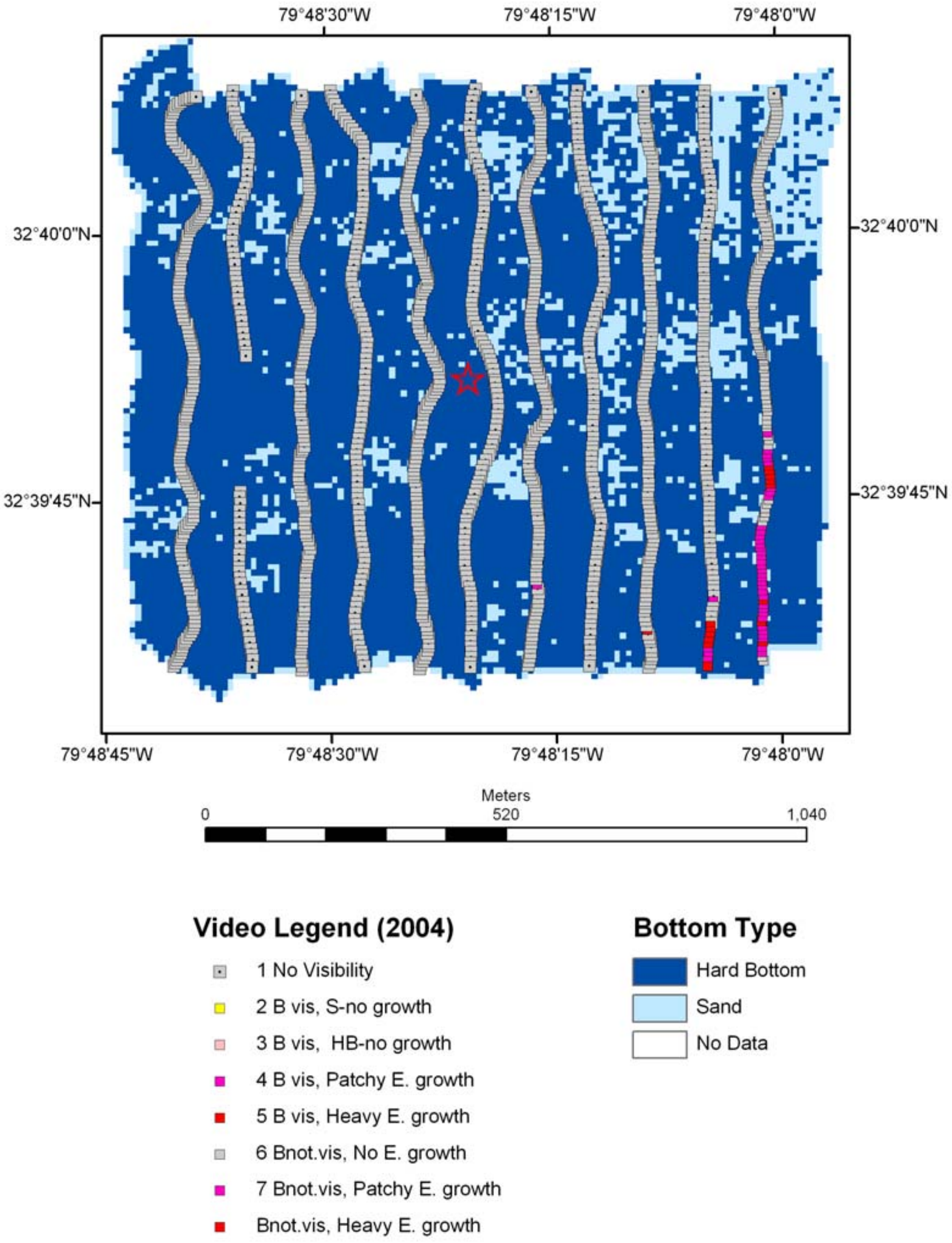

Figure 2.4b. Habitat mapping and coded video points of site WB based on the sidescan-sonar mosaic from field season 2004.

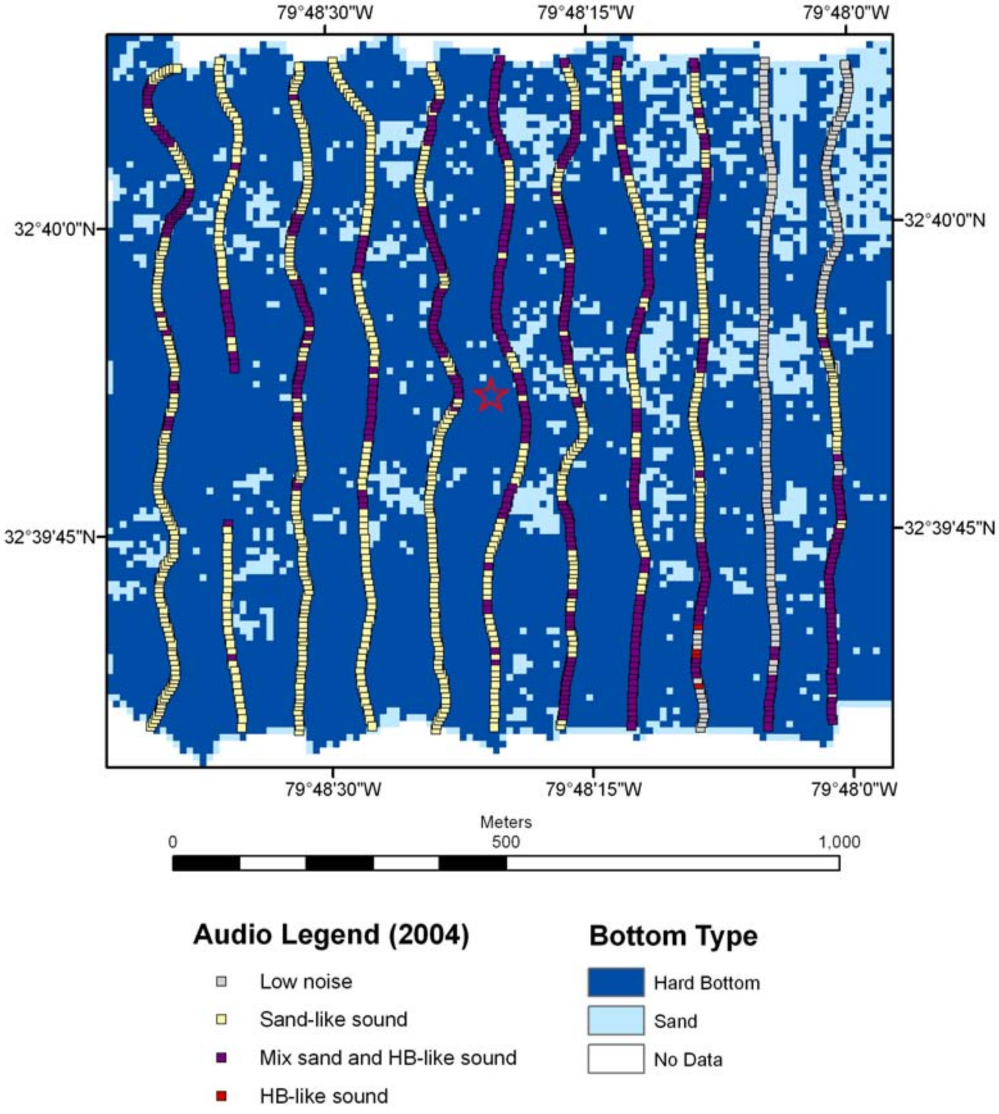

Figure 2.4c. Habitat mapping and coded audio points of site WB based on the sidescan-sonar mosaic from field season 2004.

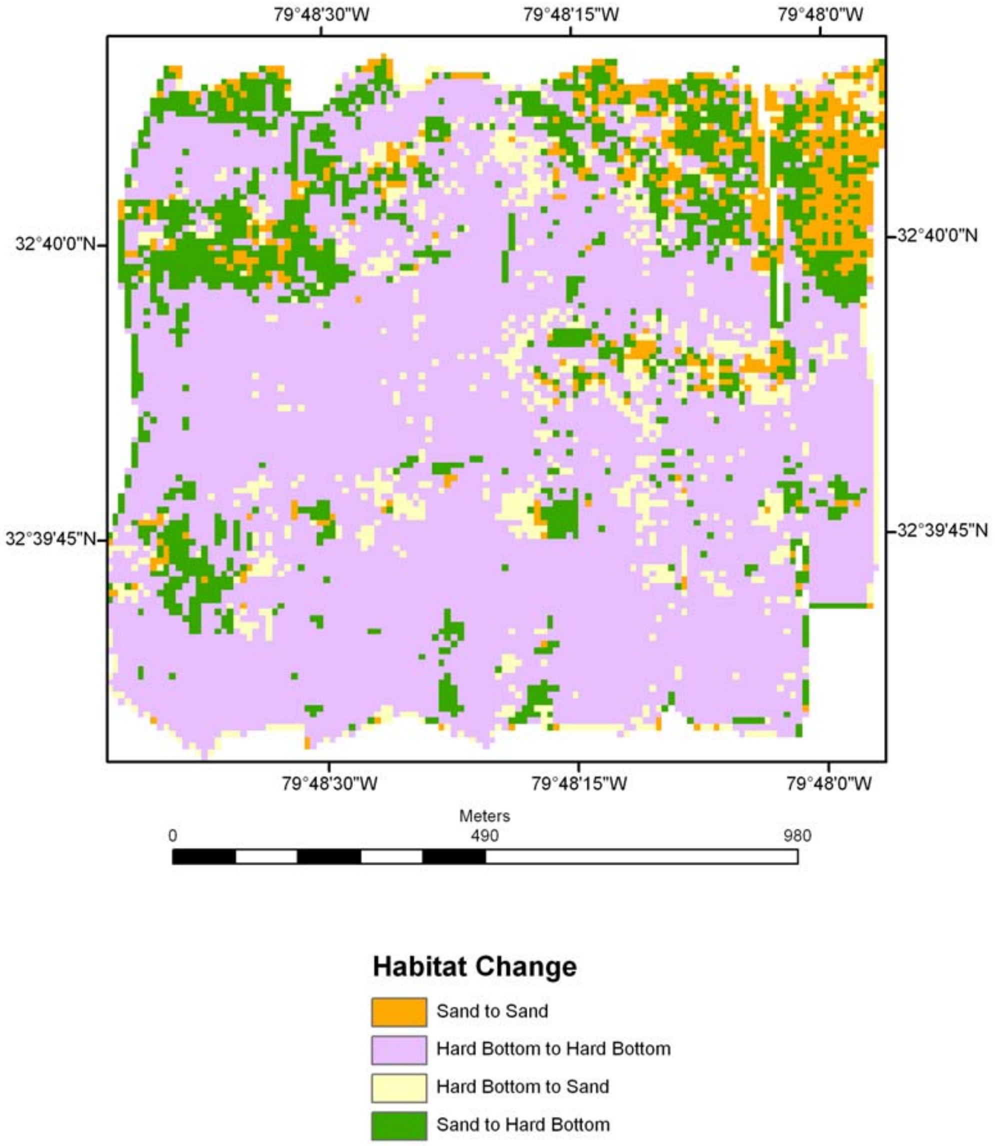

Figure 2.4d. Map of habitat change at site WB during the inter-survey period 2002-2004.

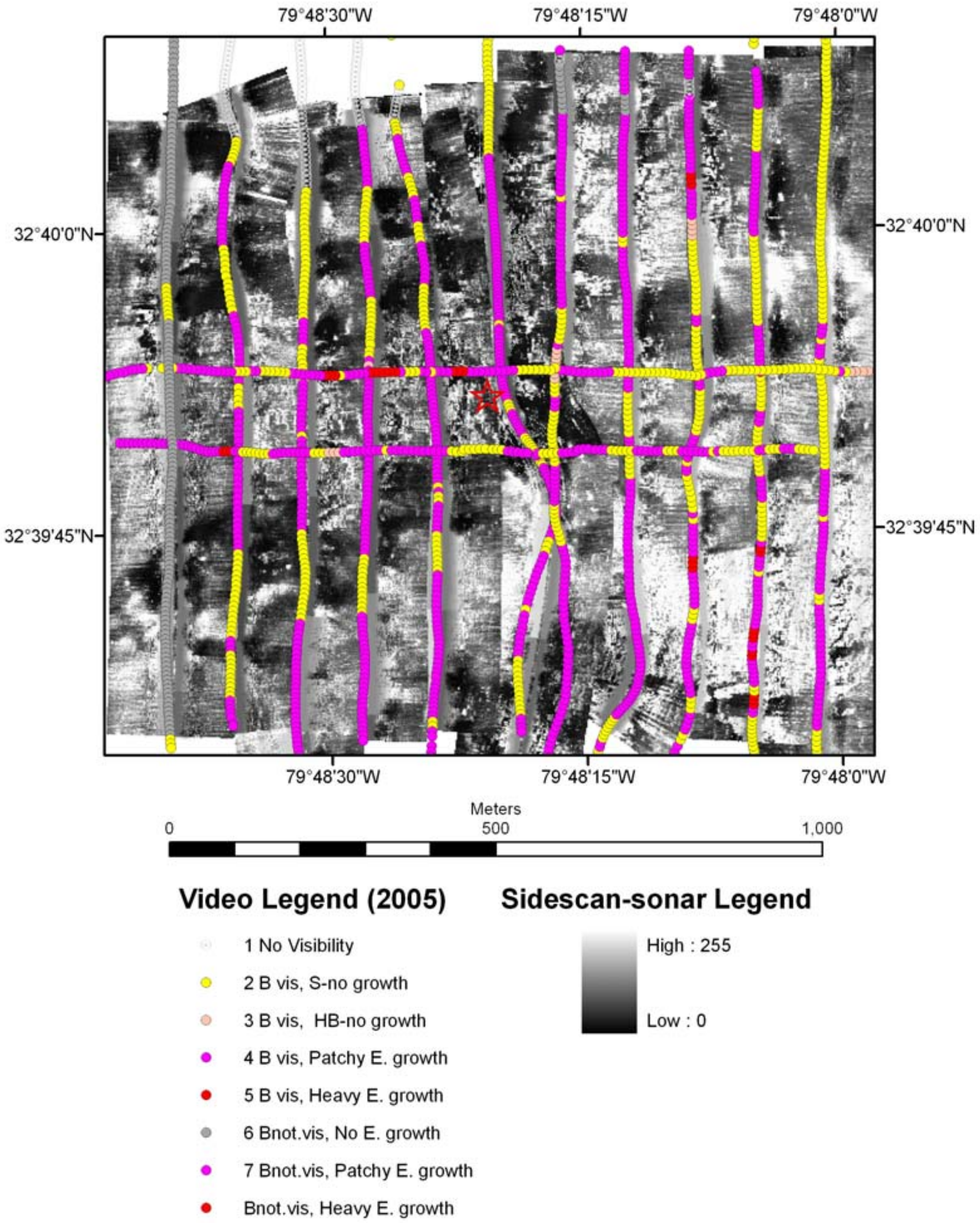

Figure 2.5a. Sidescan-sonar and coded video data collected over site WB during the 2005 field season.

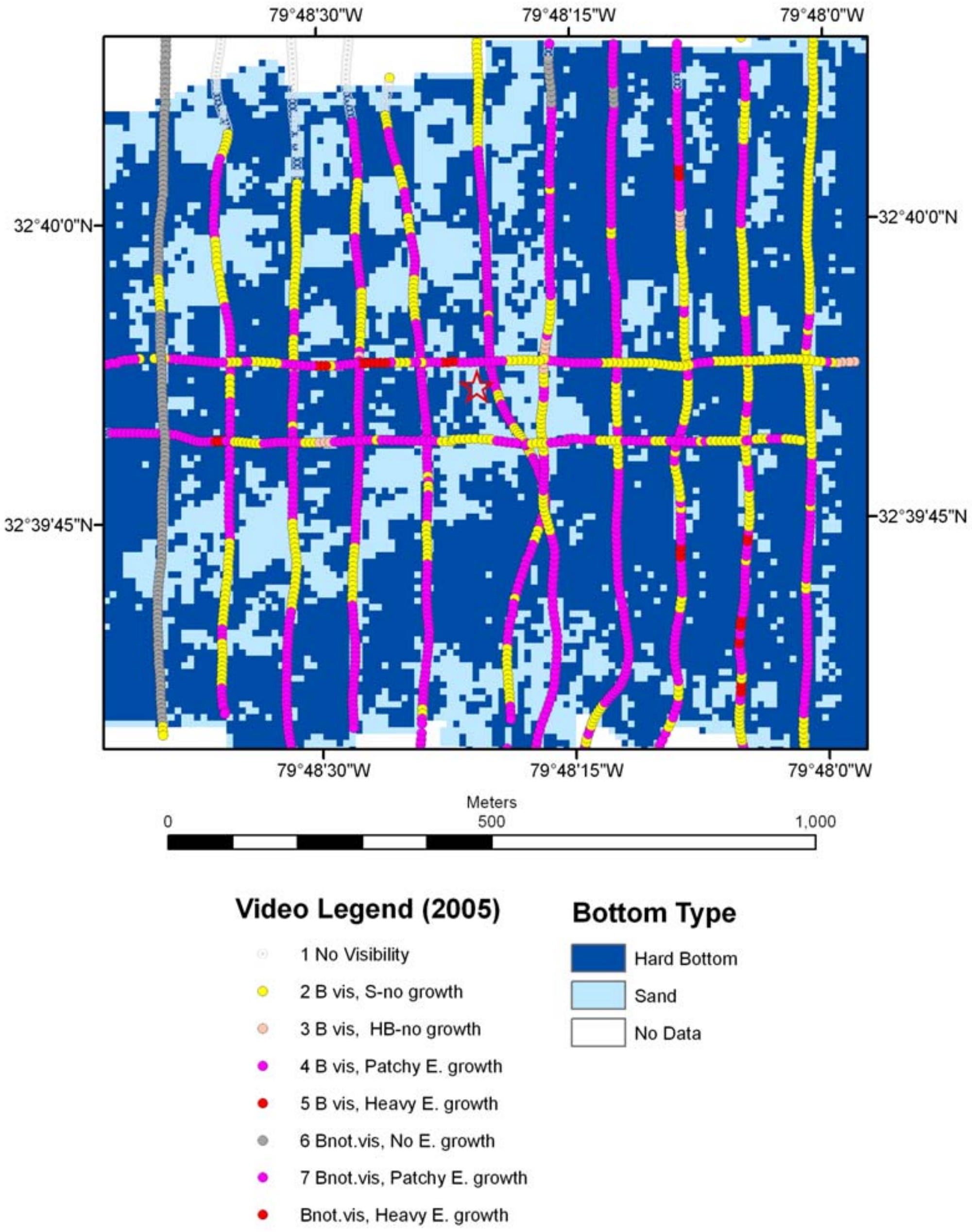

Figure 2.5b. Habitat mapping and coded video points of site WB based on the sidescan-sonar mosaic from field season 2005.

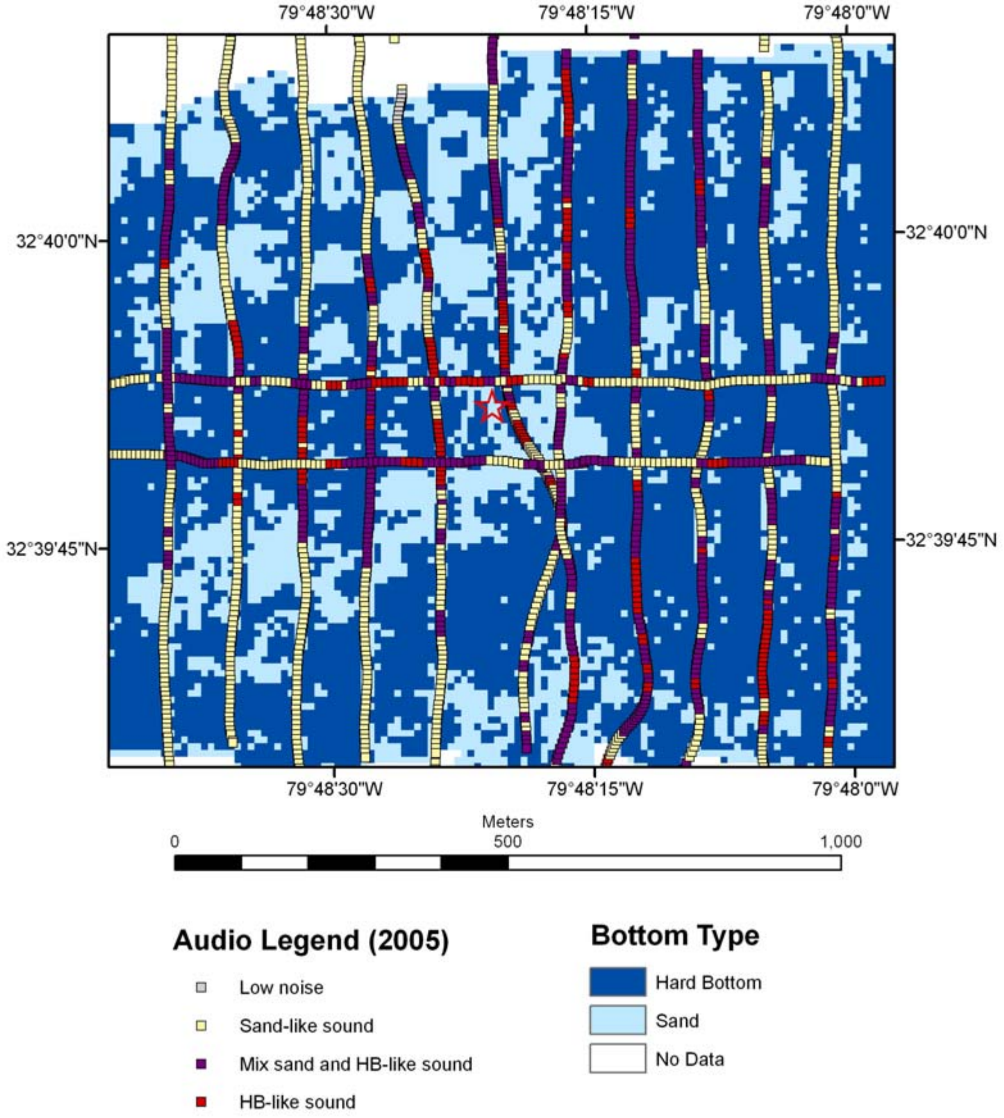

Figure 2.5c. Habitat mapping and coded audio points of site WB based on the sidescan-sonar mosaic from field season 2005.

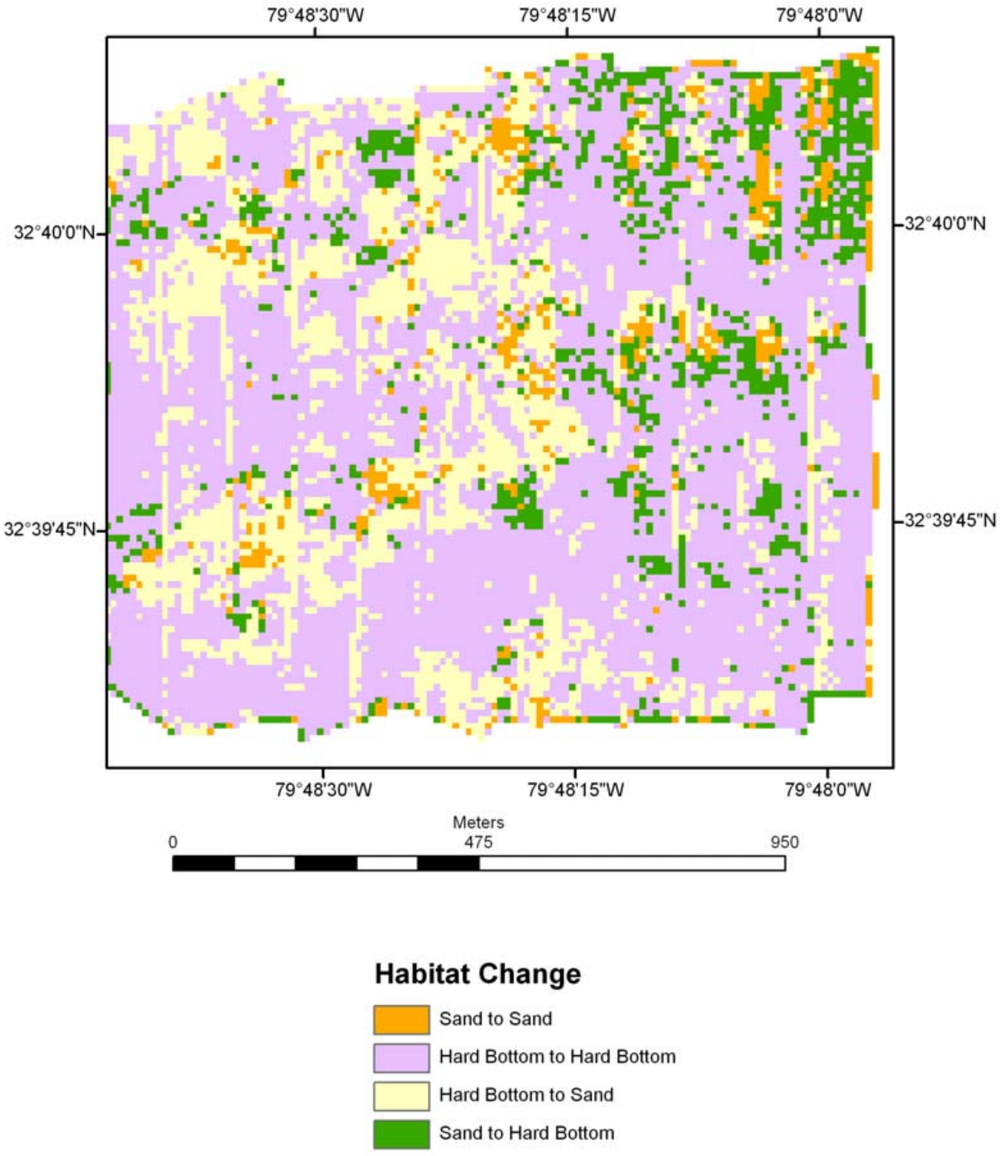

Figure 2.5d. Map of habitat change at site WB during the inter-survey period 2004-2005.

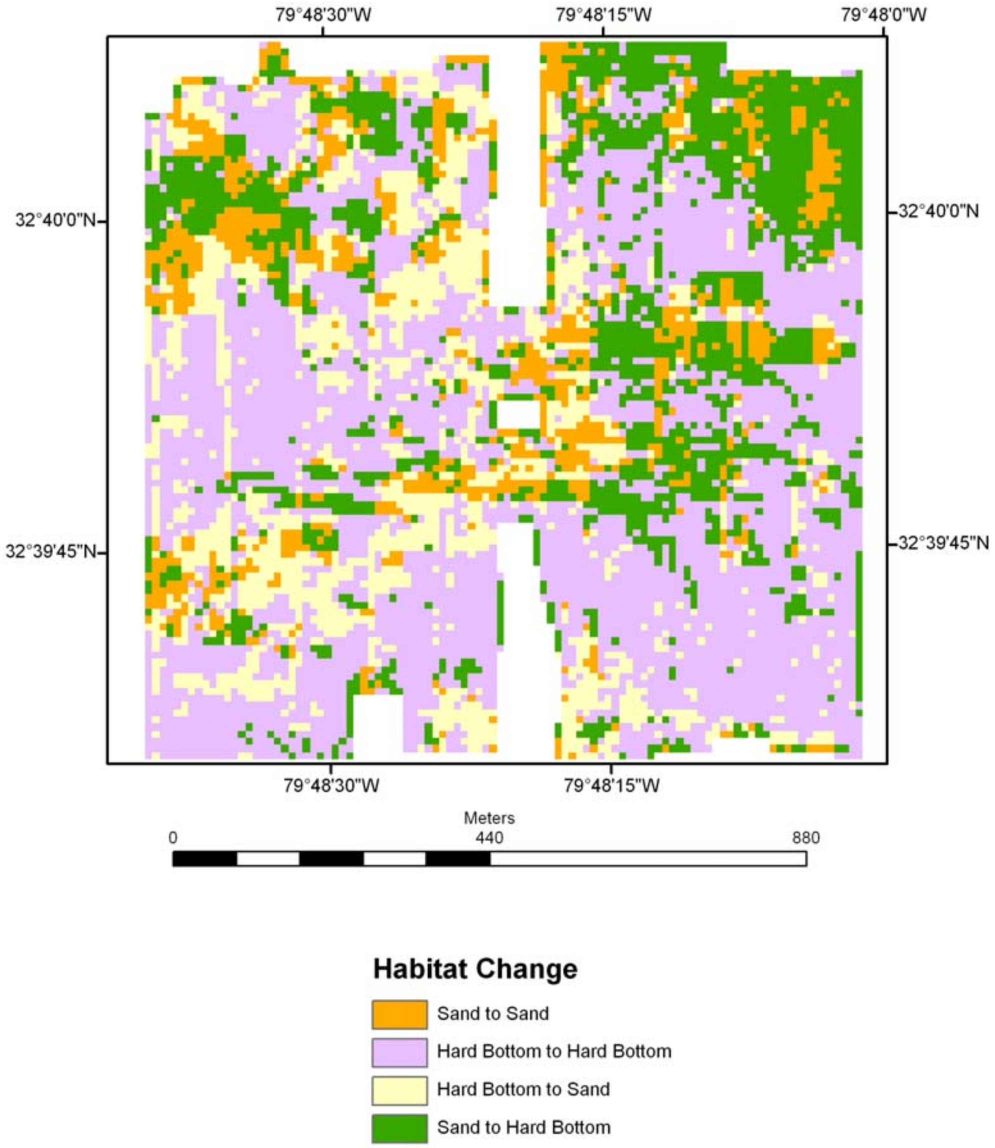

Figure 2.5e. Map of habitat change at site WB during the inter-survey period 2001-2005.

Site SWB

Site SWB is located 4.6 km south-southwest of the disposal site (Figure 2.1). This site has been video surveyed over the five year history of this project though poor visibility rendered the data un-interpretable in the first year. Video data collected annually from 2001-2005 characterize the site as varying between 70% and 85% sand (Table 2.9). In the two most recent years, the largest percentage of hard bottom area is classified as 'heavy emergent growth' (9.2% and 21.9% in 2004 and 2005, respectively).

Table 2.9. Habitat distribution on site SWB based on coded video points within a 1-km2 box centered on reef site. 1 = No visibility, 2 = Bottom visible: sand with no growth, 3 = Bottom visible: hard bottom no growth, 4 = Bottom visible: patchy emergent growth, 5 = Bottom visible: heavy emergent growth, 6 = Bottom not visible: no emergent growth, 7 = Bottom not visible: patchy emergent growth, 8 = Bottom not visible: heavy emergent growth. Percentages are in term of total points, and in parentheses total identifiable sand and hard bottom classes.

SWB	**2000**		**2001**		**2002**		**2004**		**2005**	
	total points coded	%	total points coded	%	total points coded	%	total points coded	%	total points coded	%
1	0	**0**	98	**7.9**	1	**0.1**	439	**22.7**	0	**0**
2	0	**0**	658	**53.3**	1023	**70.3**	788	**40.8**	809	**75.3**
3	0	**0**	0	**0**	28	**1.9**	0	**0**	0	**0**
4	0	**0**	166	**13.4**	135	**9.3**	20	**1**	30	**2.8**
5	0	**0**	56	**4.5**	267	**18.4**	86	**4.5**	235	**21.9**
6	130	**100**	188	**15.3**	0	**0**	560	**29**	0	**0**
7	0	**0**	69	**5.6**	0	**0**	24	**1.2**	0	**0**
8	0	**0**	0	**0**	0	**0**	13	**0.7**	0	**0**
TOTALS										
Hard bottom	0	**0**	291	**23.6**	430	**29.6**	106	**5.5**	265	**24.7**
Sand	0	**0**	658	**53.3**	1023	**70.3**	788	**40.8**	809	**75.3**
No Visibility	130	**100**	286	**23.1**	1	**0.1**	1036	**53.7**	0	**0**
Total video collected	130	**100**	1235	**100**	1454	**100**	1930	**100**	1074	**100**

Sidescan-sonar data were collected in addition to video data during each of the four most recent years of surveying. The 2004 and 2005 mosaics are characterized by similar backscatter intensity patterns (Figure 2.6a and 2.7a). Both surveys show a large patch of high backscatter intensity dominating the northeast area of site SWB. The southwest area of the site consists of low backscatter seafloor. Visual comparison of the two most recent mosaics reveals very similar features and grayscale distribution from 2004 to 2005. Further comparison of video code distribution between 2001 (Gayes *et al.* 2001), 2002 (Gayes *et al.* 2002), and 2005 (Figure 2.7a) reveals strikingly similar distributions of hard ground classification. The video from 2004 may not compare as well due to the large area of no visibility. Nonetheless, throughout the history of the SWB surveys, hard ground percentage and distribution are fairly time invariant features.

Output from the textural analysis routine suggests significantly different results from video analysis and visual inspection of the mosaics (Table 2.10; Figures 2.6b and 2.7b). Hard bottom percentages range from 55 % to as much as 85.5 % throughout the history of the surveys, with values of 70.7 % and 62.9 % reported for 2004 and 2005. Interestingly, audio code overlain on the habitat maps supports the video classification (mostly sand throughout the site) and do not match as well with the textural analysis (Figures 2.6c and 2.7c). Audio data is classified by the sound made as the video sled slides across the seafloor. A hissing sound (as the sled travels through sand) is easily distinguished from the clanging sound of the sled as it bumps over hard bottom.

Differences in the appearance of the sidescan mosaics and the video/audio seafloor classifications owe to the presence of a thin veneer of sand overlying hard bottom in the northeast part of site SWB (Gayes *et al.* 2002). While the backscatter intensity data recorded in sidescan-sonar surveys is non-unique, visual confirmation of the sand veneer confirms the earlier interpretation of Gayes *et al.* 2002. It is important to consider that despite the shortcomings of each method (video versus textural analysis) both approaches suggest fairly constant percentages of hard bottom on a year to year basis, and little overall change throughout the five-year duration of the project.

Table 2.10. Habitat distribution on site SWB based on interpretive textural analysis of the sidescan-sonar mosaic. Areas are in units of 10^5 m^2.

	2000		**2001**		**2002**		**2004**		**2005**	
	area	%	area	%	area	%	area	%	area	%
Hard bottom	-	**-**	5.496	**55**	8.546	**85.5**	7.066	**70.7**	6.29	**62.9**
Sand	-	**-**	3.626	**36.3**	1.454	**14.5**	2.89	**28.9**	3.477	**34.8**
No Data	-	**-**	0.878	**8.7**	0	**0**	0.044	**0.4**	0.233	**2.3**
Total area	-	**-**	10	**100**	10	**100**	10	**100**	10	**100**

Bottom type change maps calculated from the habitat maps suggest net hard bottom loss has occurred during the two most recent inter-survey periods (Table 2.11; Figures 2.6d and 2.7d). In contrast, the overall change in hard bottom between 2001 and 2005 is a small (~2.6 %) net gain in hard bottom area (Table 2.11; Figure 2.7e).

The inter-survey periods from year to year suggest dynamic sediment redistribution at site SWB. Significant net gains or losses are suggested by the textural analysis algorithm for one year periods. The four year interval, however, only records a minor change in net hard bottom area. This result suggests that the thin veneer of sand that covers a significant percentage of this site is easily mobilized within the area, but no significant gain or loss occurs over time.

Table 2.11. Spatial analysis of change, site SWB. Values are numbers of m^2.

	2001 to 2002	2002 to 2004	2004 to 2005	2001 to 2005
from sand to sand	86,100	71,100	141,900	161,500
from hard bottom to hard bottom	482,700	632,300	483,700	379,500
from hard bottom to sand	55,900	217,900	204,900	167,300
from sand to hard bottom	269,700	74,300	142,300	190,600
Total area of analysis	894,400	995,600	972,800	898,900
Area of no change (%)	63.6 %	70.7 %	64.3 %	60.2 %
Area of change (%)	36.4 %	29.3 %	35.7 %	39.8 %
Net hard bottom change * (%)	23.9 %	-14.4 %	-6.4 %	2.6 %

* positive values indicate net gain; negative values indicate net loss.

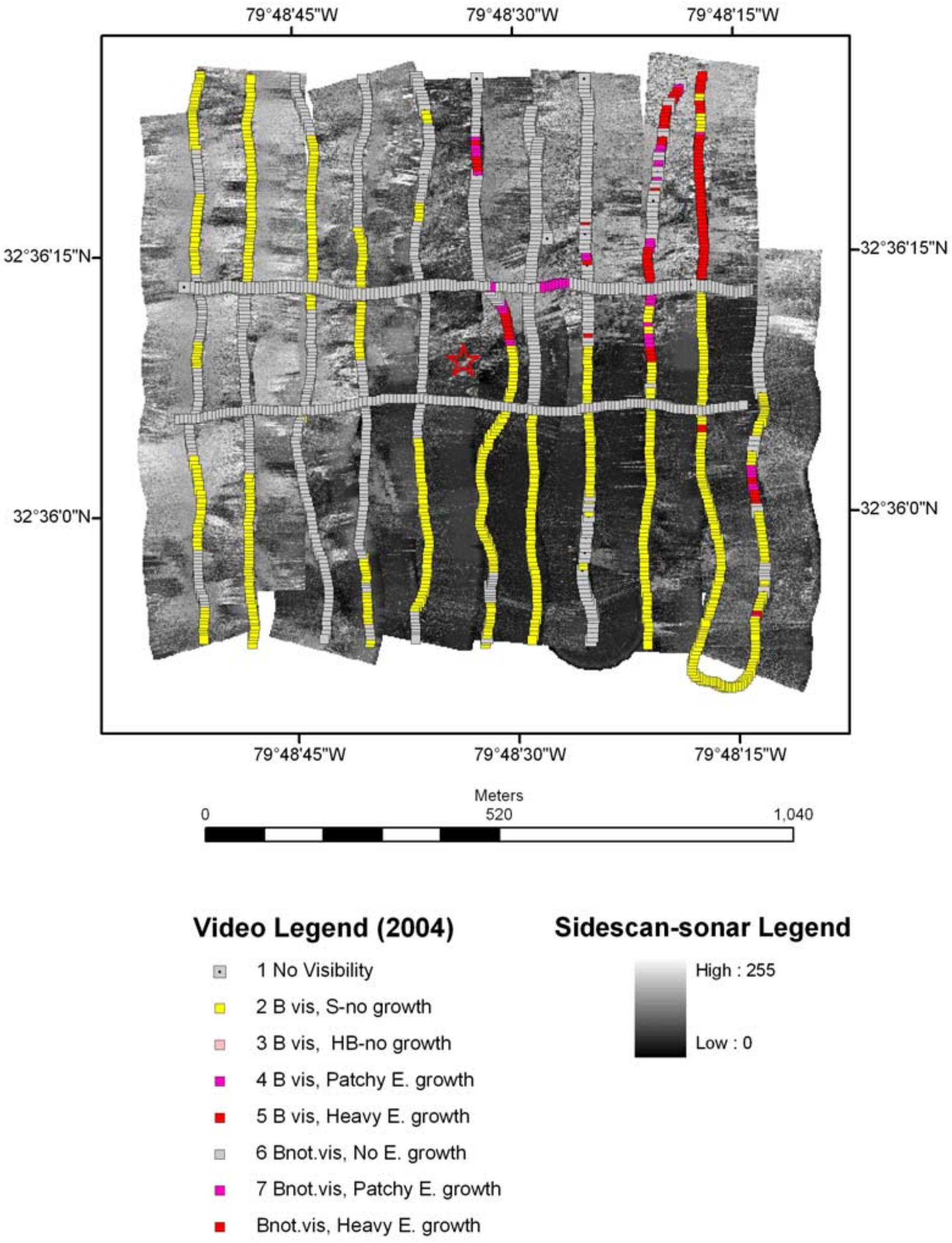

Figure 2.6a. Sidescan-sonar and coded video data collected over site SWB during the 2004 field season.

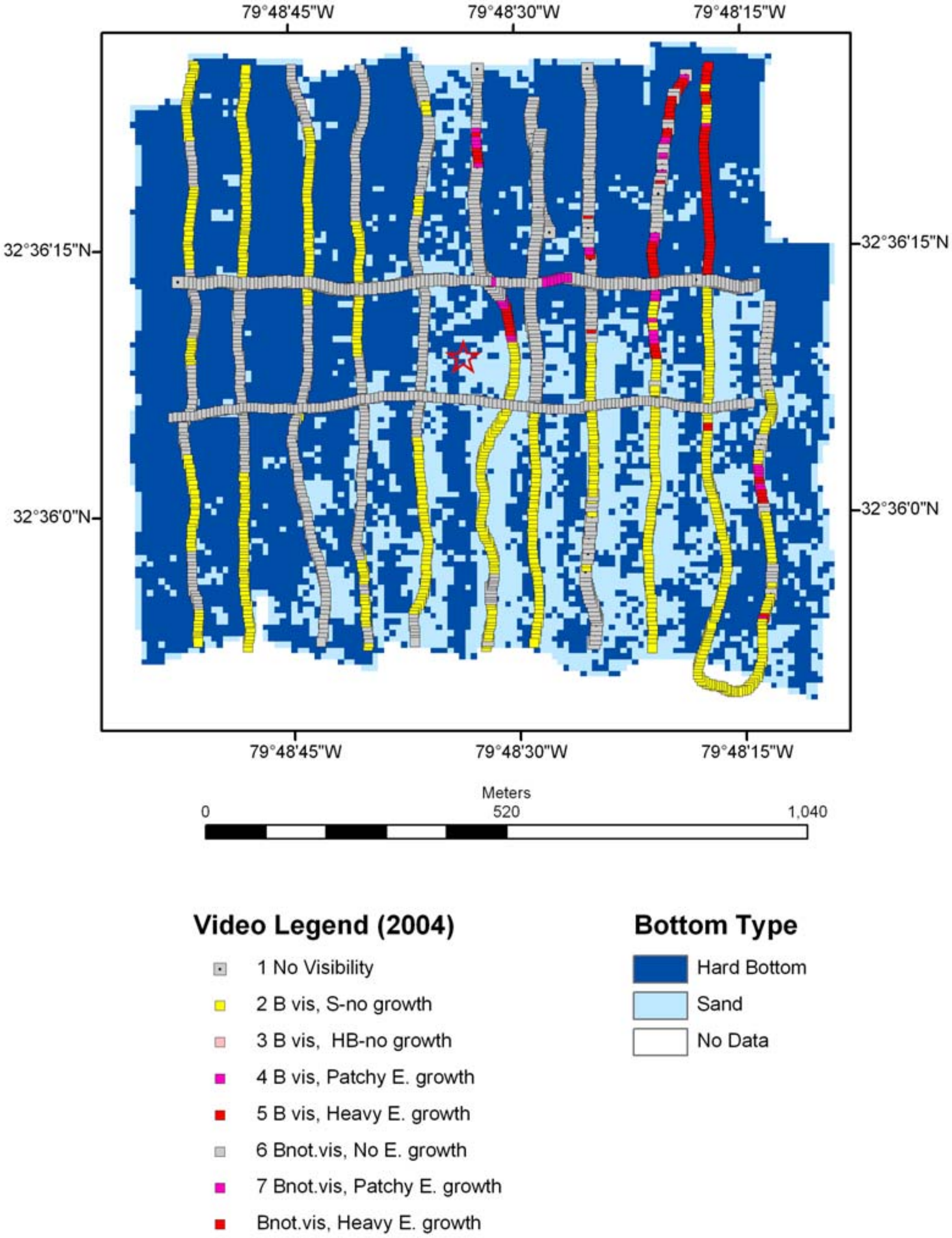

Figure 2.6b. Habitat mapping and coded video points of site SWB based on the sidescan-sonar mosaic from field season 2004.

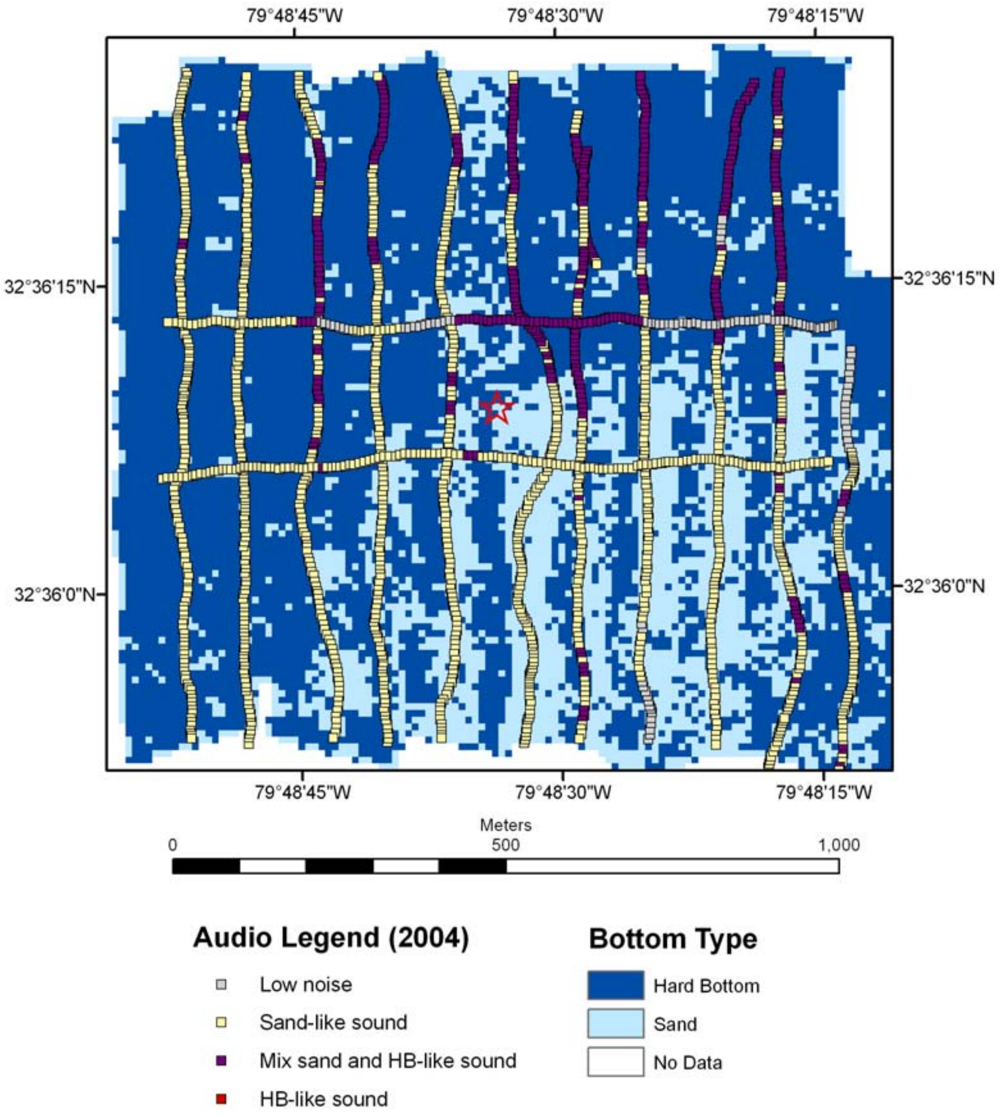

Figure 2.6c. Habitat mapping and coded audio points of site SWB based on the sidescan-sonar mosaic from field season 2004.

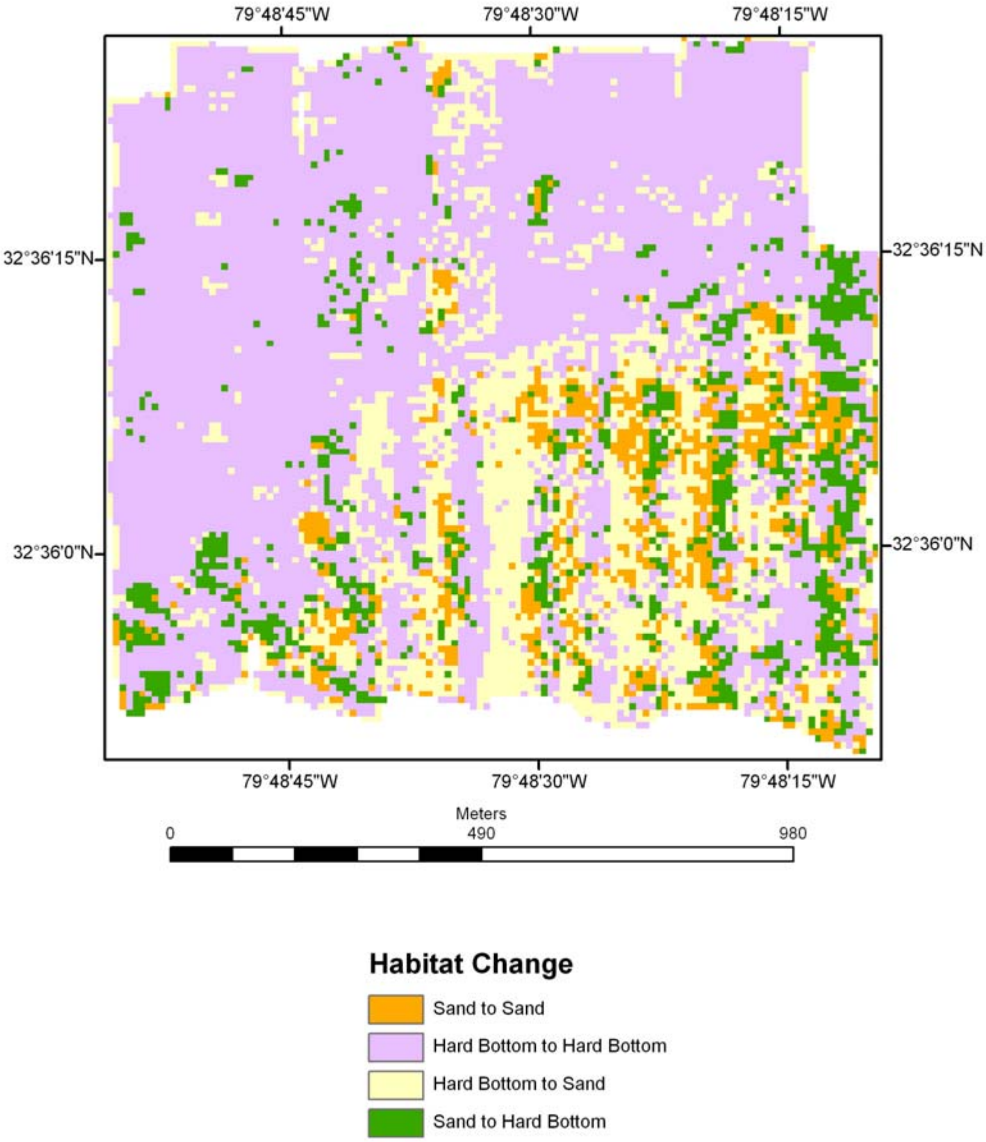

Figure 2.6d. Map of habitat change at site SWB during the inter-survey period 2002-2004.

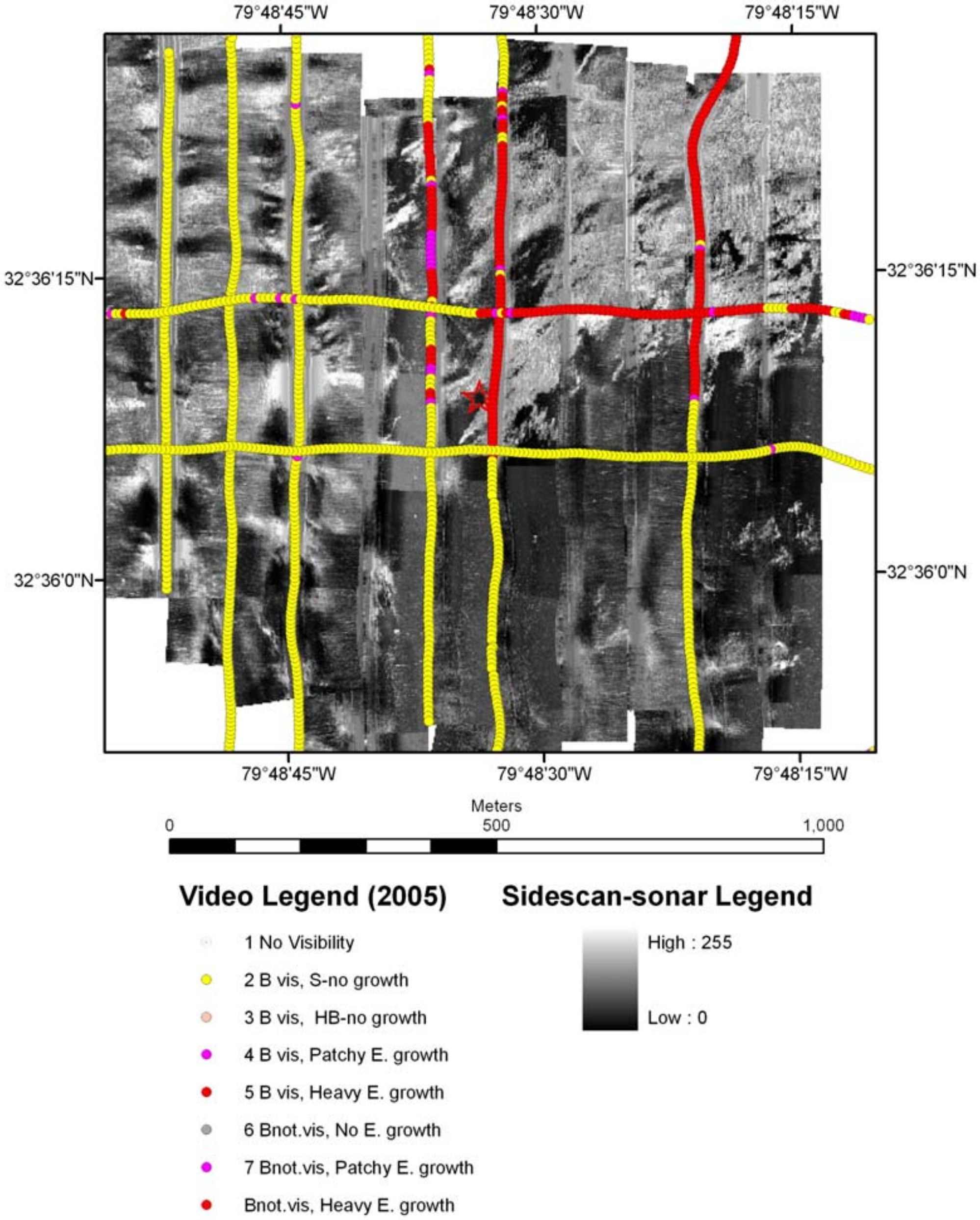

Figure 2.7a. Sidescan-sonar and coded video data collected over site SWB during the 2005 field season.

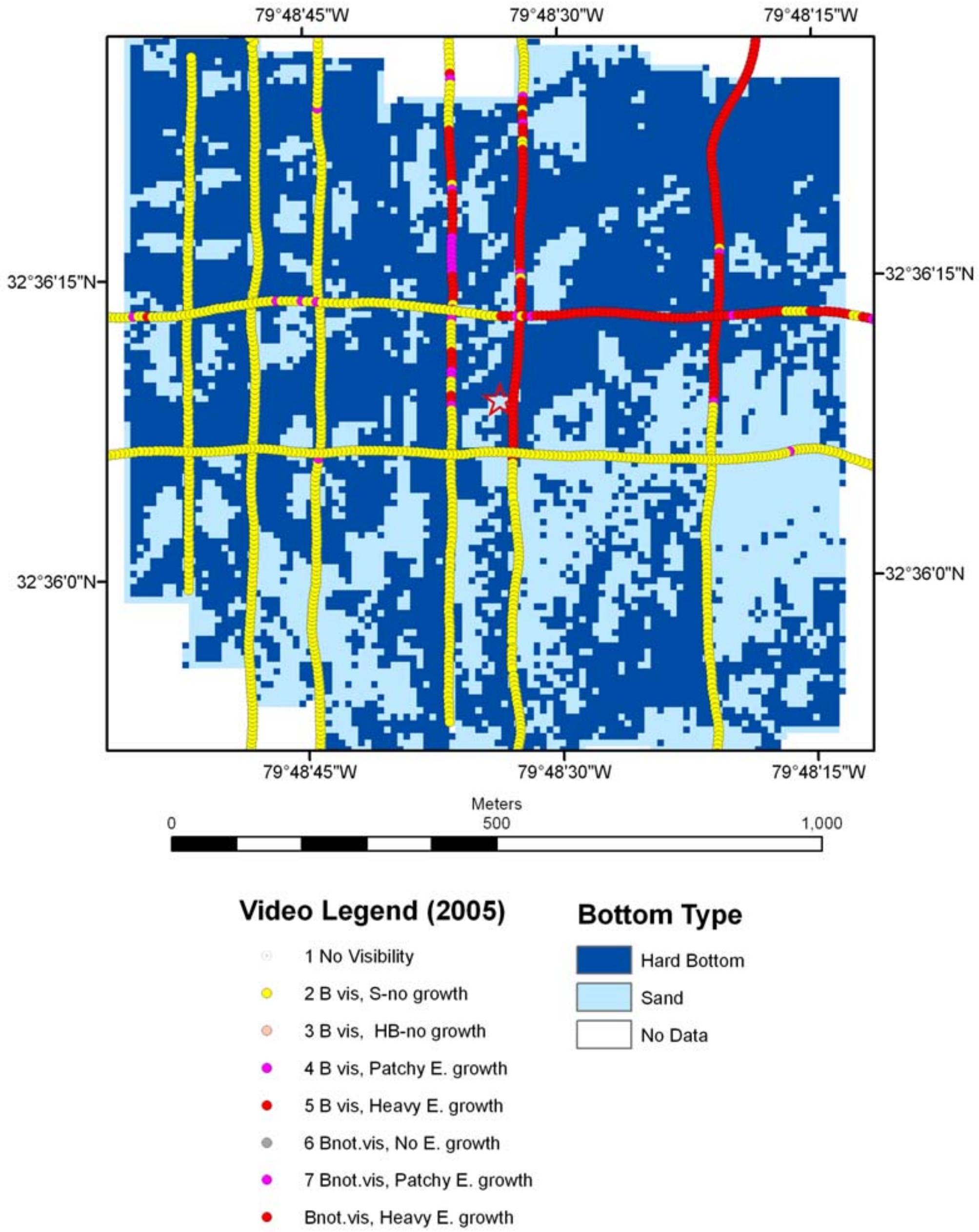

Figure 2.7b. Habitat mapping and coded video points of site SWB based on the sidescan-sonar mosaic from field season 2005.

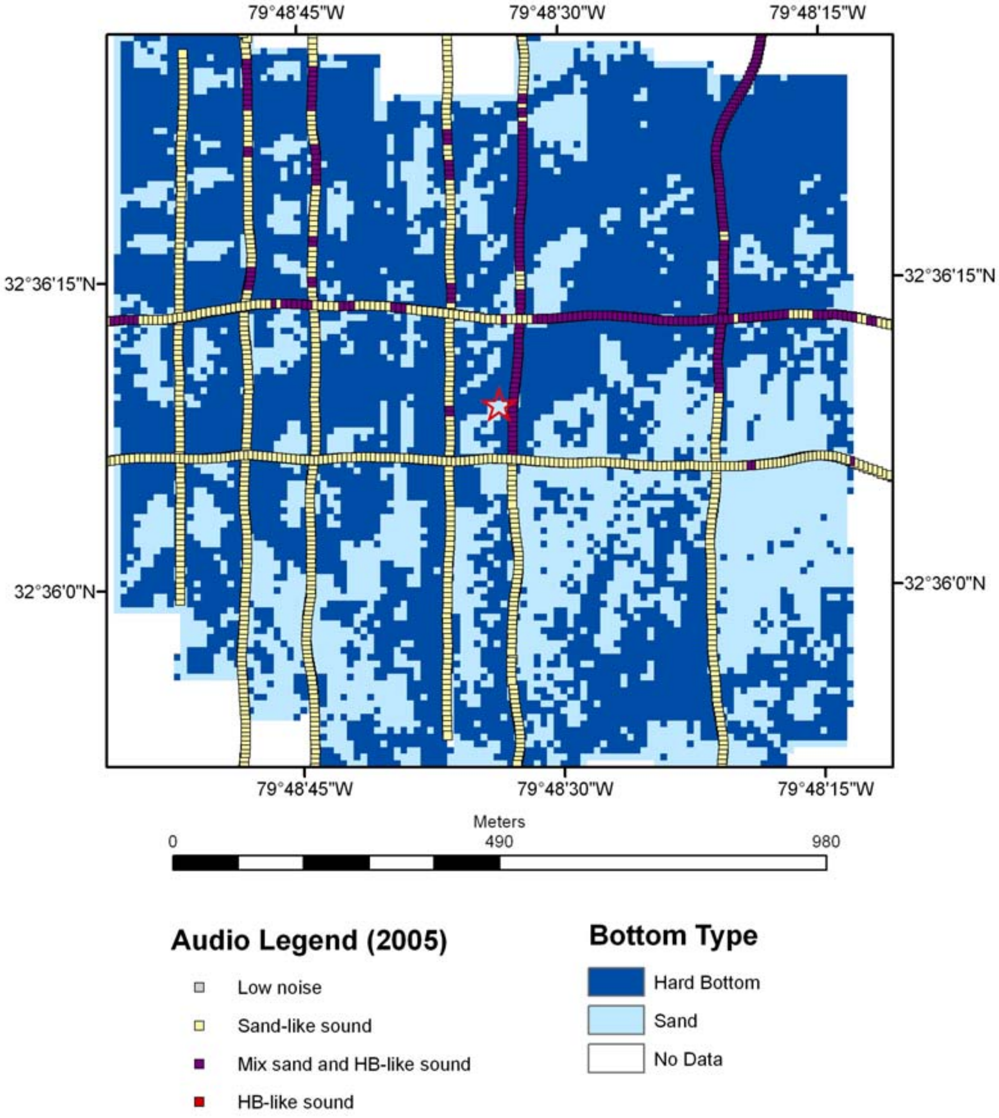

Figure 2.7c. Habitat mapping and coded audio points of site SWB based on the sidescan-sonar mosaic from field season 2005.

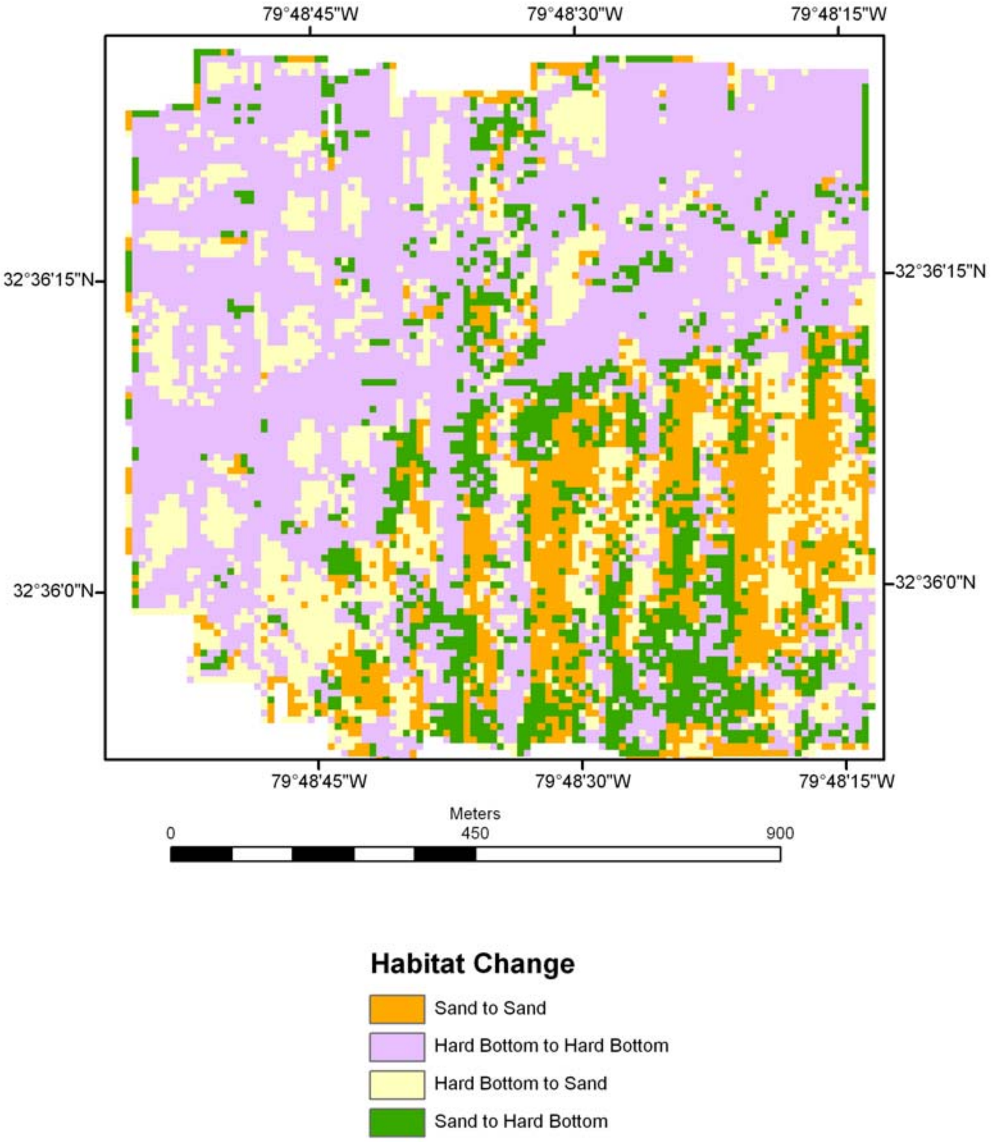

Figure 2.7d. Map of habitat change at site SWB during the inter-survey period 2004-2005.

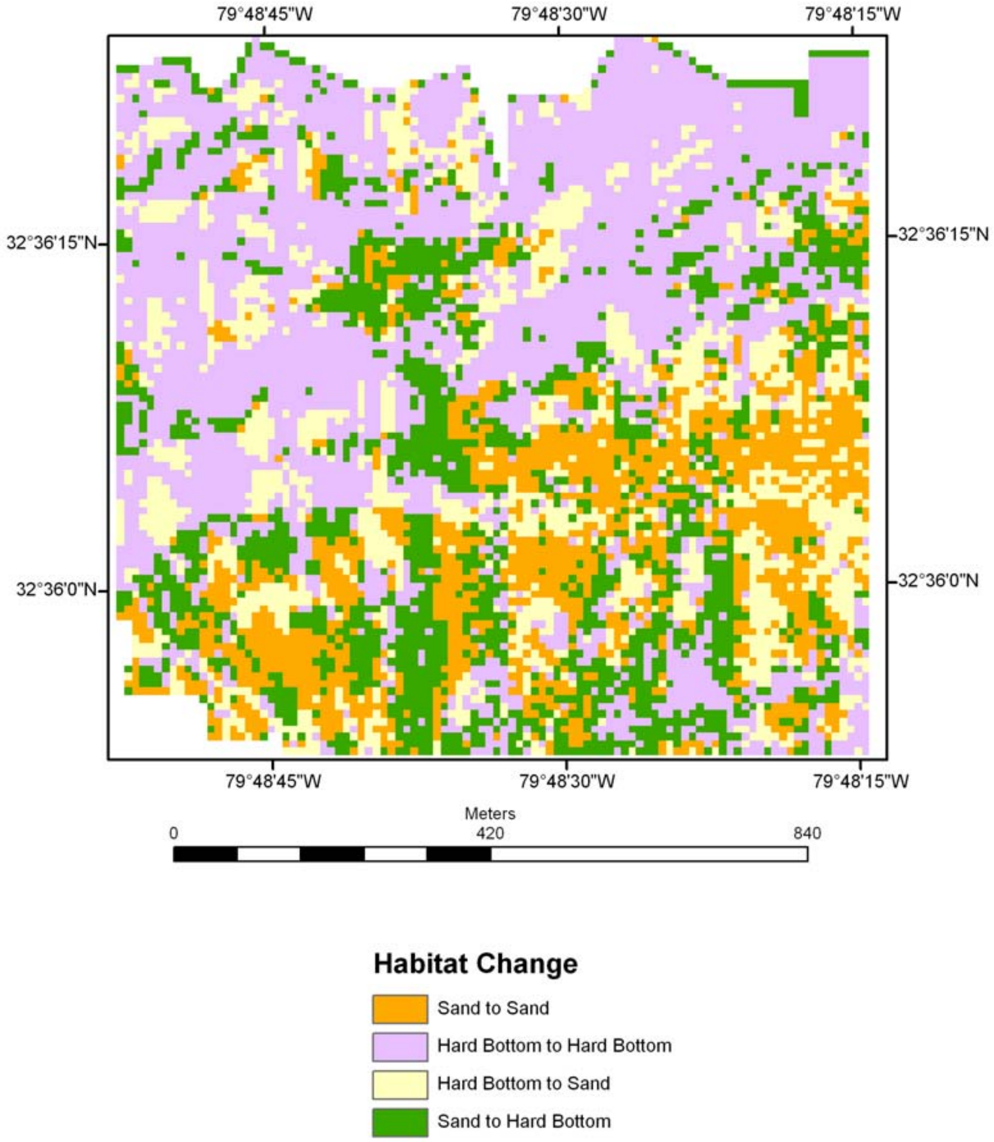

Figure 2.7e. Map of habitat change at site SWB during the inter-survey period 2001-2005.

Site EB

Site EB is located 6.7 km southeast of the Charleston ODMDS (Figure 2.1). Analysis of video data collected during the 2004 and 2005 surveys indicate hard bottom areas of 21.2 % and 23.7 %, respectively (Table 2.12). The 2000 survey resulted in a similar percentage; however, the 2002 and 2004 video surveys suggest ~ 10 % less hard bottom.

Table 2.12. Habitat distribution on site EB based on coded video points within a 1-km2 box centered on reef site. 1 = No visibility, 2 = Bottom visible: sand with no growth, 3 = Bottom visible: hard bottom no growth, 4 = Bottom visible: patchy emergent growth, 5 = Bottom visible: heavy emergent growth, 6 = Bottom not visible: no emergent growth, 7 = Bottom not visible: patchy emergent growth, 8 = Bottom not visible: heavy emergent growth. Percentages are in term of total points.

EB	**2000**		**2001**		**2002**		**2004**		**2005**	
	total points coded	%	total points coded	%	total points coded	%	total points coded	%	total points coded	%
1	0	**0**	0	**0**	33	**2.5**	0	**0**	0	**0**
2	234	**74.8**	984	**69.4**	1105	**83.6**	313	**78.8**	933	**76.4**
3	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**
4	76	**24.3**	99	**7**	101	**7.6**	32	**8.1**	288	**23.6**
5	3	**0.9**	55	**3.9**	82	**6.2**	52	**13.1**	1	**0.1**
6	0	**0**	234	**16.5**	0	**0**	0	**0**	0	**0**
7	0	**0**	46	**3.2**	0	**0**	0	**0**	0	**0**
8	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**
TOTALS										
Hard bottom	79	**25.2**	200	**14.1**	183	**13.9**	84	**21.2**	289	**23.7**
Sand	234	**74.8**	984	**69.4**	1105	**83.6**	313	**78.8**	933	**76.4**
No Visibility	0	**0**	234	**16.5**	33	**2.5**	0	**0**	0	**0**
Total video collected	313	**100**	1418	**100**	1321	**100**	397	**100**	1222	**100**

The sidescan mosaics for 2004 and 2005 are similar in appearance to those from previous years (Figures 2.8a and 2.9a). Throughout the history of sidescan surveys at site EB, backscatter values have been high in the southern third of the site and lower in the northern two-thirds of the site. Textural analysis of the mosaics classified 66.1 % and 64.9 % of the site as hard ground during the 2004 and 2005 surveys. These values are not appreciably different than those from 2002 and 2001 (61.1 % and 57.8 %, respectively). Though the video code suggests a smaller amount of hard bottom on average than the textural analysis, both sets of numbers have been fairly consistent throughout the four years of complete surveying. These data, along with visual inspection of sidescan mosaics suggest that site EB is relatively stable in terms of hard ground percentage and location of hard grounds. Interpretation of these data should always take into consideration the differences in each type of analysis. While robust in terms of spatial coverage and spatial accuracy, the textural analysis routine is computer driven and lacks the ability to subclassify varieties of hard bottom. Very thin, discontinuous sand veneers could also potentially be mis-classified. The video data are very accurate in terms of bottom type classification, however, the field of view in the video is limited to the area very near the transect line. Though the percentage of area classified as hard bottom may be different for each of the methods, the variation from year to year is similar for both types of analysis.

Table 2.13. Habitat distribution on site EB based on interpretive textural analysis of the sidescan-sonar mosaic. Areas are in units of 10^5 m^2.

	2000		**2001**		**2002**		**2004**		**2005**	
	area	%	area	%	area	%	area	%	area	%
Hard bottom	-	**-**	8.062	**57.8**	6.11	**61.1**	6.614	**66.1**	6.488	**64.9**
Sand	-	**-**	4.629	**40.8**	3.799	**38**	3.38	**33.8**	3.143	**31.4**
No Data	-	**-**	0.141	**1.4**	0.091	**0.9**	0.006	**0.1**	0.369	**3.7**
Total area	-	**-**	10	**100**	10	**100**	10	**100**	10	**100**

Analysis of change maps for the two recent surveys suggest significant area of change percentages within site EB (37.3 % during 2002-2004, and 43.2 % during 2004-2005), however, the net hard bottom changes are only a few percent (Table 2.14, Figures 2.8d and 2.9d). For the period between 2001 and 2004, again a significant percentage (45.6 %) of the area has changed between sand and hard bottom (Figure 2.9e). Overall, site EB has had a 9.7 % net gain of hard bottom.

Table 2.14. Spatial analysis of change, site EB. Values are numbers of m^2.

	2001 to 2002	2002 to 2004	2004 to 2005	2001 to 2005
from sand to sand	188,300	171,100	116,000	138,600
from hard bottom to hard bottom	385,200	449,900	431,200	380,800
from hard bottom to sand	190,500	160,800	198,300	171,200
from sand to hard bottom	213,300	208,800	217,200	264,200
Total area of analysis	977,300	990,600	962,700	954,800
Area of no change (%)	58.7 %	62.7 %	56.8 %	54.4 %
Area of change (%)	41.3 %	37.3 %	43.2 %	45.6 %
Net hard bottom change * (%)	2.3 %	4.8 %	2 %	9.7 %

* positive values indicate net gain; negative values indicate net loss.

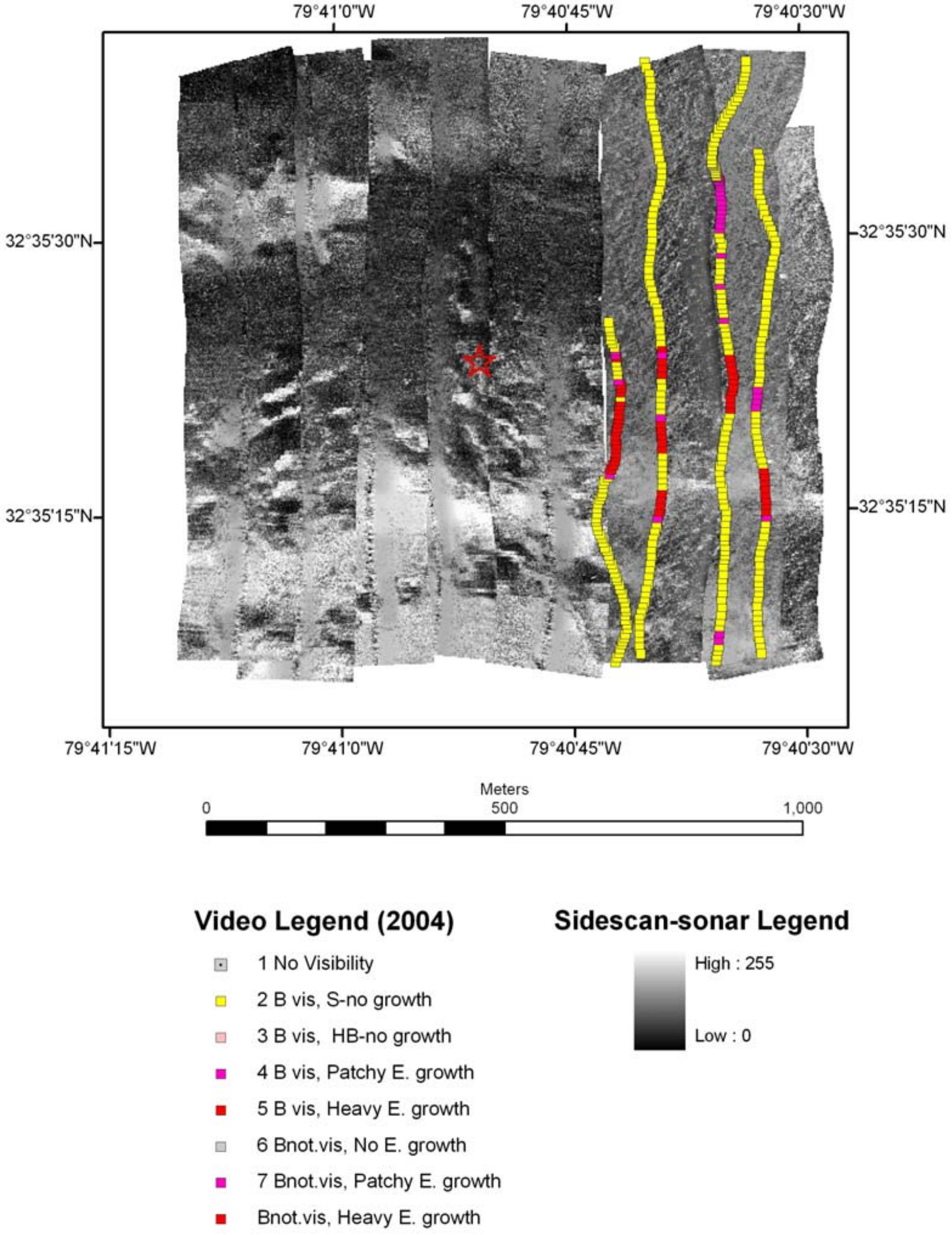

Figure 2.8a. Sidescan-sonar and coded video data collected over site EB during the 2004 field season.

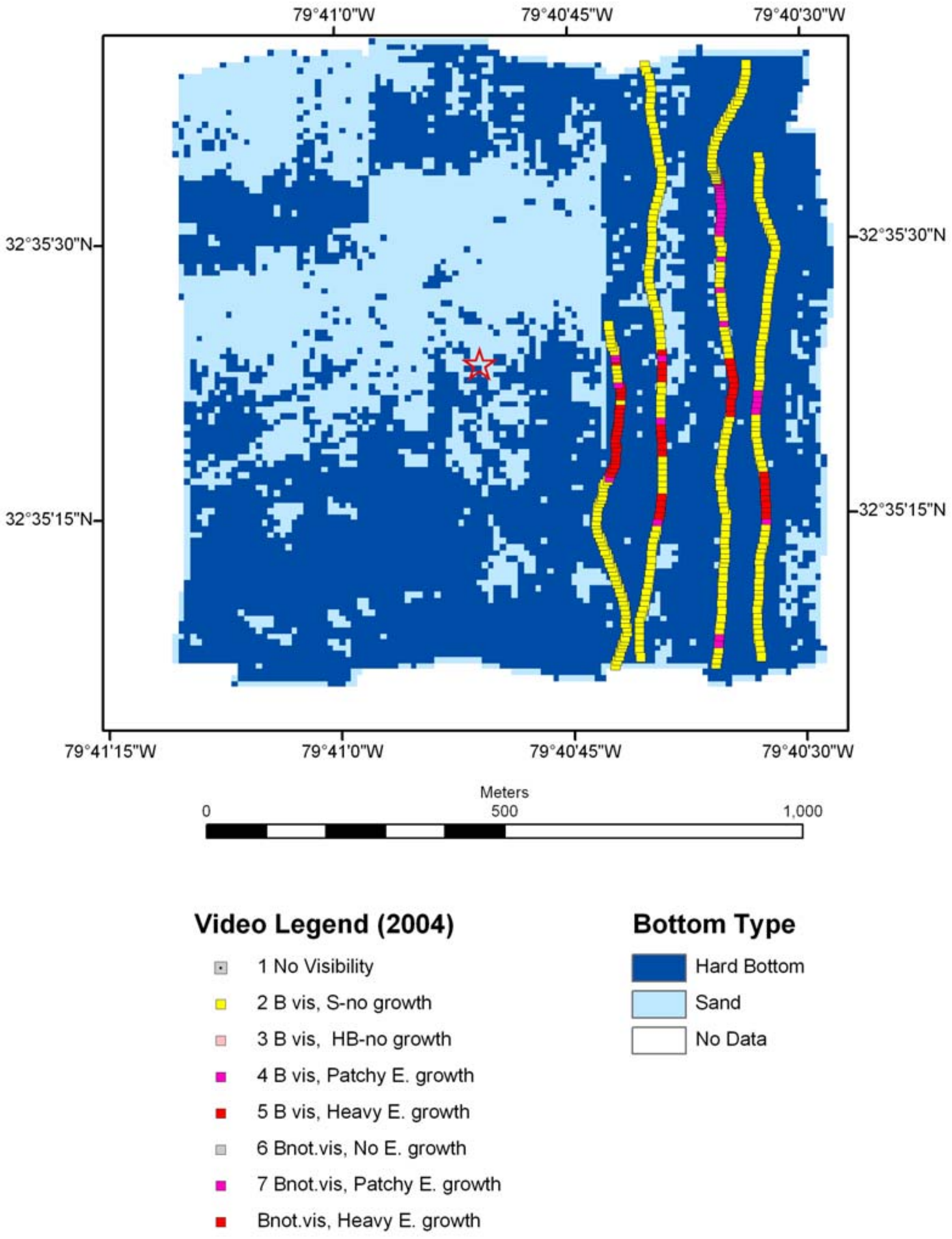

Figure 2.8b. Habitat mapping and coded video points of site EB based on the sidescan-sonar mosaic from field season 2004.

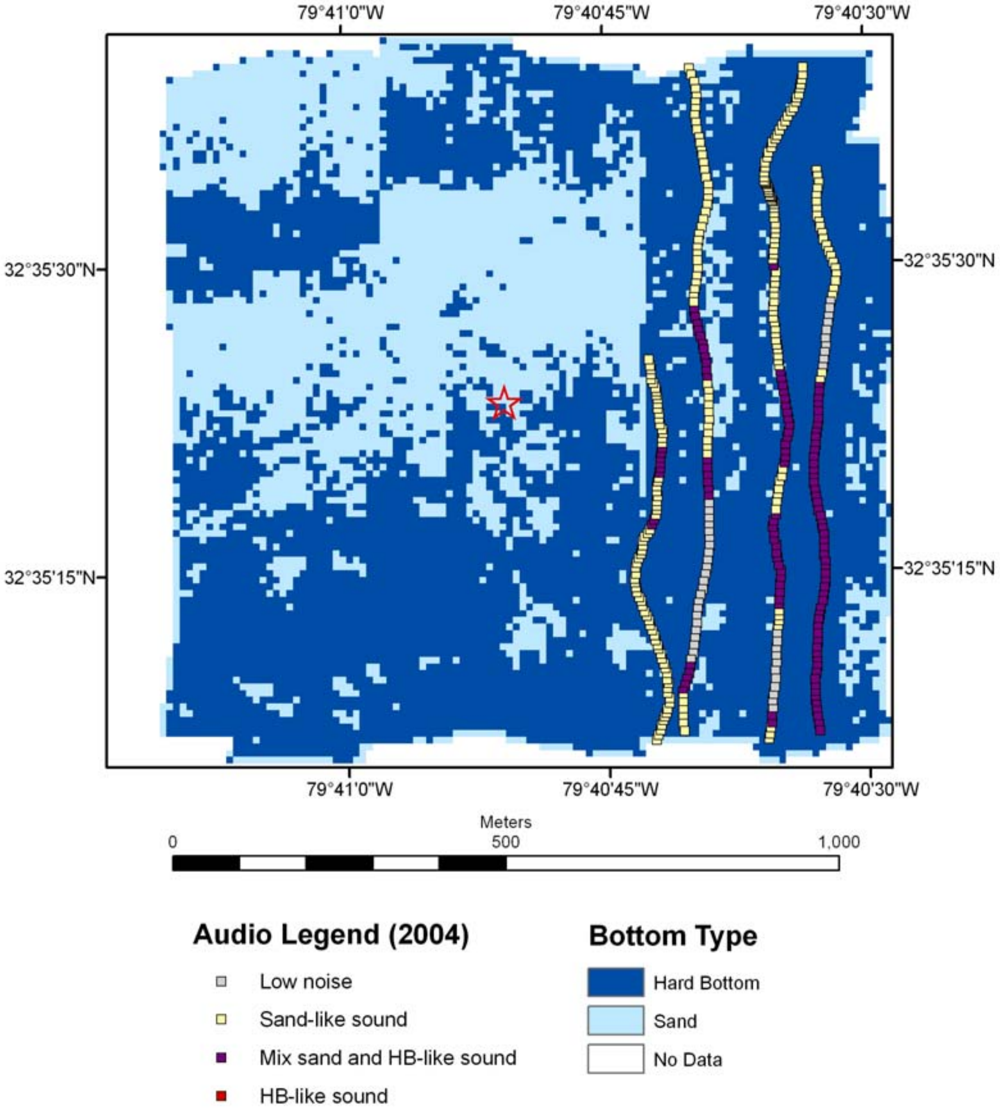

Figure 2.8c. Habitat mapping and coded audio points of site SWA based on the sidescan-sonar mosaic from field season 2004.

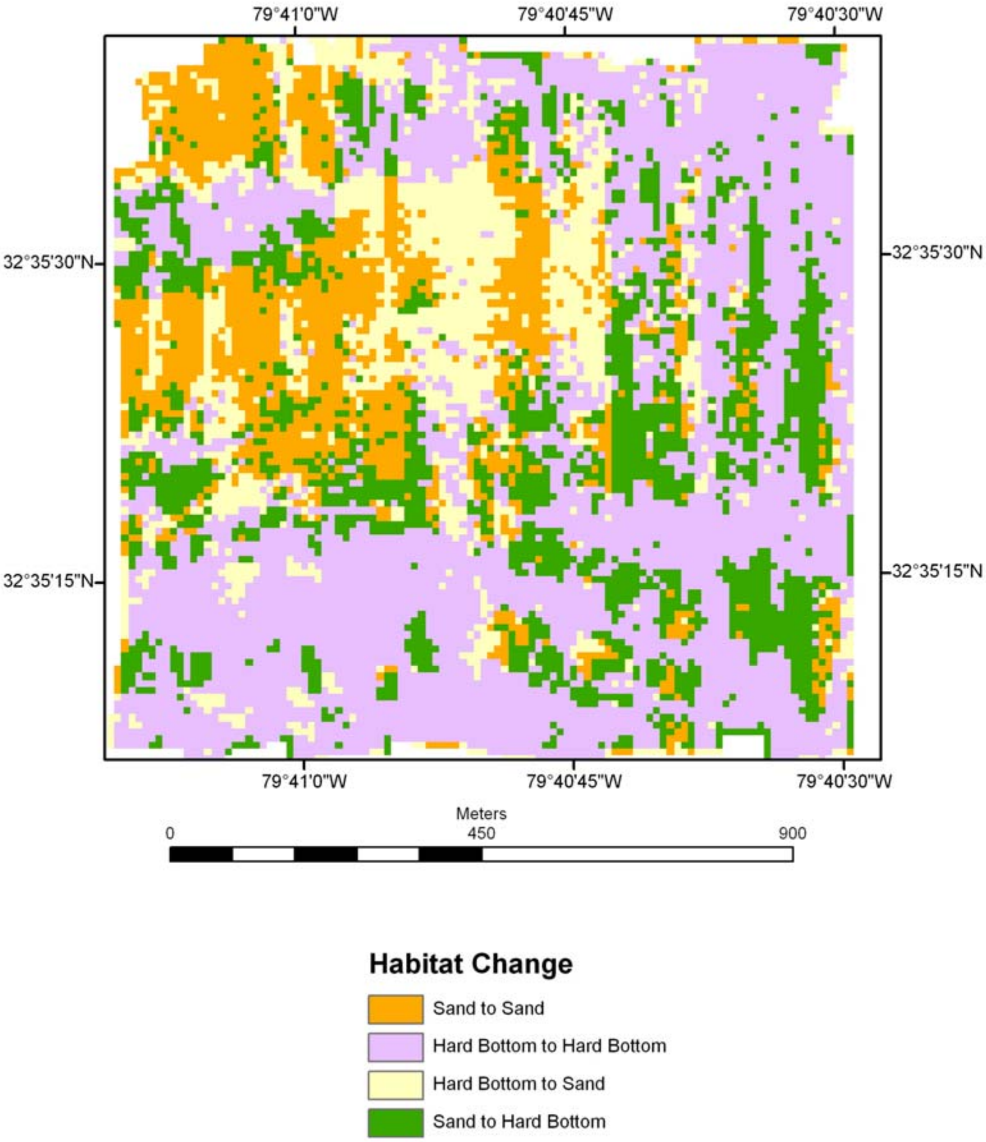

Figure 2.8d. Map of habitat change at site EB during the inter-survey period 2002-2004.

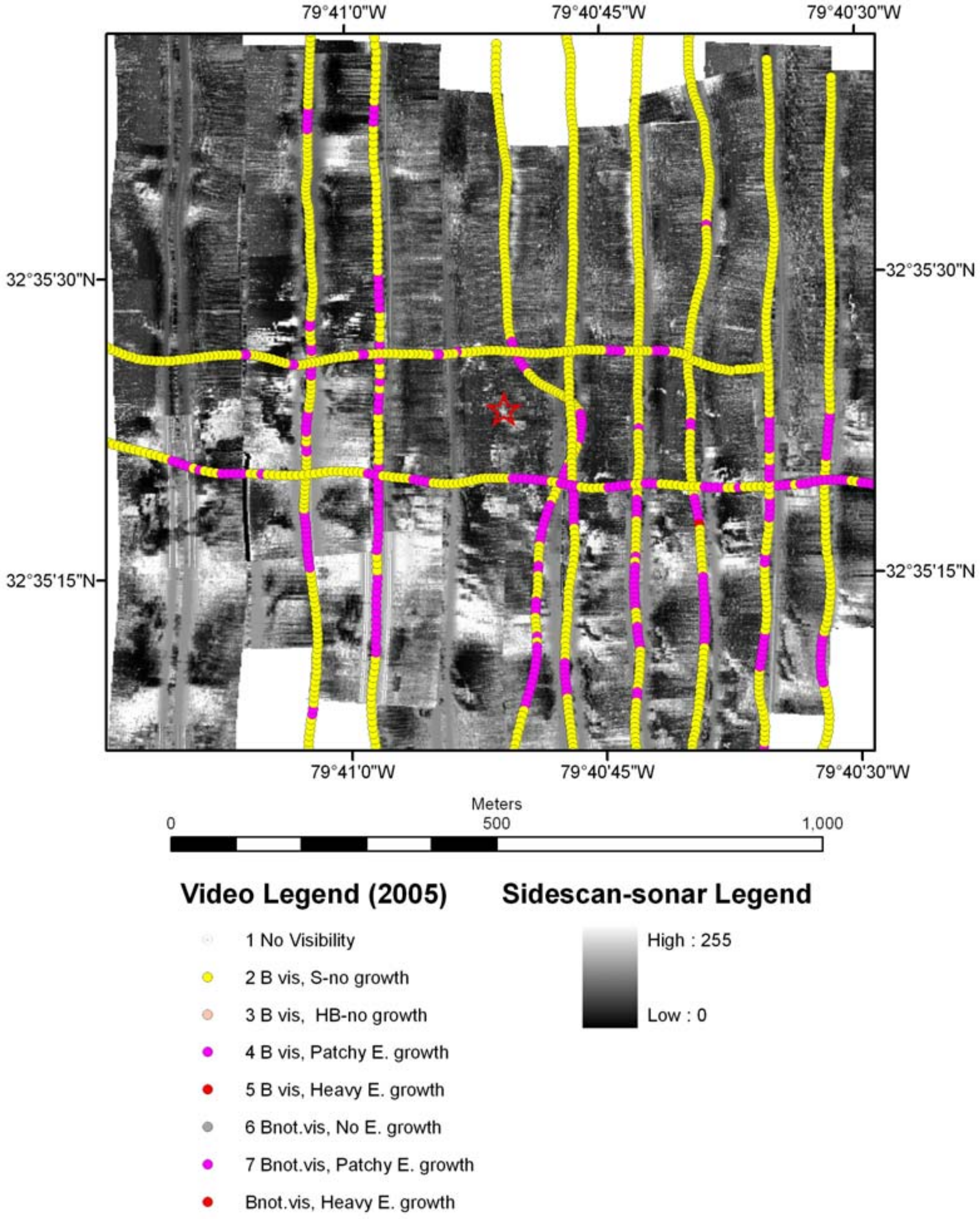

Figure 2.9a. Sidescan-sonar and coded video data collected over site EB during the 2005 field season.

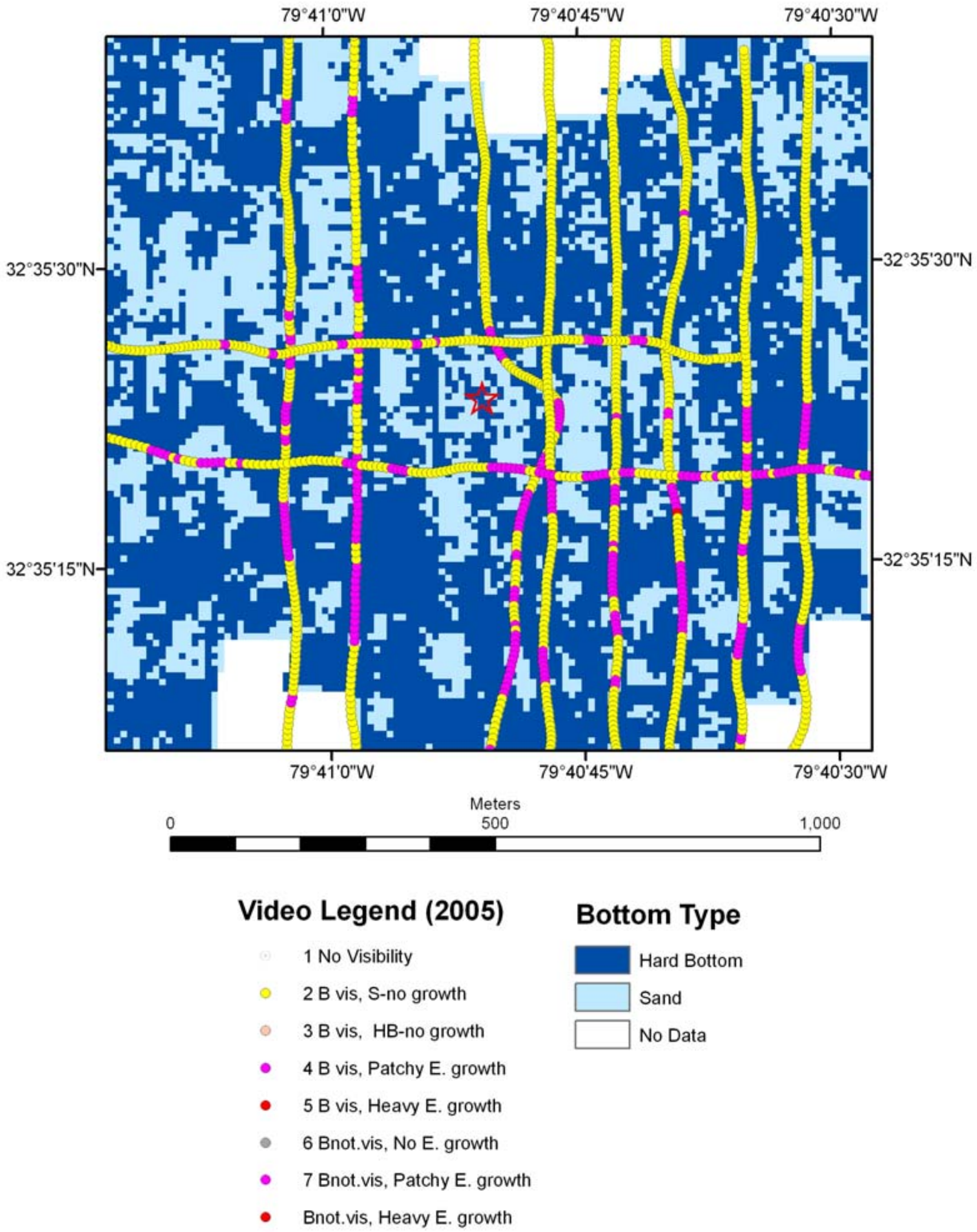

Figure 2.9b. Habitat mapping and coded video points of site EB based on the sidescan-sonar mosaic from field season 2005.

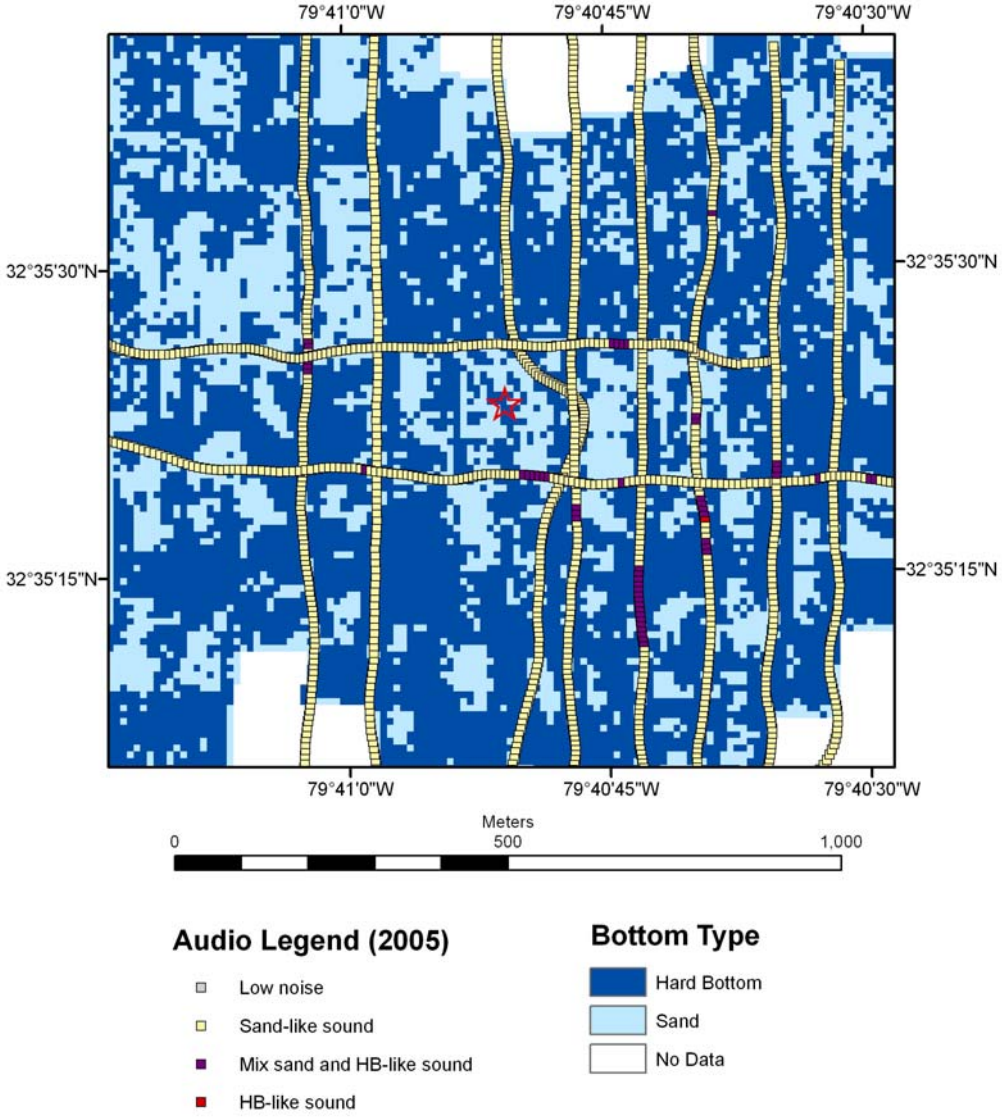

Figure 2.9c. Habitat mapping and coded audio points of site EB based on the sidescan-sonar mosaic from field season 2005.

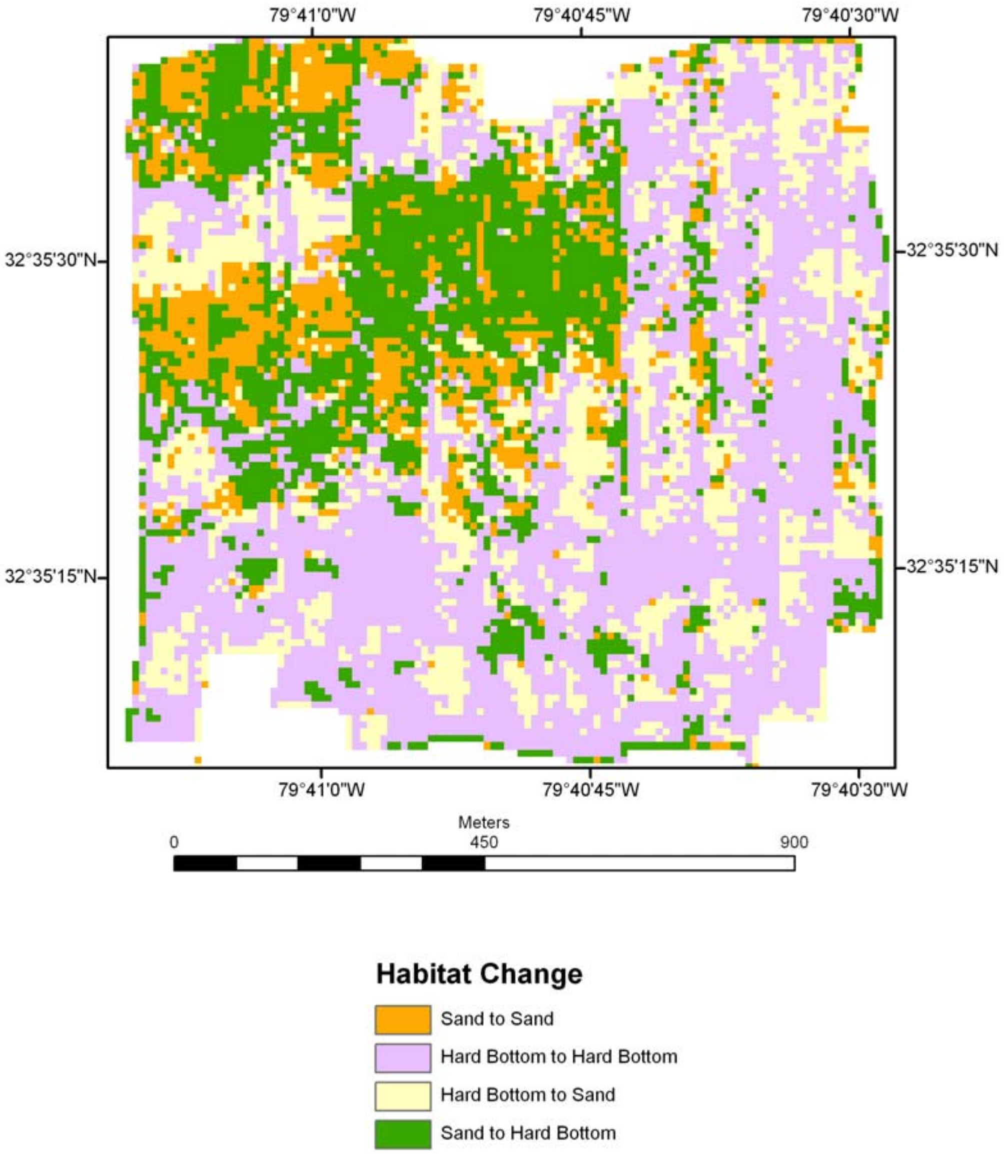

Figure 2.9d. Map of habitat change at site EB during the inter-survey period 2004-2005.

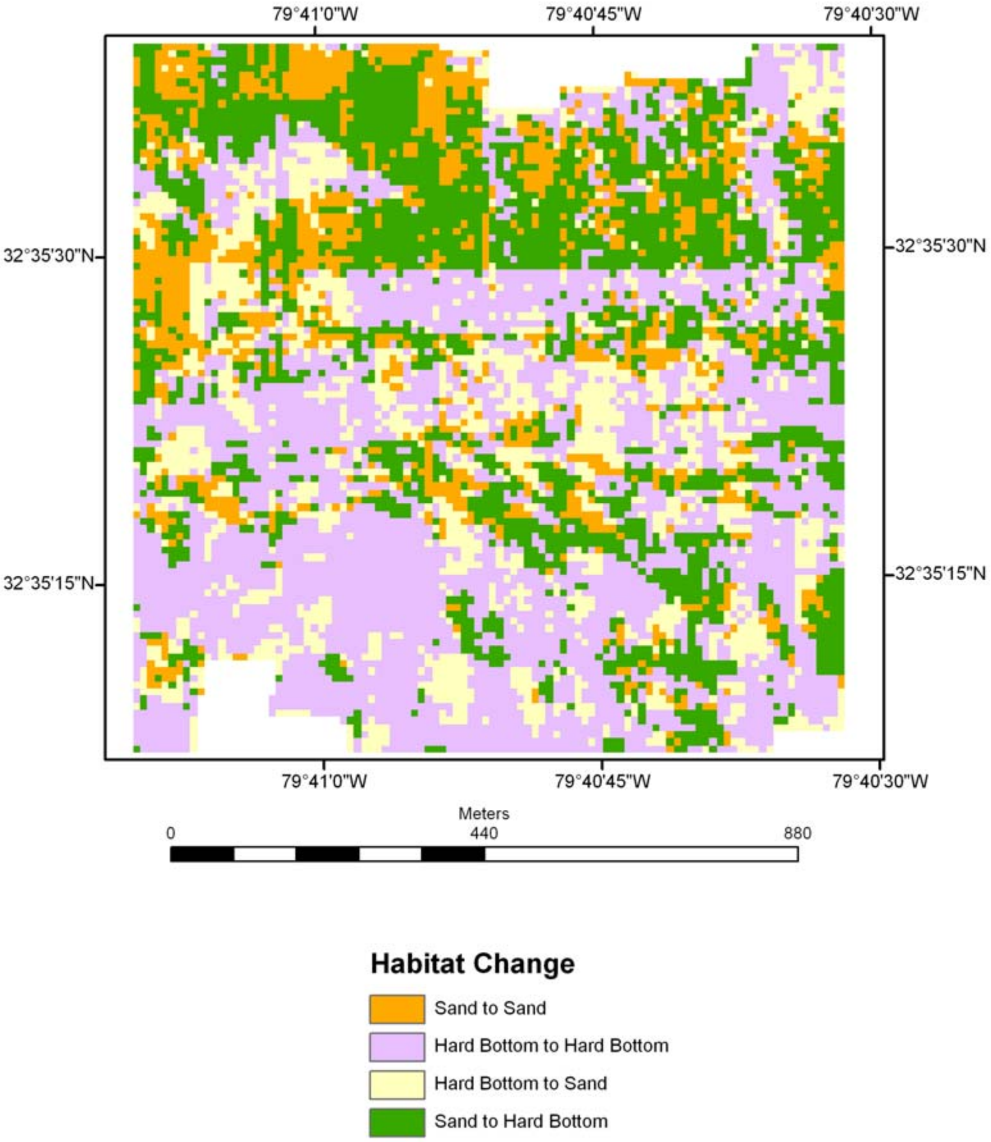

Figure 2.9e. Map of habitat change at site EB during the inter-survey period 2001-2005.

Site C1

Site C1 is located 8.2 km east-southeast of the disposal site, and is the southernmost of the six index reef sites (Figure 2.1). C1 is one of two sites designated as 'reference areas' for benthic monitoring by SCDNR. This site was not surveyed in 2000, but has video and sidescan-sonar data for the period 2001-2004.

Video analysis indicates that hard bottom covered 48.4 % of the site in 2004, and 34.5 % in 2005 (Table 2.15). Site C1 has significant variability in hard bottom area indicated by video analysis throughout the 2001-2004 period. Most of time, hard bottom has been coded as patchy-heavy emergent growth. Interestingly, however, in 2002 a significant percentage of the hard bottom was identified as void of growth.

Table 2.15. Habitat distribution on site C1 based on coded video points within a 1-km2 box centered on reef site. 1 = No visibility, 2 = Bottom visible: sand with no growth, 3 = Bottom visible: hard bottom no growth, 4 = Bottom visible: patchy emergent growth, 5 = Bottom visible: heavy emergent growth, 6 = Bottom not visible: no emergent growth, 7 = Bottom not visible: patchy emergent growth, 8 = Bottom not visible: heavy emergent growth. Percentages are in term of total points.

C1	**2000**		**2001**		**2002**		**2004**		**2005**	
	total points coded	%	total points coded	%	total points coded	%	total points coded	%	total points coded	%
1	-	**-**	32	**0**	0	**0**	5	**0.4**	89	**8**
2	-	**-**	457	**44.5**	561	**43.8**	606	**51.4**	671	**60.3**
3	-	**-**	0	**0**	233	**18.2**	1	**0.1**	0	**0**
4	-	**-**	141	**13.7**	256	**20**	177	**15**	45	**4**
5	-	**-**	95	**9.2**	230	**18**	381	**32.3**	308	**27.7**
6	-	**-**	277	**27**	0	**0**	0	**0**	0	**0**
7	-	**-**	26	**2.5**	0	**0**	9	**0.8**	0	**0**
8	-	**-**	0	**0**	0	**0**	0	**0**	0	**0**
TOTALS										
Hard bottom	-	**-**	262	**25.5**	719	**56.2**	559	**47.4**	353	**31.7**
Sand	-	**-**	457	**44.5**	561	**43.8**	606	**51.4**	671	**60.3**
No Visibility	-	**-**	309	**30**	0	**0**	14	**1.2**	89	**8**
Total video collected	-	**-**	1028	**100**	1280	**100**	1930	**100**	1113	**100**

Sidescan imagery of site C1 has a very distinct high backscatter intensity region in the southern half of the area. The region of high backscatter is clearly seen in the 2004 mosaic as well as prior years (Figure 2.10a). The 2005 mosaic is plagued by noise and thus very difficult to interpret visually (Figure 2.11a). The noise is due to difficulties experienced during the data collection.

Habitat maps from site C1 reveal remarkable similar hard bottom percentages in years 2004 (62.7 %) and 2005 (59.4 %). These values are not very different from the previous two years of surveying, suggesting a very stable percentage of hard bottom though time at this site (Table 2.16). While the 2005 sidescan image is very noisy, the textural analysis algorithm has identified the southern portion of the site as dominated by hard ground (Figure 2.11b). This result is very similar to the distribution suggested by backscatter patterns and habitat maps from the previous years (e.g. Figure 2.10b).

Table 2.16. Habitat distribution on site C1 based on interpretive textural analysis of the sidescan-sonar mosaic. Areas are in units of 10^5 m^2.

	2000		**2001**		**2002**		**2004**		**2005**	
	area	%	area	%	area	%	area	%	area	%
Hard bottom	-	**-**	5.733	**57.3**	6.026	**60.3**	6.271	**62.7**	5.94	**59.4**
Sand	-	**-**	3.902	**39**	3.911	**39.1**	3.721	**37.2**	2.321	**23.2**
No Data	-	**-**	0.365	**3.7**	0.063	**0.6**	0.008	**0.1**	1.739	**17.4**
Total area	-	**-**	10	**100**	10	**100**	10	**100**	10	**100**

The area of change statistics are remarkably similar throughout all for time intervals examined (Table 2.17). Roughly 37-40 % of the area changes between hard bottom and sand on an annual interval, as well as during the 2001 to 2005 interval. Each interval represents an increasing net hard bottom area gain, with a total gain of 12.3 % between 2001 and 2005.

The change maps provide an interesting view of hard bottom distribution (Figures 2.10d, 2.11d, and 2.11e). Though designed to detect changes in bottom type, these maps also feature areas of no change. Present in each change map is a consistent area of hard bottom in the southern half of site C1. This area matches well with high backscatter intensity regions on the sidescan mosaics. The 2005 maps demonstrate the power of the habitat classification routine by successfully identifying this hard bottom area which is historically consistent from year to year, despite the poor visual quality of the accompanying mosaic.

Table 2.17. Spatial analysis of change, site C1. Values are numbers of m^2.

	2001 to 2002	2002 to 2004	2004 to 2005	2001 to 2005
from sand to sand	197,500	196,900	103,100	113,500
from hard bottom to hard bottom	383,900	430,700	406,400	363,600
from hard bottom to sand	175,700	171,600	128,900	112,900
from sand to hard bottom	182,400	193,700	187,100	211,900
Total area of analysis	939,500	992,900	825,500	801,900
Area of no change (%)	61.9 %	63.2 %	61.7 %	59.5 %
Area of change (%)	38.1 %	36.8 %	38.3 %	40.5 %
Net hard bottom change * (%)	0.7 %	2.2 %	7.1 %	12.3 %

* positive values indicate net gain; negative values indicate net loss.

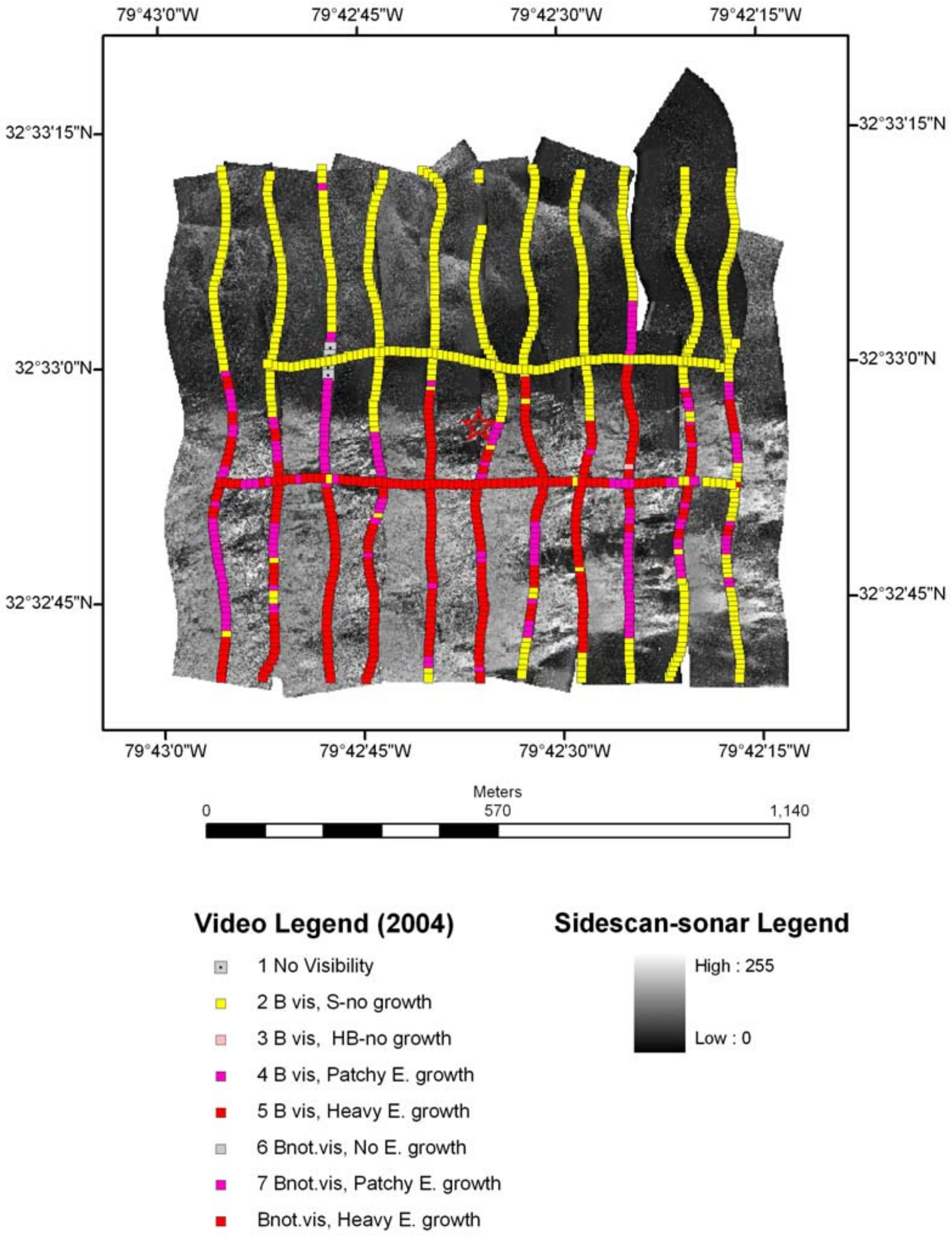

Figure 2.10a. Sidescan-sonar and coded video data collected over site C1 during the 2004 field season.

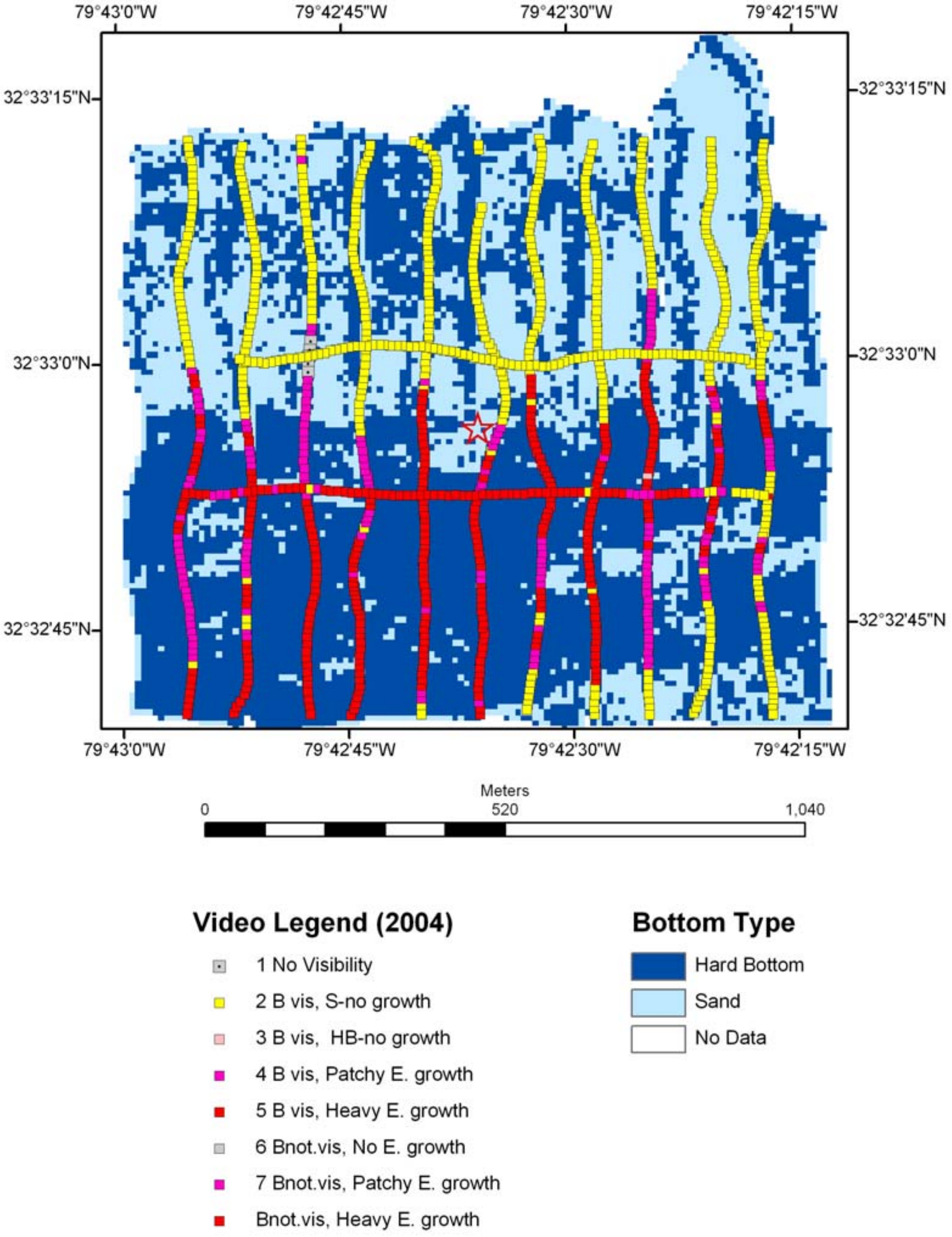

Figure 2.10b. Habitat mapping and coded video points of site C1 based on the sidescan-sonar mosaic from field season 2004.

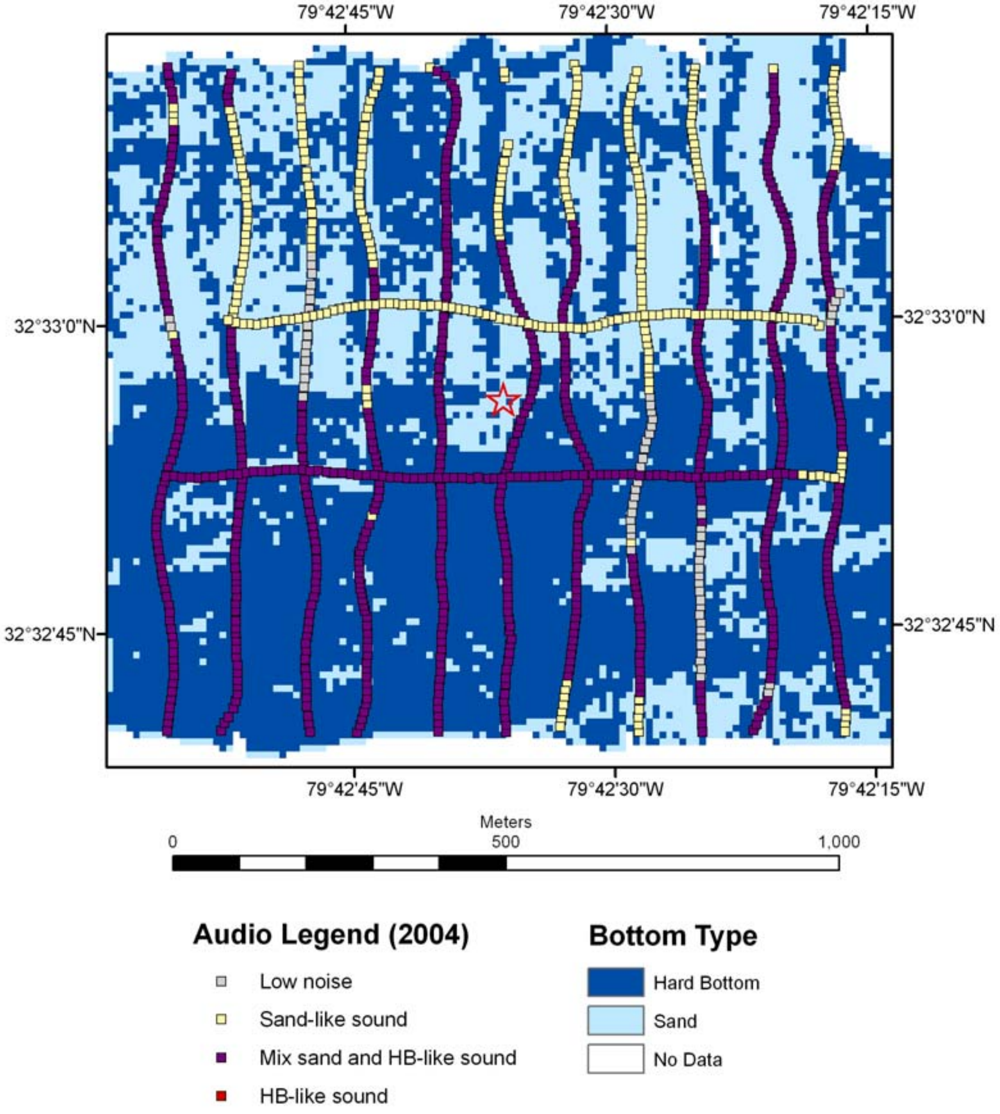

Figure 2.10c. Habitat mapping and coded audio points of site C1 based on the sidescan-sonar mosaic from field season 2004.

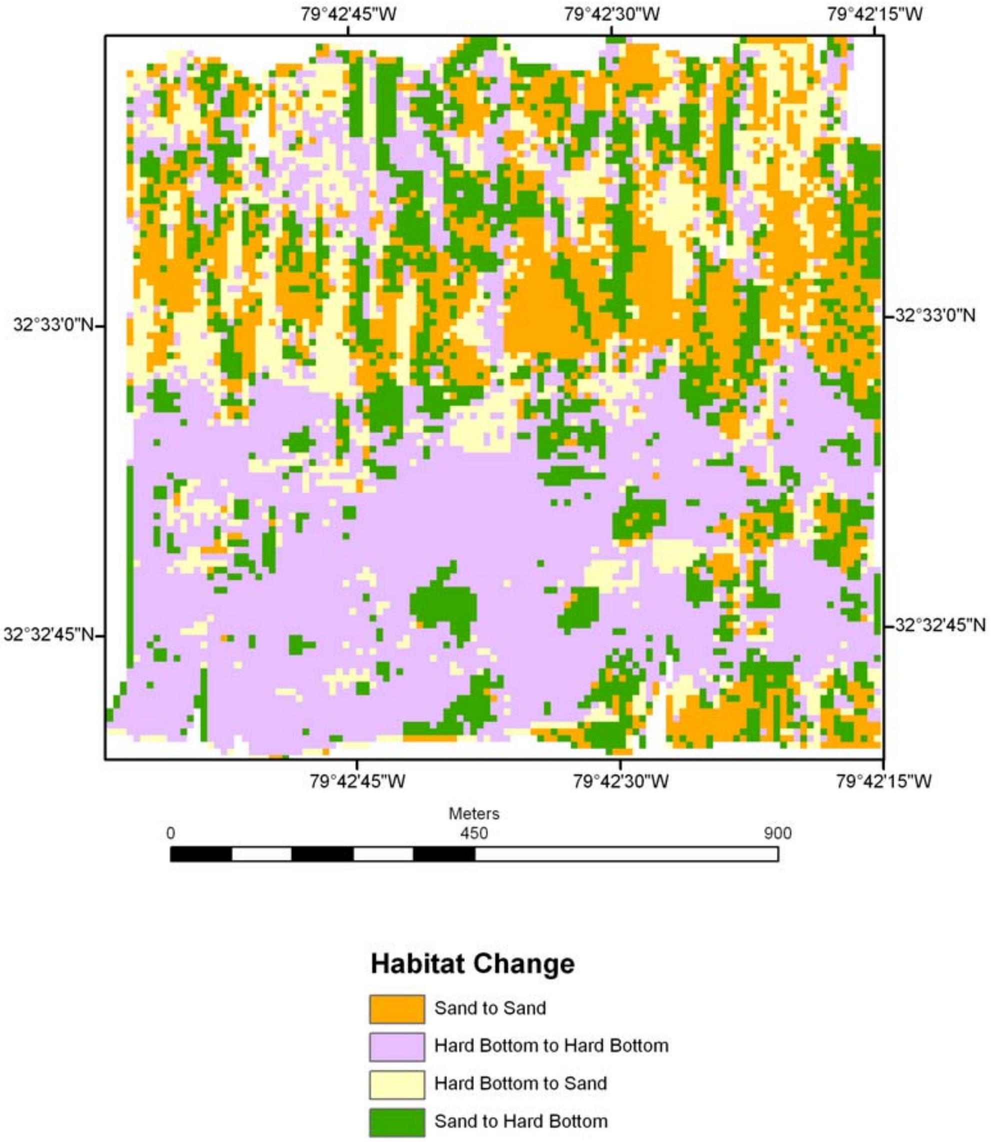

Figure 2.10d. Map of habitat change at site C1 during the inter-survey period 2002-2004.

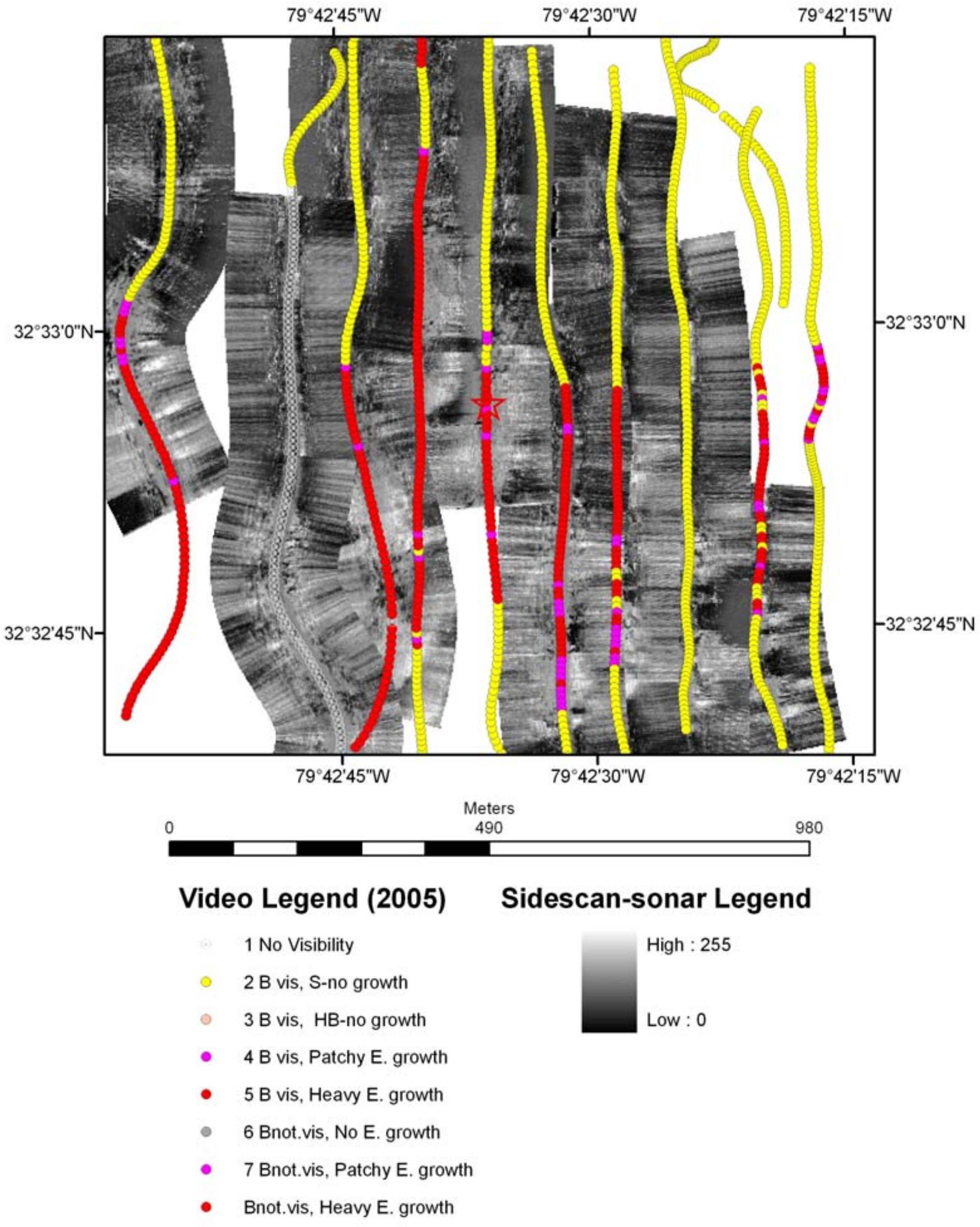

Figure 2.11a. Sidescan-sonar and coded video data collected over site C1 during the 2005 field season.

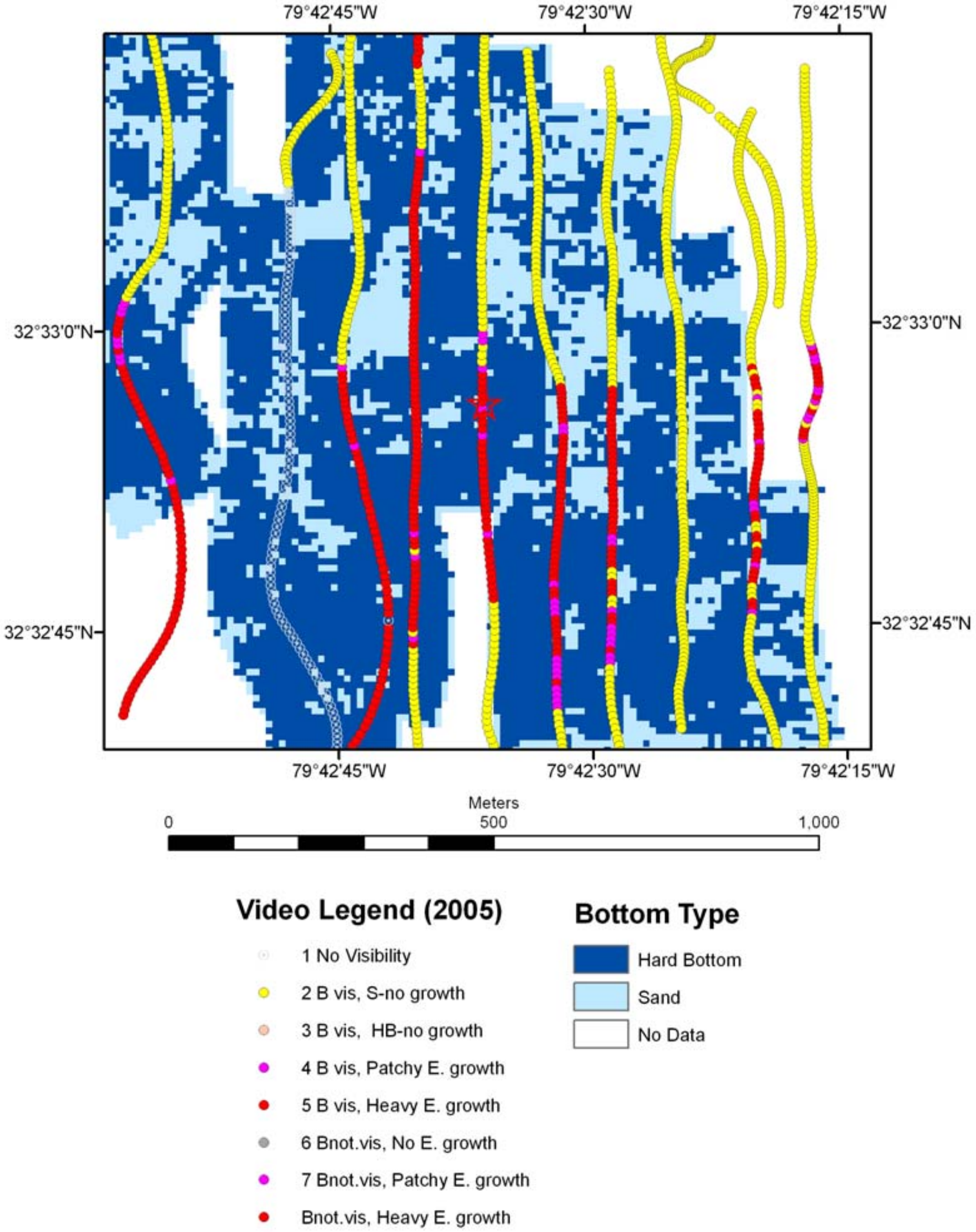

Figure 2.11b. Habitat mapping and coded video points of site C1 based on the sidescan-sonar mosaic from field season 2005.

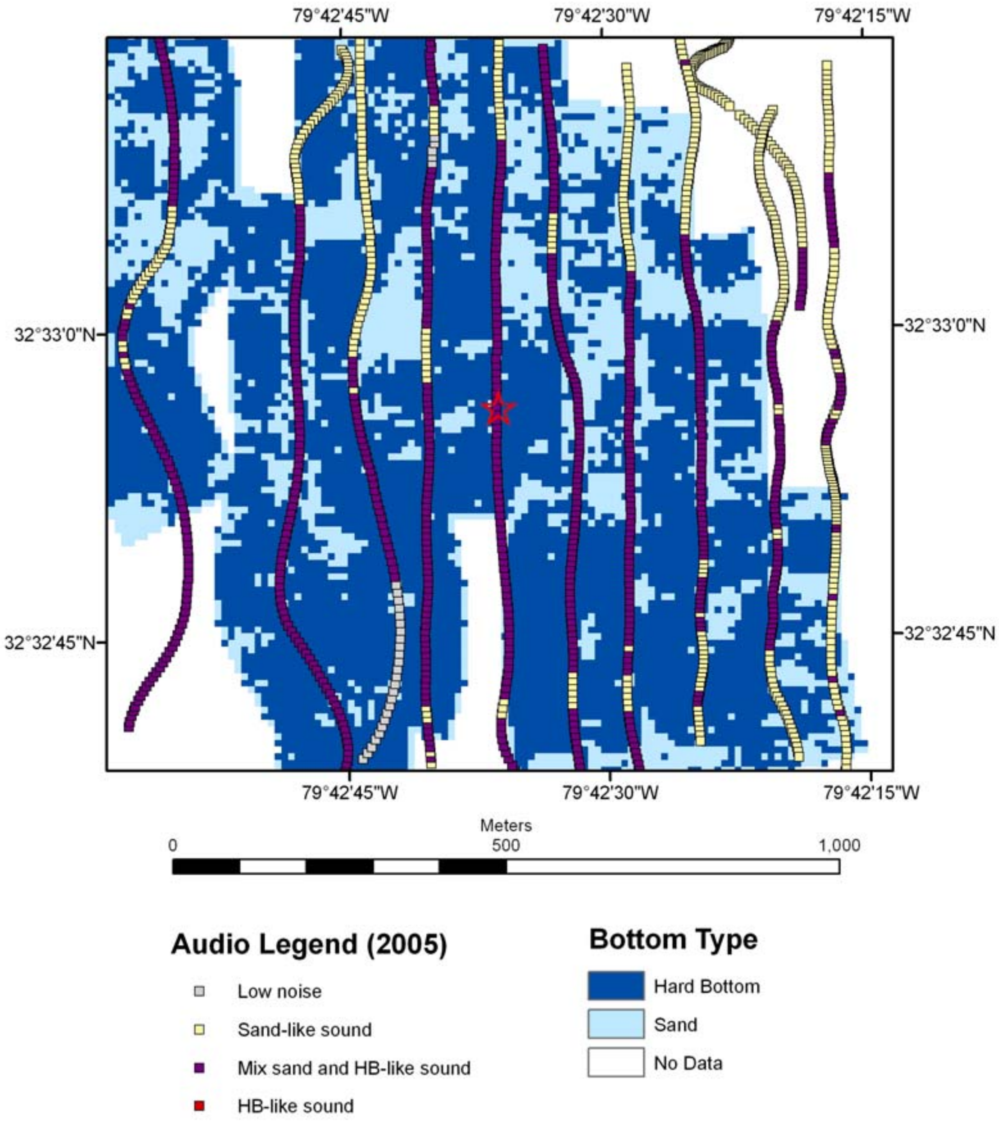

Figure 2.11c. Habitat mapping and coded audio points of site C1 based on the sidescan-sonar mosaic from field season 2005.

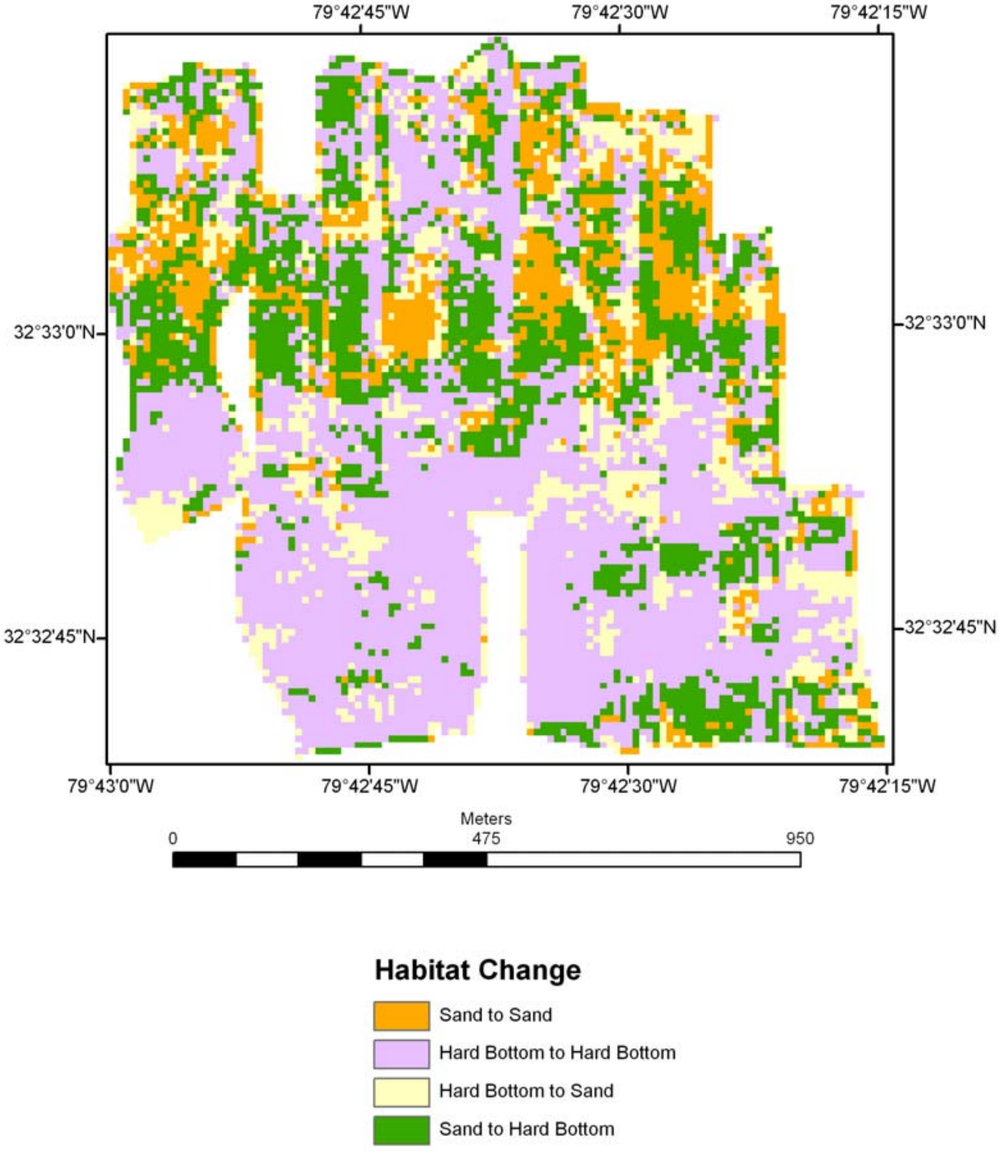

Figure 2.11d. Map of habitat change at site C1 during the inter-survey period 2004-2005.

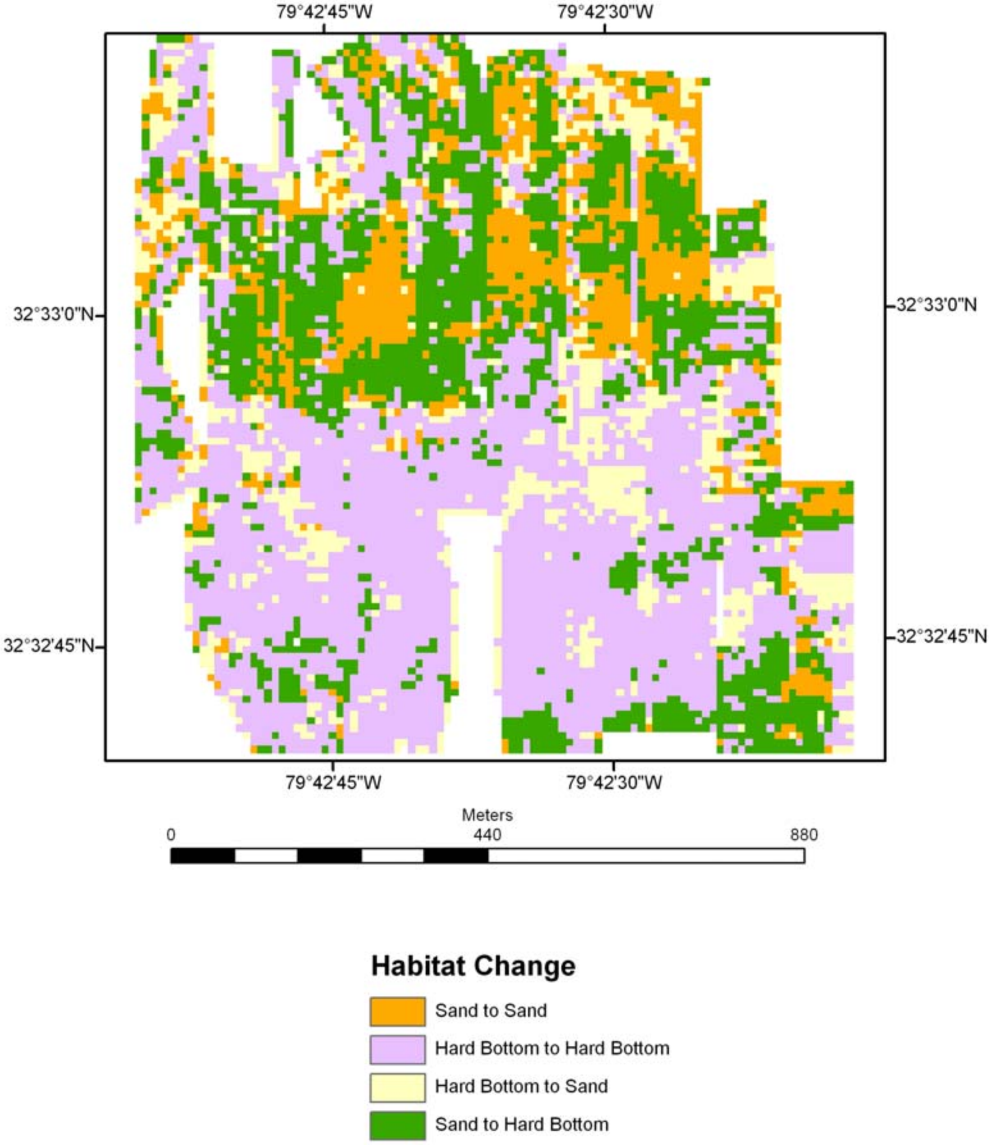

Figure 2.11e. Map of habitat change at site C1 during the inter-survey period 2001-2005.

Site C2

Site C2 is the northern most site, located 9.6 km north-northeast of the disposal site (Figure 2.1). C2 is one of the two SCDNR benthic monitoring reference sites. Like C1, this site was not surveyed during the 2000 field season, but subsequently has been annually surveyed with sidescan-sonar and video.

Coded video data from the 2004 and 2005 surveys identify 38 % and 42.9 % of the site area as hard bottom (Table 2.18). These numbers are significantly less than the values of 65.6 % and 61.6 % reported for the 2001 and 2002 surveys. Most of the hard ground identified in 2005 was coded as patchy emergent growth, in contrast to earlier surveys which also had large percentages of heavy emergent growth.

Table 2.18. Habitat distribution on site C2 based on coded video points within a 1-km2 box centered on reef site. 1 = No visibility, 2 = Bottom visible: sand with no growth, 3 = Bottom visible: hard bottom no growth, 4 = Bottom visible: patchy emergent growth, 5 = Bottom visible: heavy emergent growth, 6 = Bottom not visible: no emergent growth, 7 = Bottom not visible: patchy emergent growth, 8 = Bottom not visible: heavy emergent growth. Percentages are in term of total points.

C2	**2000**		**2001**		**2002**		**2004**		**2005**	
	total points coded	%	total points coded	%	total points coded	%	total points coded	%	total points coded	%
1	-	**-**	0	**0**	1	**0.1**	44	**3.7**	0	**0**
2	-	**-**	67	**6.7**	440	**38.3**	601	**50.2**	520	**57.1**
3	-	**-**	0	**0**	0	**0**	0	**0**	0	**0**
4	-	**-**	0	**0**	148	**12.9**	139	**11.6**	382	**42**
5	-	**-**	44	**4.4**	559	**48.7**	158	**13.2**	8	**0.9**
6	-	**-**	801	**80.4**	0	**0**	183	**15.3**	0	**0**
7	-	**-**	84	**8.5**	0	**0**	50	**4.2**	0	**0**
8	-	**-**	0	**0**	0	**0**	22	**1.8**	0	**0**
TOTALS										
Hard bottom	-	**-**	128	**12.9**	707	**61.6**	297	**24.8**	390	**42.9**
Sand	-	-	67	**6.7**	440	**38.3**	601	**50.2**	520	**57.1**
No Visibility	-	**-**	801	**80.4**	1	**0.1**	277	**23**	0	**0**
Total video collected	-	**-**	996	**100**	1148	**100**	1197	**100**	910	**100**

The sidescan mosaics from 2004 and 2005 are similar in location of areas with the highest backscatter intensity (Figures 2.12a and 2.13a). The central portion of each mosaic is dominated by high backscatter intensity. In both 2004 and 2005 this area occupies about three-fourths of the site. The 2004 data is highly speckled and has less contrast than the 2005 mosaic. Both mosaics, however, are very similar to 2001 and 2002 data in terms of aerial extent and position of the high backscatter region.

Textural analysis of the 2004 and 2005 surveys results in classification of 74.2 % and 51.1 % of the site as hard ground, respectively (Table 2.19). Earlier surveys report

53.3 % and 58.4 % hard bottom. The large discrepancy between 2004 and the other three years may be due to the large amount of speckle (noise) in the 2004 mosaic. Since the habitat classification routine compares each pixel of data with neighboring pixels, poor contrast and lots of noise will reduce the accuracy of the computer algorithm.

Table 2.19. Habitat distribution on site C2 based on interpretive textural analysis of the sidescan-sonar mosaic. Areas are in units of 10^5 m^2.

	2000		**2001**		**2002**		**2004**		**2005**	
	area	%	area	%	area	%	area	%	area	%
Hard bottom	-	**-**	5.332	**53.3**	5.84	**58.4**	7.42	**74.2**	5.109	**51.1**
Sand	-	**-**	3.623	**36.2**	4.125	**41.2**	2.539	**25.4**	4.048	**40.5**
No Data	-	**-**	1.045	**10.5**	0.035	**0.4**	0.041	**0.4**	0.843	**8.4**
Total area	-	**-**	10	**100**	10	**100**	10	**100**	10	**100**

Change maps from the 2002-2004 and 2004-2005 intervals suggest large areas of no change in each site (Table 2.20). Visual inspection of the change maps indicates that most of the unchanged area is the hard bottom region in the middle of the site (Figures 2.12d and 2.13d). The large net hard bottom changes in the intervals 2002-2004 and 2004-2005, are due to the large hard ground classification from the 2004 sidescan data. These changes could be due to one of two very different phenomena. One possibility suggests that the changes are documenting addition and removal of sands to the central portion of site C2 during the survey intervals. The other possibility is that noise in the 2004 data reduced the sharpness of the details within the central hard bottom region to an extent that the classification algorithm did not detect subtle, low backscatter intensity features within that region. The 2001-2002 interval yields a 4.4 % net hard ground gain. The overall interval between 2001 and 2005 suggests only a 0.2 % net hard bottom increase.

Table 2.20. Spatial analysis of change, site C2. Values are numbers of m^2.

	2001 to 2002	2002 to 2004	2004 to 2005	2001 to 2005
from sand to sand	181,000	175,500	143,300	164,200
from hard bottom to hard bottom	392,300	508,000	441,700	329,200
from hard bottom to sand	140,800	75,700	257,900	162,700
from sand to hard bottom	180,400	233,800	68,900	164,400
Total area of analysis	894,500	993,000	911,800	820,500
Area of no change (%)	64.1 %	68.8 %	64.2 %	60.1 %
Area of change (%)	35.9 %	31.2 %	35.8 %	39.9 %
Net hard bottom change * (%)	4.4 %	15.9 %	-20.7	0.2 %

* Positive values indicate net gain; negative values indicate net loss.

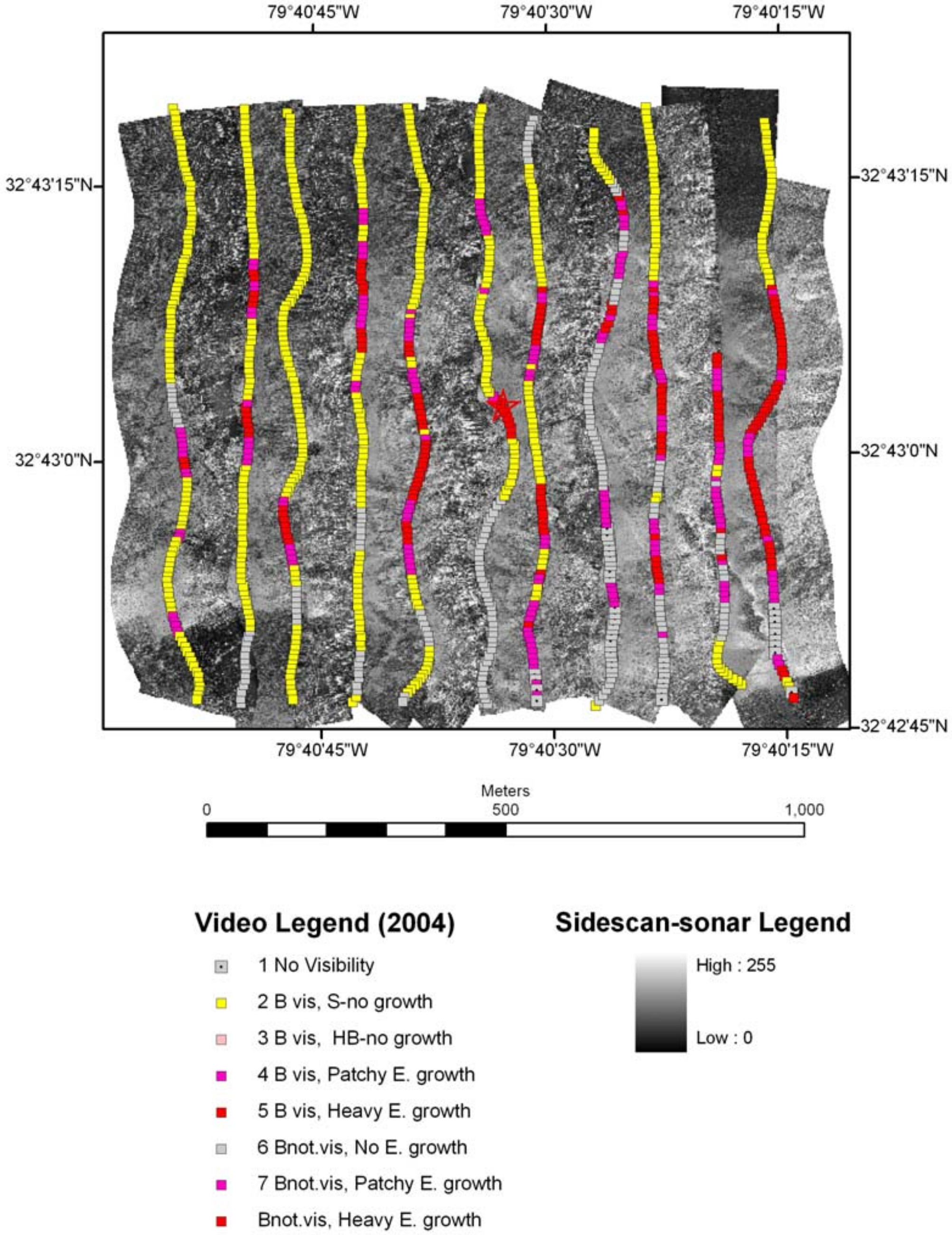

Figure 2.12a. Sidescan-sonar and coded video data collected over site C2 during the 2004 field season.

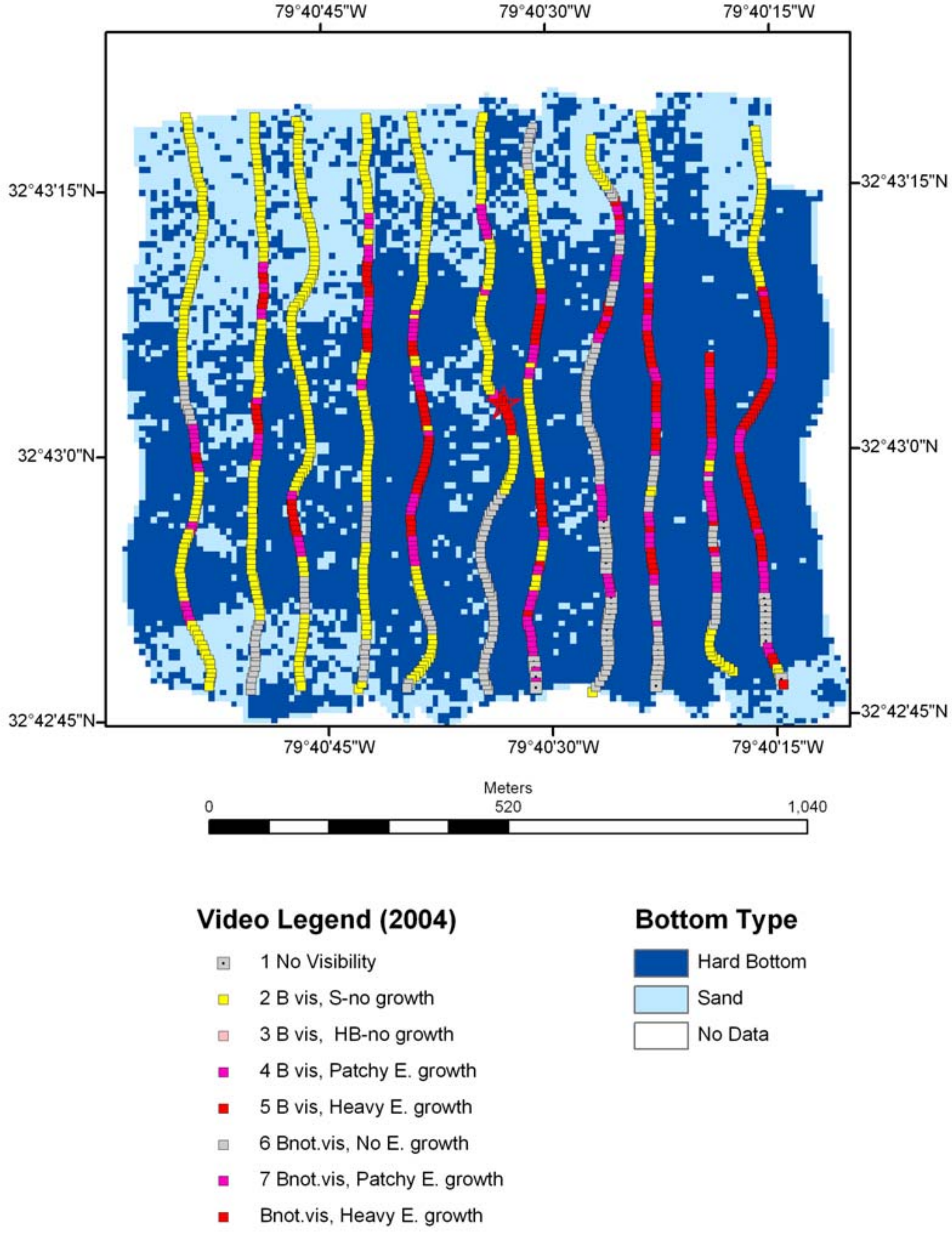

Figure 2.12b. Habitat mapping and coded video points of site C2 based on the sidescan-sonar mosaic from field season 2004.

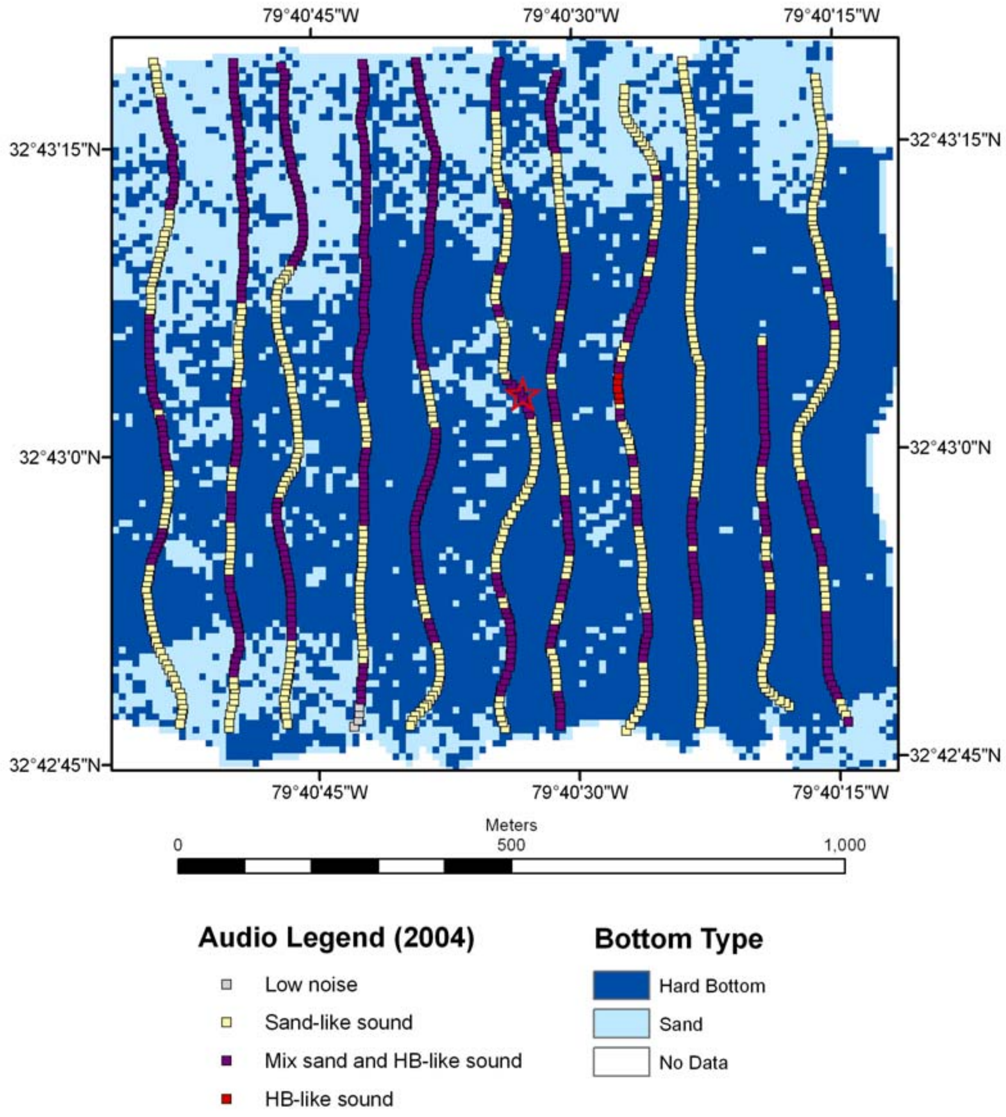

Figure 2.12c. Habitat mapping and coded audio points of site C2 based on the sidescan-sonar mosaic from field season 2004.

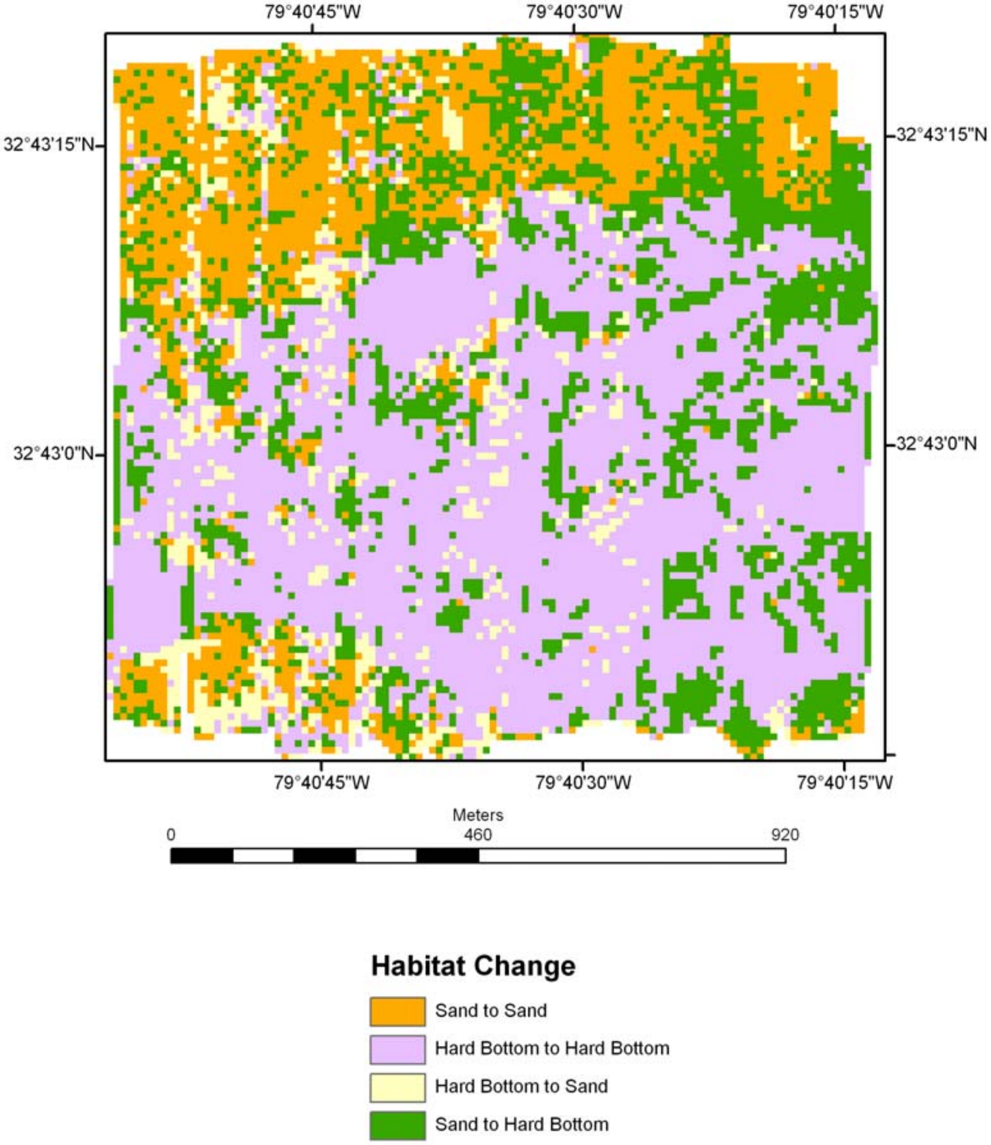

Figure 2.12d. Map of habitat change at site C2 during the inter-survey period 2002-2004.

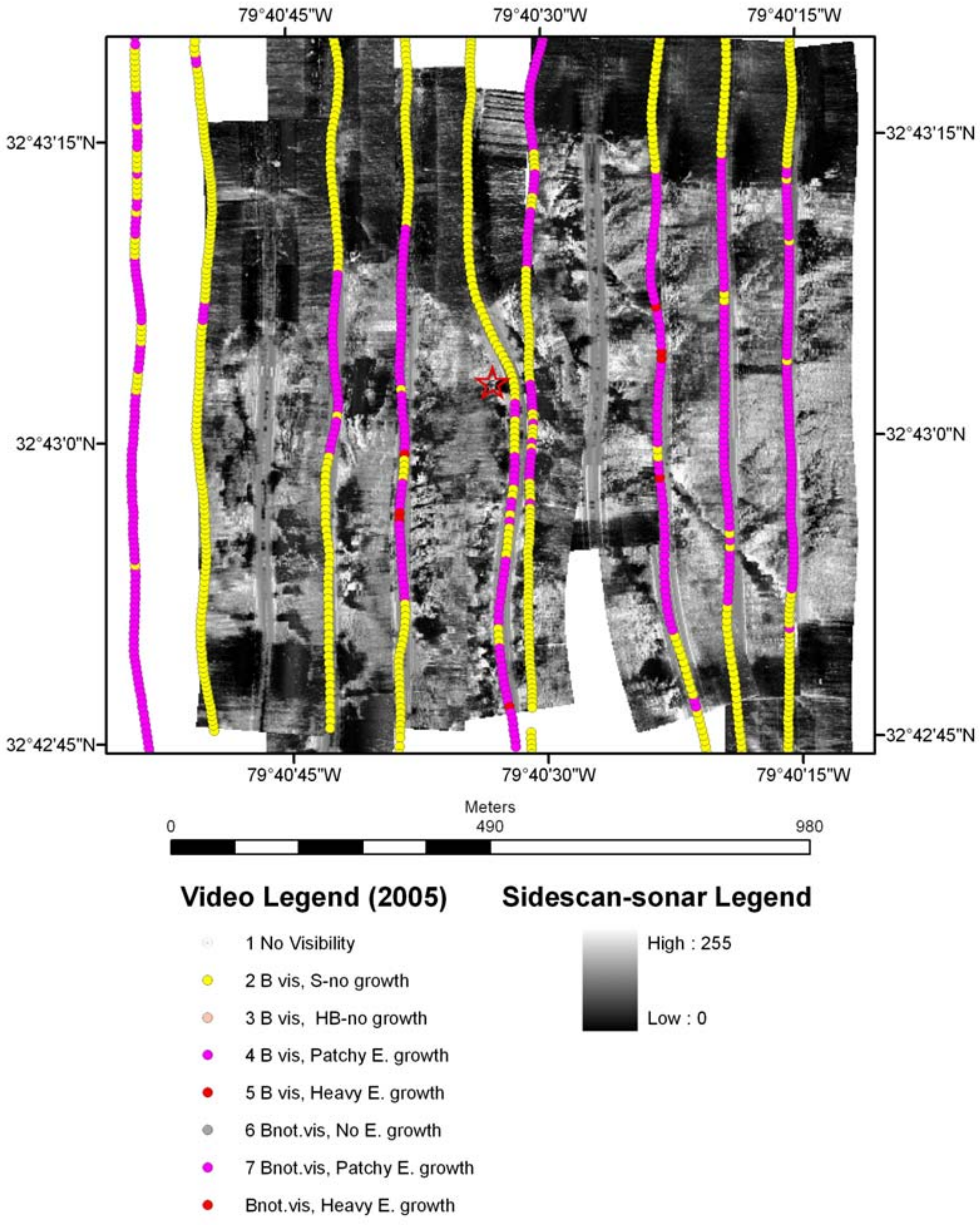

Figure 2.13a. Sidescan-sonar and coded video data collected over site C2 during the 2005 field season.

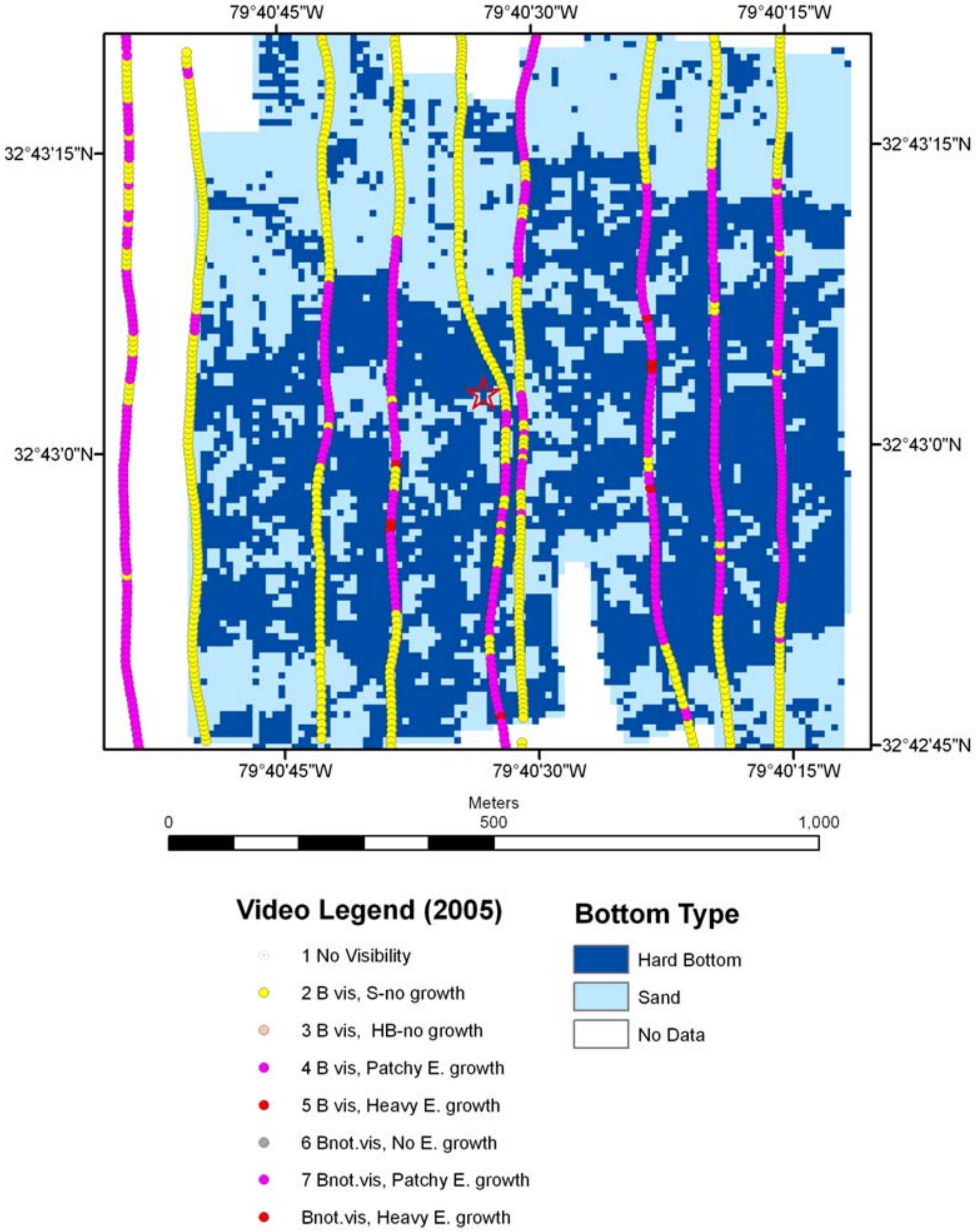

Figure 2.13b. Habitat mapping and coded video points of site C2 based on the sidescan-sonar mosaic from field season 2005.

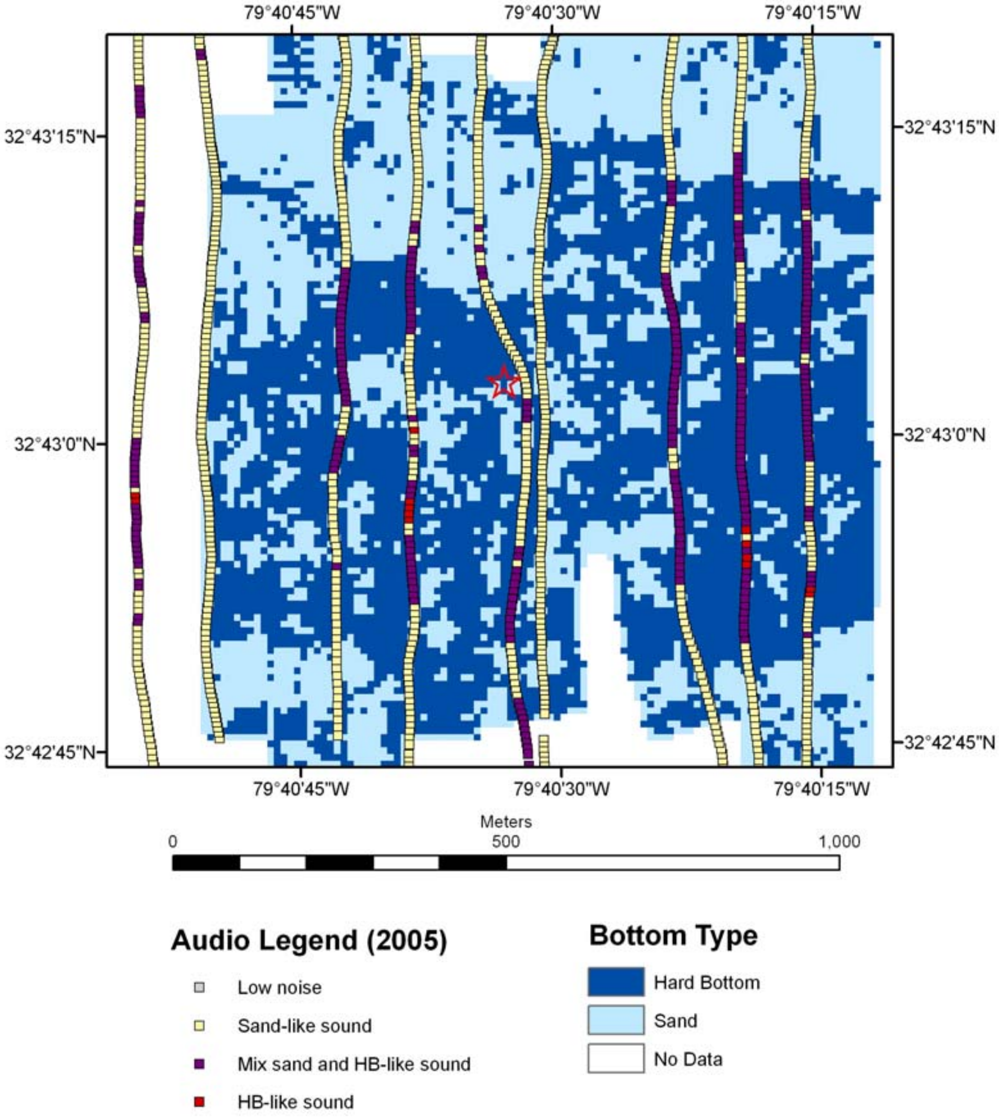

Figure 2.13c. Habitat mapping and coded audio points of site C2 based on the sidescan-sonar mosaic from field season 2005.

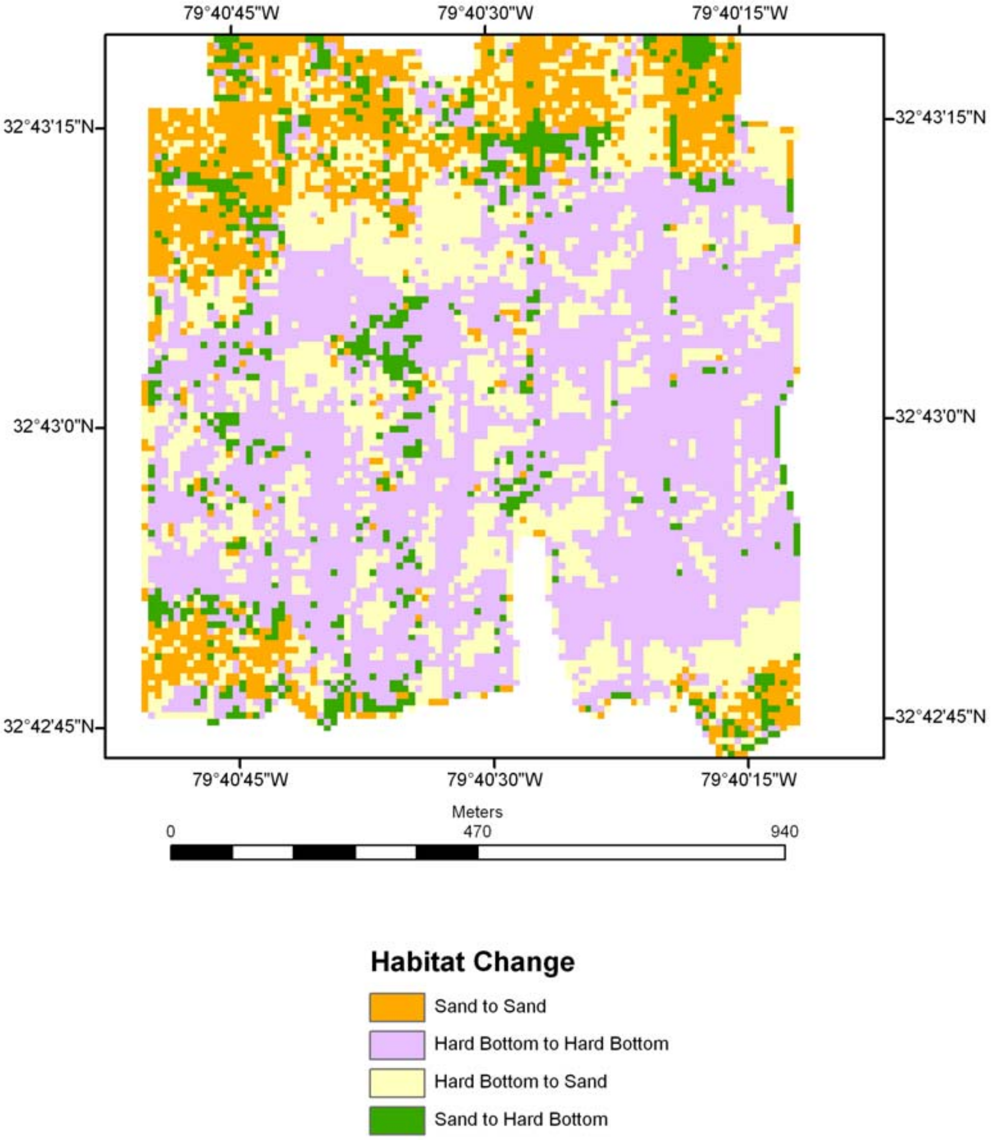

Figure 2.13d. Map of habitat change at site C2 during the inter-survey period 2004-2005.

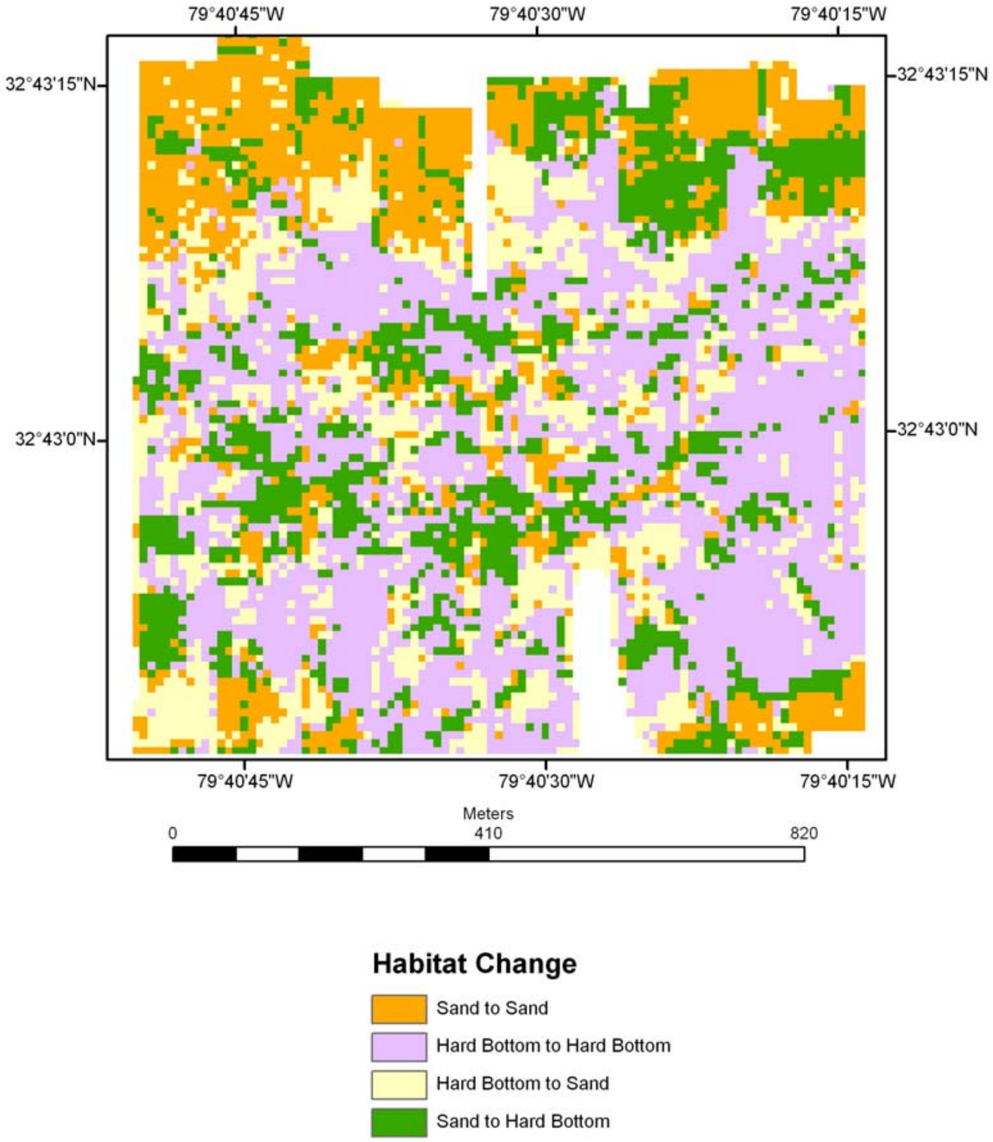

Figure 2.13e. Map of habitat change at site C2 during the inter-survey period 2001-2005.

2.5 DISCUSSION

With the 2005 data, four consecutive years of sidescan-sonar surveying have been completed over sites SWB, WB, EB, C1, and C2. The first survey in 2000 covered site SWA and thus a five years of sidescan exist for that site. Five years of video data have been collected over sites SWA, WB, SWB, and EB. Surveys have been conducted during different seasons and aboard different research vessels. Nonetheless, robust analysis of seafloor characteristics and habitat classification are becoming apparent with accumulation of new data.

Net hard bottom change between 2001 and 2005 has been a small gain in all sites with the exception of SWA (Table 2.21). With most net hard bottom changes being just a few percent, it is likely that sediment dumped at the ODMDS is not significantly changing the surrounding habitats. Small gains or losses of hard ground during the inter-survey periods at each site suggest that only a small amount of mobile sediment, with a transient nature, is present in this area of the South Carolina inner shelf system.

Comparisons between backscatter intensity, textural analysis, and coded video data suggest that a thin veneer of sand is sometimes capable of disguising hard bottom, but not always detrimental to sessile benthic ecosystems.

Table 2.21. Summary of results from video point counts and textural analysis.

			SWA	WB	SWB	EB	C1	C2
2000	Textural analysis	HB	96.4%	-	-	-	-	-
		Sand	3.6%	-	-	-	-	-
	Spatial change	**2001-2000**	**-29.3%**	**-**	**-**	**-**	**-**	**-**
	Video coding	HB	100%	60%	0%	25.2%	-	-
		Sand	0%	40%	0%	74.8%	-	-
2001	Textural analysis	HB	66.8%	61.2%	55%	57.8%	57.3%	53.3%
		Sand	32.7%	30.5%	36.3%	40.8%	39%	36.2%
	Spatial change	**2001-2002**	**3.4%**	**14.7%**	**23.9%**	**2.3%**	**0.7%**	**4.4%**
	Video coding	HB	21.3%	65.9%	30.7%	16.9%	36.5%	65.6%
		Sand	78.7%	34.1%	69.3%	83.1%	63.5%	34.4%
2002	Textural analysis	HB	69.4%	81%	85.5%	61.1%	60.3%	58.4%
		Sand	29.2%	18.3%	14.5%	38%	39.1%	41.2%
	Spatial change	**2002-2004**	**-2.1%**	**5.5%**	**-14.4%**	**4.8%**	**2.2%**	**15.9%**
	Video coding	HB	24%	49.9%	29.6%	14.2%	56.2%	61.6%
		Sand	76%	50.1%	70.4%	85.8%	43.8%	38.3%
2004	Textural analysis	HB	68.1%	86.9%	70.7%	66.1%	62.7%	74.2%
		Sand	31.9%	13.1%	28.9%	33.8%	37.2%	25.4%
	Spatial change	**2004-2005**	**-7.1%**	**-18%**	**-6.4**	**2%**	**7.1%**	**-20.7%**
	Video coding	HB	18.5%	100%	15.4%	21.2%	48.4%	38%
		Sand	81.5%	0%	84.6%	78.8%	51.6%	62%
2005	Textural analysis	HB	59.3%	67.7%	62.9%	64.9%	59.4%	51.1%
		Sand	36.5%	30.6%	34.8%	31.4%	23.2%	40.5%
	Spatial change	**2001-2005**	**-5.4%***	**2.8%**	**2.6%**	**9.7%**	**12.3%**	**0.2%**
	Video coding	HB	21.8%	65.2%	24.7%	23.7%	34.5%	42.9%
		Sand	78.2%	34.8%	75.3%	76.4%	65.5%	57.1%

* -33.1% change between 2005 and 2000.

CHAPTER 3:

Diver Collected Video Surveys of Reef Sites and Analysis of Sediment Composition

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3.1 INTRODUCTION

This section describes the results of the hard bottom reef monitoring portion of the overall monitoring study, including results of visual and video surveys of study sites by divers and laboratory analysis of sediment composition and grain size. Specific objectives of this portion of the study were to document changes in:

- Sedimentation rates, sediment composition, and grain size
- Sponge and coral density and condition
- Finfish assemblages

3.2 METHODS

Field Sampling

Four study sites (WB, SWA, SWB, EB) and two control sites (C1, C2) in the areas surrounding the Charleston ODMDS were monitored from fall 2000 through spring 2005 (Figure 3.1). The original study was planned to have one set of study sites located within the inner/outer boundary zones surrounding the ODMDS, as designated by Van Dolah *et al*. (1997), and a second set of study sites located outside of the inner/outer boundary zones surrounding the ODMDS (Figure 3.2). However, only one suitable reef site (SWA) could be found in the boundary zones. The remaining sites were located outside the boundary zones (WB, SWB, EB). Permanent markers were placed at each site with four transect lines (20 m) extending from the central marker at 90° angles. Transect lines were repaired or replaced as needed when deterioration, damage, or fouling occurred. Each study site was sampled twice per year (spring and fall) to assess physical and biological conditions.

Water quality data were collected at all reef sites using a YSI® Model 85 water quality meter to obtain surface and bottom measurements of dissolved oxygen, temperature, and salinity.

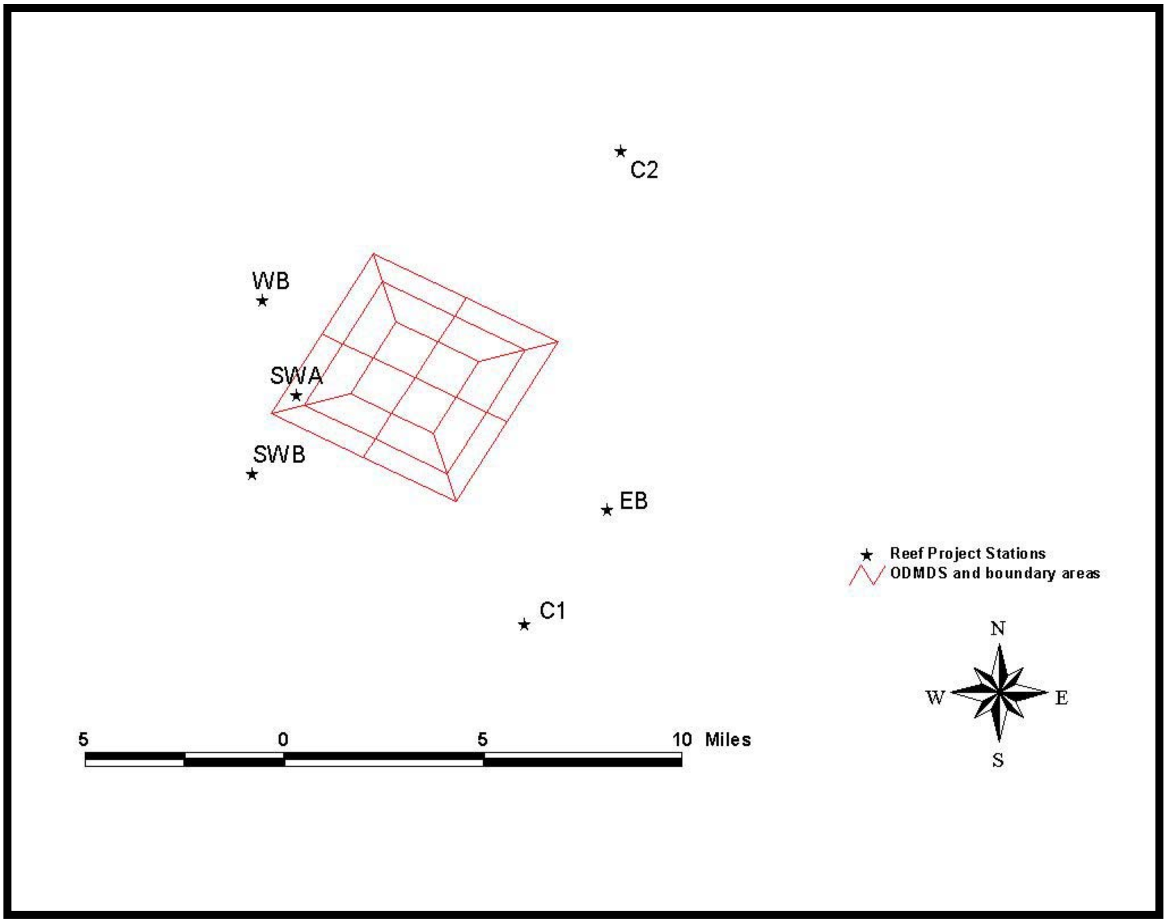


Figure 3.1. Location of hard bottom reef sites established during the first year of the study.

Sediment cores were collected at 5, 10, and 15 m intervals along each of the four transects at each site. A 3.5 cm diameter core was used to collect the top layer (~2.5 cm) of sediments. Upon return to the surface, each core was placed in a pre-labeled plastic bag, kept on ice for transport to the lab, and stored in a freezer (-20°) until analysis. Concurrent with sediment core collection, surficial sediment depth was measured to the nearest 0.5 cm by inserting a stainless steel ruler into the sediment adjacent to the 5, 10, and 15 m interval marker on each transect line.

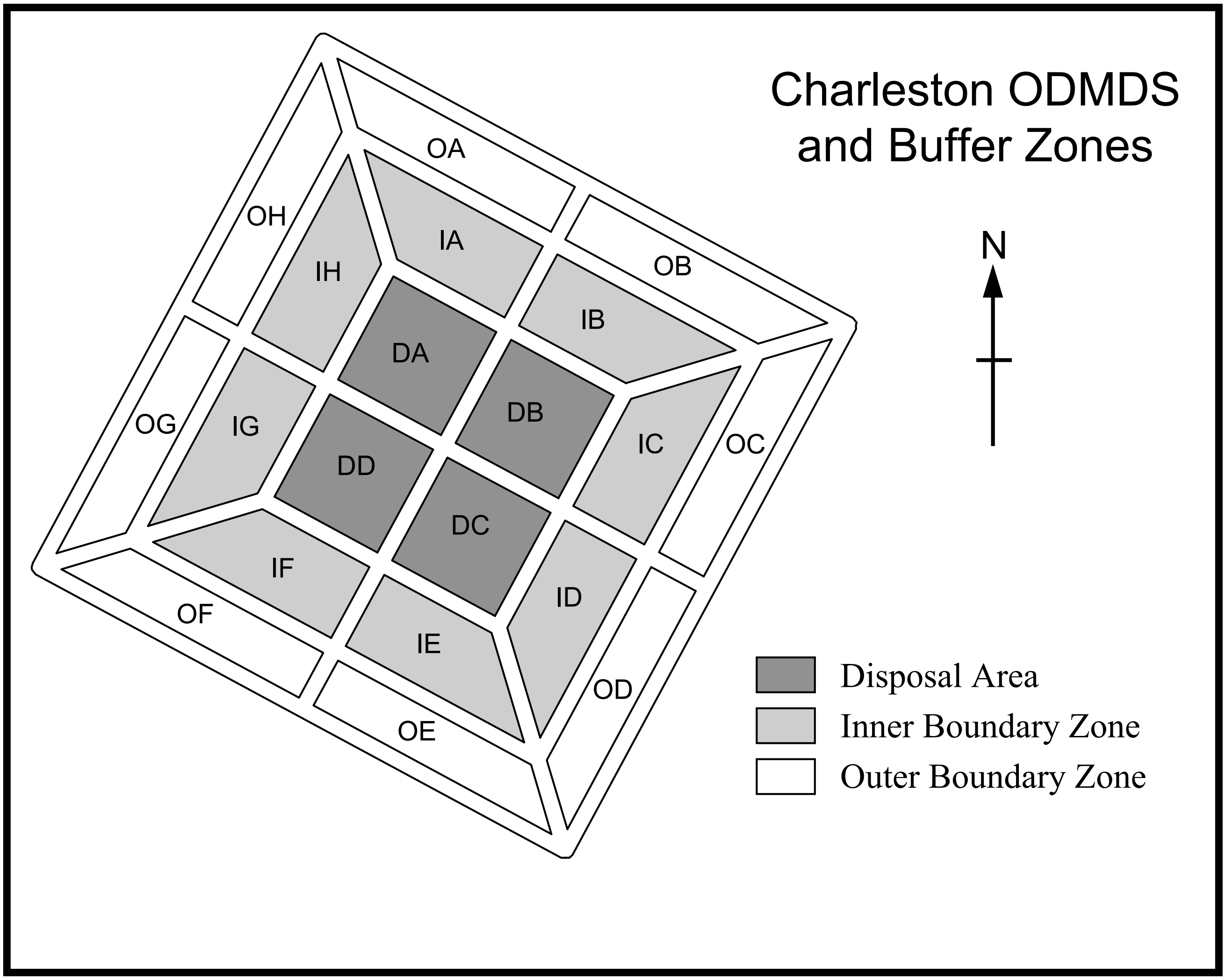


Figure 3.2. Location of the disposal area and the inner and outer boundary zones as designated by Van Dolah *et al*. (1997). Figure from Van Dolah *et al.* (1997).

Sediment traps were deployed during each sampling period at all sites. Each trap had a length of 46 cm, an inside diameter of 5.8 cm, a length-to-width ratio of 7.9, and was equipped with a baffle system of approximately nine smaller tubes (length ~ 7.5 cm) inserted in the top of the tube. Open cylinders with a length-to-width ratio of approximately two or greater have been found to yield representative measurements of sedimentation. The use of baffles to slow down circulation within the sediment trap allows particles to settle, making the trap a more efficient collector. Traps were placed near the center of each site with the distal end approximately one meter above the seafloor. From fall 2000 through spring 2002, a single trap was deployed at each site. Beginning in fall 2002, two to three replicate traps were deployed at each site. In addition to vertical deposition of sediments, redistribution of bottom sediments may make some contribution to the total volume within a sediment trap. Therefore, volume measures from sediment traps are considered to be rough estimations of sediment accumulation from the water column. The material collected in each trap was used to quantify the relative sediment accumulation rates of various sedimentary constituents (%sand, %silt/clay, %$CaCO_3$, and grain size). The composition of the material collected in the trap, particularly percent silt/clay content, permits the comparison of fines in the water column among study sites.

Underwater video surveys were collected at each site by divers to obtain information on the fish and sponge/coral communities inhabiting each site and to examine changes in the composition, abundance, and condition of these organisms over time. During each sampling period, two video surveys were recorded along each of the four transects at each site. The first survey was completed with the camera held parallel to the seafloor (horizontal surveys), followed by a second transect with the camera held perpendicular to the seafloor (vertical surveys).

3.3 LABORATORY PROCESSING

Sediment

Sediment analyses were performed using a modification of the pipette method described in Plumb (1981). All samples for each site were stored at -20^{o}C until processing began. After thawing, each sample was thoroughly homogenized, and a 20 g subsample was removed for particle size analysis. Twenty ml of a dispersant (sodium hexametaphosphate) solution was added to the subsample. The subsample was then wet sieved through a 63-micron stainless steel sieve using distilled water. Filtrate was collected in a 1000 ml graduated cylinder for pipette extraction of the fine component (silts and clays). The material retained on the sieve (sand and $CaCO_3$) was dried at 90^{o}C to obtain a total dry weight for the sand and $CaCO_3$ fractions. The filtrate mixture was resuspended and a 20 ml sample was withdrawn from a depth of 20 cm at the time and temperature described by Plumb (1981) to determine the amount of silt and clay in suspension. An additional 20 ml was withdrawn at the 10 cm depth after further settlement of the filtrate to estimate the amount of clay in suspension. Extracts were thoroughly dried and weighed to the nearest 0.001 gram.

The total dry weights of the silt and clay fractions were corrected for the dispersant and were used to calculate percentage estimates to the nearest 0.1%. It should be noted that pipette analysis is probably not accurate to this level for the estimates of percent silt versus clay; therefore combined estimates of silt and clay were calculated.

Material retained on the 63-micron sieve was subjected to 10% HCl and 550° incineration to eliminate $CaCO_3$ and organic matter respectively. The remaining sand was dry-sieved using a Ro-tap mechanical shaker and sand grain size was determined using fourteen 0.5 phi-interval screens, where phi = $-\log_2$ (grain diameter in mm) according to the Udden-Wentworth Phi classification (Brown and McLachlan 1990).

Ten percent of the samples were reanalyzed by a second researcher using the same procedures to provide quality assurance/quality control (QA/QC) information. Criteria for acceptance require that a difference of no greater than 10% may exist in the dominant component, representing either sand/$CaCO_3$ combined or silt/clay combined.

Video review

Video surveys from each season were reviewed in the laboratory to assess abundance of sessile sponges and corals and finfish from the reef sites. Invertebrate video surveys (vertical surveys) were subdivided into 10-second intervals for analysis. Presence/absence was recorded during each interval for massive sponges including *Ircinia* sp., encrusting sponges, and the soft corals *Leptogorgia* sp. and *Titanideum* sp. In addition, if one or more of these organisms was present, that particular interval was also recorded as having hard bottom reef habitat present.

Finfish counts were generated separately for both horizontal (n = 4 per sampling period) and vertical surveys at each site (n = 4 per sampling period). The mean number of fish families and the mean abundance of fish from each transect at the six sites was recorded.

3.4 DATA ANALYSES

Sediment Characteristics

Analyses of sediment data (% sand, % silt/clay, % $CaC0_3$, and mean phi size) were conducted to identify differences among sampling periods within each site and between sites. Percent sand, silt/clay, and calcium carbonate were rank transformed, and analyzed using ANOVA followed by Dunn's test. When appropriate, data were natural log transformed, and analyzed with ANOVA followed by post-hoc comparisons with the Tukey test. SigmaStat for Windows Version 3.1 (SPSS 2004) was used for all statistical tests.

For the sediment core samples, mean values for each of the sediment parameters was based on a total of 10-12 cores collected during each sampling event at a site. At sites where fewer than 12 cores were collected, samples were either lost during transfer to the surface or insufficient sediment was available.

Sediment traps were analyzed to determine average sediment accumulation rates (grams/day). No data are available for the SWA site in spring 2001 or the EB site in spring 2002 due to trap damage. In fall 2001, traps at sites WB, SWB, SWA, EB, and C2 were collected after a deployment period greater than 100 days due to poor weather conditions and staffing limitations. This time period was substantially longer than the average 34-day deployment period during the other study periods. Therefore, most of the sediment traps deployed in Fall 2001, with the exception of reference area C1, are likely inaccurate estimates of the actual volume of material deposited on the sites because (1) only a limited volume of material can be held by each trap, (2) as traps fill and the length-to-width ratio decreases, particles are less likely to settle, and (3) winter storm activity may have been sufficient to move sediment out of the traps. Data from this trap deployment is presented only for comparison among sites during that period.

Video Surveys

Invertebrate Surveys

Data on invertebrate communities were collected from vertical surveys (n = 4/site/survey period). The invertebrate data from the sampling periods within each study year were combined for analyses. In fall 2000, the vertical survey collected on transect four at site SWA was lost, and invertebrate community estimates were based on the remaining three transect values. Video surveys ranged in length from 1.0-5.5 minutes per transect (mean = 1.9 minutes), and were subdivided into 10-second intervals for analysis. The percentage of intervals with hard bottom and dominant organisms found at each site and study year were statistically analyzed with ANOVA followed by the Tukey test to determine if significant differences occurred between sites and within a site for each sampling date and study year.

Finfish Surveys

Fish abundance and number of families were analyzed using ANOVA followed by Dunn's test for both the horizontal and vertical surveys. Data from the two sampling periods comprising each study year were combined in order to simplify analyses (i.e. fall 2000 and spring 2001 = study year 1). In fall 2000, horizontal and vertical surveys collected on transect four at site SWA were lost, and finfish community estimates were based on the remaining three transect values.

3.5 RESULTS AND DISCUSSION

Hydrographic Data

Temperature, salinity, and dissolved oxygen values were similar among sites and seasons (Table 3.1). Surface and bottom values of those same parameters were also similar within a season with the exception of salinity, which often varied by 2-3 ppt between the two measurements. Values were within typical levels for coastal South Carolina waters.

Sediment Data

Sediment Cores

Sand was the predominant sediment type at all sites, with the average ranging from 54.9-90.1 % (Figure 3.3). Calcium carbonate was the second largest component (7.3-43.4 %) and silt/clay content rarely exceeded 6% at any site. SWB and EB, which are located outside the ODMDS boundary zones, had very consistent sand content over the five year study period (Figure 3.3). The SWB site had significantly higher sand values than all other sites. The EB site also had significantly higher sand content than all other sites except SWB ($p < 0.001$). Sites that had less sand content

Table 3.1. Hydrographic data collected at reef sites during the study period. Average bottom depths (m) at each site are as follows: SWA=13, WB=12.6, SWB=13.2, EB=14.6; C1=15.1, C2=13.2.

Temperature (°c)					***SURFACE***					
	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003	Spring 2004	Fall 2004	Spring 2005
SWA	ND	23.4	ND	ND	22.8	23.4	20.5	23.6	23.1	21.7
WB	ND	22.8	22.8	23.9	21.8	22.2	27.6	24.5	13.0	26.2
SWB	21.9	23.5	23.3	24.0	ND	22.3	20.5	23.2	23.0	20.4
EB	22.5	ND	23.6	23.2	ND	21.7	20.2	23.0	ND	ND
C1	21.6	20	24.2	25.0	22.8	21.9	22.9	23.0	23.8	22.6
C2	ND	24.1	22.7	24.3	22.2	23.6	22.6	23.7	17.6	25.2
Temperature (°c)					***BOTTOM***					
	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003	Spring 2004	Fall 2004	Spring 2005
SWA	ND	22.6	ND	ND	22.8	22.4	19.8	21.2	22.6	19.6
WB	ND	22.3	22.6	23.2	22.6	20.8	21.8	21.3	12.2	24.1
SWB	21.1	22.6	23.2	23.4	ND	22.6	19.8	21.3	22.6	19.1
EB	22.0	ND	23.5	23.0	ND	20.3	20.3	20.9	ND	ND
C1	21.6	19.7	23.7	24.4	22.9	20.4	23.3	20.9	23.7	20.1
C2	ND	24.2	23.4	24.1	23.0	23.3	21.8	20.7	17.5	23.9

Salinity (ppt)					***SURFACE***					
	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003	Spring 2004	Fall 2004	Spring 2005
SWA	ND	34.5	ND	ND	33.8	35.9	35.5	34.6	33.5	33.0
WB	ND	33	36.2	36.7	33.3	31.2	34.8	32.8	30.2	30.7
SWB	37.2	35.9	37.0	36.1	ND	35.8	35.5	34.7	32.3	33.7
EB	38.0	ND	37.2	35.5	ND	33.5	36.2	34.2	ND	ND
C1	37.0	34.2	37.2	34	36.6	33.6	35.6	34.2	34.7	35.7
C2	ND	36.6	34.7	37.1	35.5	36.1	33	32.2	35.1	31.3
Salinity (ppt)					***BOTTOM***					
	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003	Spring 2004	Fall 2004	Spring 2005
SWA	ND	36.6	ND	ND	35.4	36.0	36.3	35.1	34.7	35.7
WB	ND	35.5	36.6	37.1	36.1	33.4	35.8	34.6	34.9	33.4
SWB	37.2	36.7	37.0	36.7	ND	35.8	36.3	35.1	34.6	34.9
EB	38.0	ND	39.2	36.0	ND	33.9	36.6	35.2	ND	ND
C1	37.0	36.3	37.3	37.2	36.5	34.0	36.9	35.2	34.9	36.3
C2	ND	36.8	37.1	37.7	36.9	36.1	35.9	34.9	35.1	34.1

Dissolved Oxygen (ppm)					***SURFACE***					
	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003	Spring 2004	Fall 2004	Spring 2005
SWA	ND	6.60	ND	ND	6.77	7.10	ND	6.96	7.17	6.68
WB	ND	7.00	6.84	6.51	6.15	7.80	7.01	ND	8.95	ND
SWB	7.16	6.83	7.37	6.80	ND	7.62	ND	6.88	7.49	7.11
EB	7.06	ND	6.61	6.60	ND	7.45	7.12	6.80	ND	ND
C1	6.91	7.39	6.94	6.63	6.38	7.75	6.70	6.80	6.14	6.72
C2	ND	7.02	7.17	6.98	6.51	6.80	6.60	6.97	6.95	ND
Dissolved Oxygen (ppm)					***BOTTOM***					
	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003	Spring 2004	Fall 2004	Spring 2005
SWA	ND	6.65	ND	ND	6.69	7.70	ND	6.85	6.23	6.92
WB	ND	6.87	6.51	6.52	6.34	7.00	6.57	ND	8.44	ND
SWB	7.10	6.86	7.28	6.67	ND	7.58	ND	6.91	6.36	7.18
EB	6.95	ND	6.57	6.52	ND	7.04	6.84	6.85	ND	ND
C1	6.89	7.37	6.86	6.49	6.40	7.49	6.70	6.85	6.21	6.95
C2	ND	6.98	6.61	6.79	6.21	6.59	7.04	6.90	7.12	ND

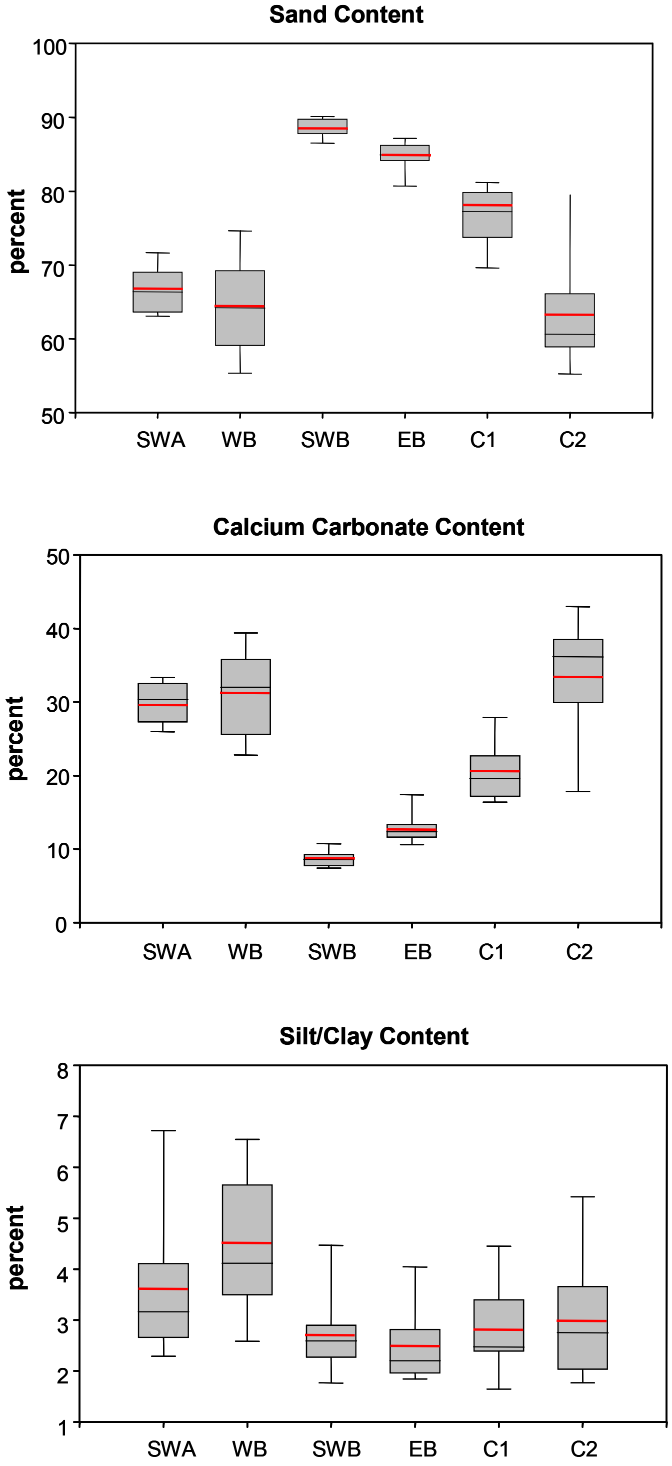


Figure 3.3. Median percent composition of sand, calcium carbonate, and silt/clay from sediment core samples. The boxes show the 25th and 75th percentiles and the error bars show the 10th and 90th percentiles. Red lines represent mean values. In cases where no black line is visible, the median and mean values are equal. Sites are listed along the x-axis with increasing distance from the disposal site. Data represent all study years combined.

$CaCO_3$ instead of silt/clay as the bulk of the remaining sediment. There was significant seasonal variability in sand content at the two reference areas, C1 and C2, but no seasonal variability at the sites near the disposal area. At site C2, overall sand content was variable, with spring 2001 and spring 2005 values being significantly higher than all other sampling dates ($p < 0.001$). There was no significant difference in sand content at site C2 between spring 2001 and spring 2005 samples ($p < 0.05$). At reference area C1, sand content was significantly lower during the spring 2001 compared to later dates ($p < 0.05$), and calcium carbonate content was significantly higher in the spring 2001 sampling period ($p < 0.05$) than later sampling dates. These results are likely due to natural variability since the site is located so distant from the disposal area.

The maximum silt/clay content during the study period was 7.0 %, found at the SWA site in fall 2004. Since a large portion of the sediments dredged from Charleston Harbor and the outer zone channel had higher silt or clay content than is typically found in South Carolina's ocean bottoms, evaluation of the differences in slit/clay content among the sites and over time provides some indication of whether dredged material may be moving into nearby reef habitats. In general, silt/clay was a minor component of sediment composition at all sites, with means below 10%, and in most cases below 5% (Figure 3.3). Overall, site WB showed significantly higher silt/clay values than all other sites ($p < 0.001$). At all sites except C2, higher silt/clay values were seen in fall 2003 than all previous sampling dates ($p < 0.001$). However, fall 2004 values were higher than all other sampling dates at sites SWA and WB, as well as both reference areas ($p < 0.001$). There was considerably more rainfall in the fall of 2004 than previous sampling seasons due to an active hurricane season (Figure 3.4). The additional rainfall and turbulent activity during the fall of 2004 may be directly related to the increased silt/clay values at study sites. There was a significant decrease in silt/clay values between the fall 2004 and spring 2005 sampling period at all sites except EB, ($p < 0.001$), a site well away from the disposal area. Although seasonal rainfall values were also higher than average in spring 2005, a majority of the rain occurred in the months immediately prior to the sampling period as opposed to the fall 2004 when rainfall was high during the sampling period.

The mean phi size of the sand fraction from sediment cores collected at all sites is presented in Figure 3.5. Overall, site EB grain size values were significantly higher than all other sites ($p < 0.001$), and therefore, on average, had a smaller grain size than all other sites. The coarsest sands were located at site SWA and the reference area C2. Study site WB and reference areas C1 and C2 showed the greatest variability in phi size, while the least variability was observed at sites SWB and EB. The most variability was noted at site WB, which is the closest study site to shore, and is most likely affected by the tidal plume. The bottom topography at the site is sandy bottom interspersed with rocky outcrops. There were significant seasonal changes observed at some sites (EB, WB, C1, and C2), however, the changes were not consistent throughout the study period. No significant seasonal change was observed during the study period at SWA or SWB. Changes observed in grain size do not appear to be related to movement of sediments from the disposal area.

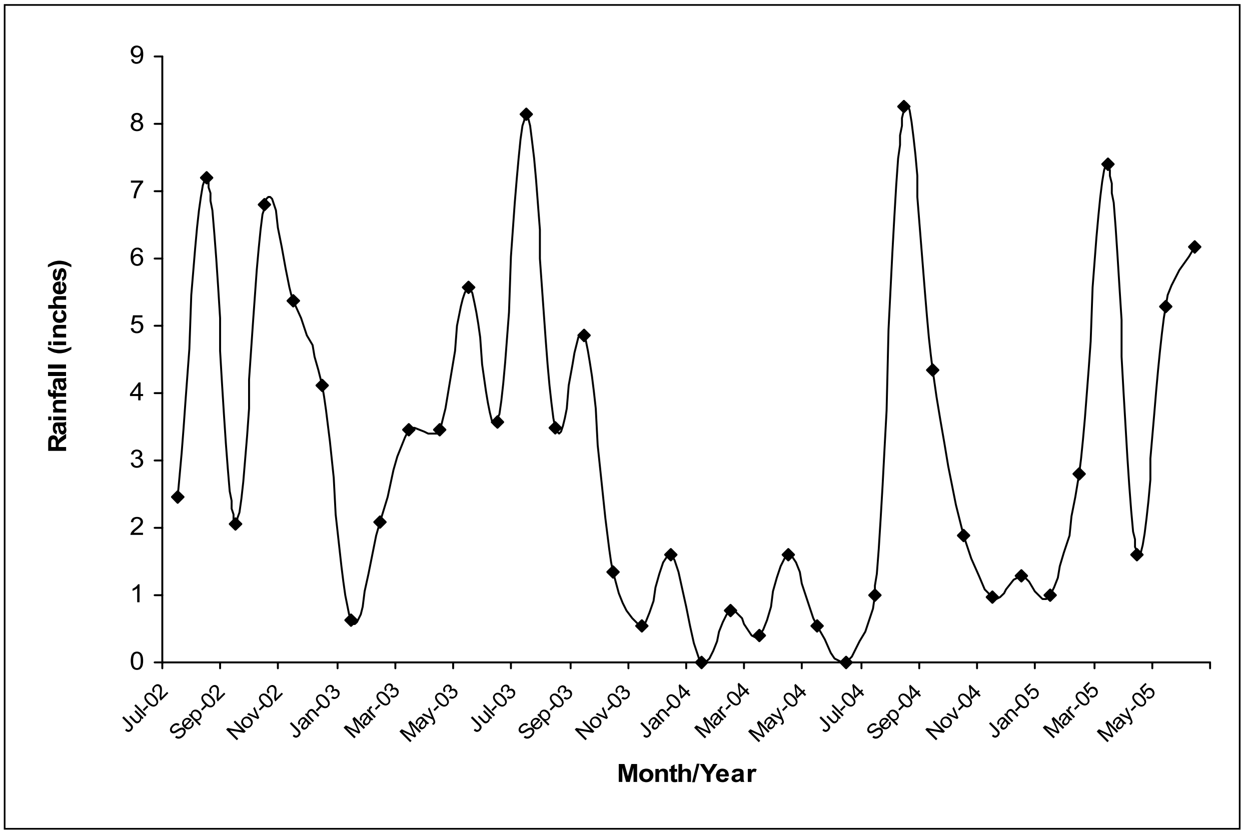


Figure 3.4. Monthly rainfall in inches recorded at Marine Resources Research Institute, Charleston, South Carolina from July 2002 to June 2005 (Davis Instruments 2004).

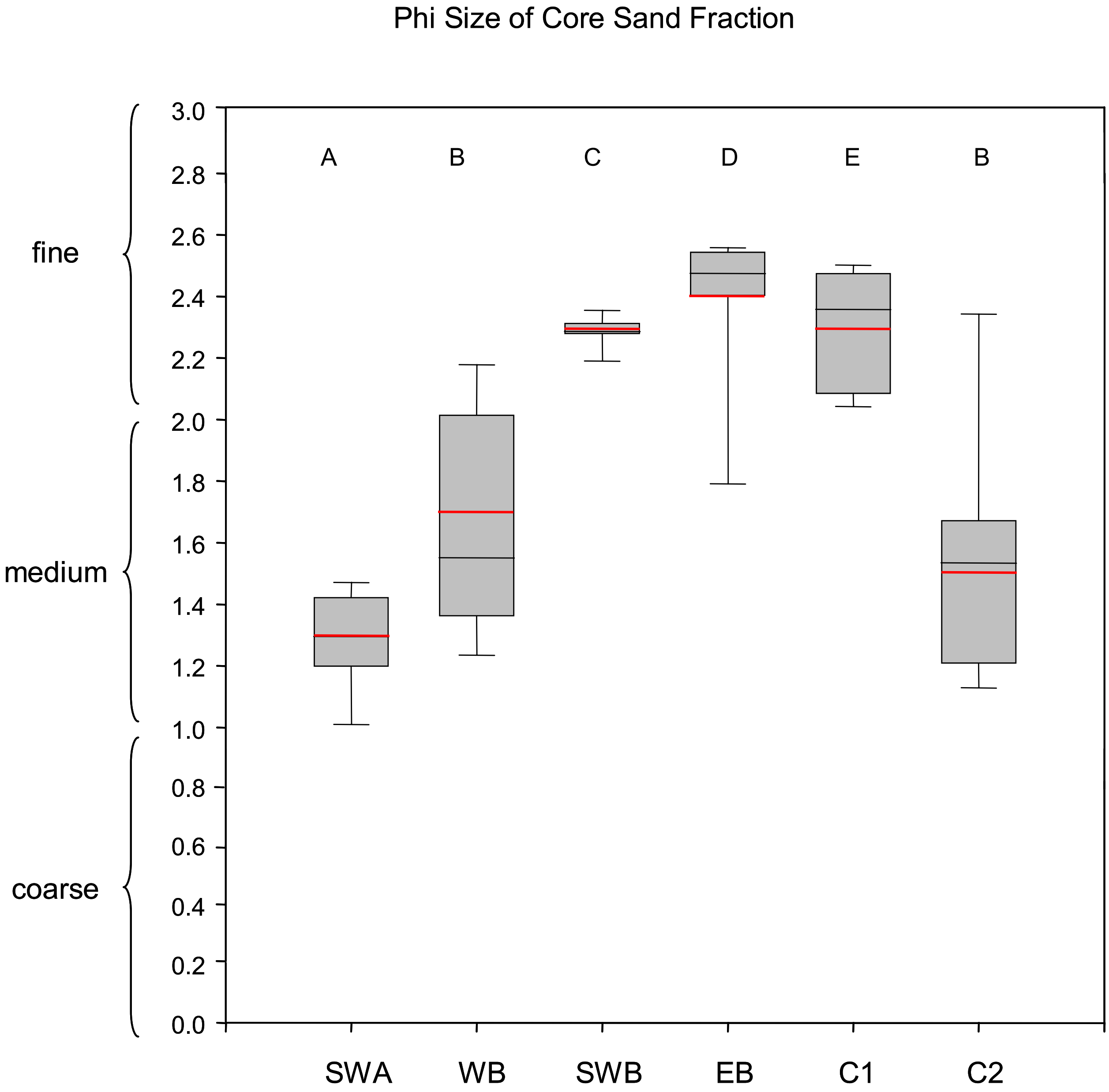


Figure 3.5. Summary of phi size of the sand fraction. The boxes show the 25th and 75th percentiles and the error bars show the 10th and 90th percentiles. Red lines represent mean values. In cases where no black line is visible, the median and mean values are equal. Sites are listed along the x-axis with increasing distance from the disposal site. Letters represent significant differences between study sites; similar letters represent no significant difference.

Surficial Sediment Depths

Surficial sediment depths were significantly different among sites (Figure 3.6) with the reference area C2 having significantly deeper sediments than all other sites ($p < 0.001$). The reference area C1 and sites EB and SWB also had significantly deeper sediments than SWA.

Comparisons among sampling dates within each site indicated significant changes at some of the sites. Site SWB had significantly deeper surficial sediment depths in fall 2003 than most previous sampling dates, and a trend of deeper surficial sediments in fall 2003 samples was also observed at most other sites. Mean sediment depth at site WB was the highest observed at 14.4 cm in the spring 2005 sampling period. Spring 2005 sediment depths at site WB were significantly higher than all previous years with the exception of 2003 ($p < 0.001$). Site WB is the closest study site to the harbor entrance channel and is located to the west of the ODMDS. Bottom current studies (Williams *et al*. 1997) indicate the possibility of sediment movement from the ODMDS in this direction, but it is not the predominant direction of currents, which primarily flow to the southwest. This site is also potentially affected by the Charleston Harbor sediment plume.

Overall, our findings suggest that surficial sediment depths over hard bottom at sites in the vicinity of the disposal area have not significantly increased over time as a result of migration of disposal area sediments. The temporary increases and decreases observed at some sites during the study period are more likely due to natural events related to storm activity and tidal currents. The average change in depth since the inception of the study was generally only a few centimeters and rarely exceeded an increase of more than 4-6 cm over time. Similar changes were observed at the control sites and at site EB which are as far away from the ODMDS as C1. One possible exception was site SWB which showed an increased sediment average depth from about 2 cm to more than 12 cm from the spring of 2002 to the fall of 2003.

Sediment Traps

The average accumulation rate (grams/day) of sediments collected in the sediment traps varied among sites (Figure 3.7). The highest average rates were observed at WB (5.10 grams/day) and SWA (2.73 grams/day). Study sites in the vicinity of the disposal area generally had higher accumulation of sediment, especially fine grained material, than reference areas. The lowest overall mean sedimentation rates were observed at the reference areas, which may reflect re-suspension of soft bottom materials disposed in the ODMDS. Site WB was the most variable with respect to sediment accumulation rates while site EB and reference area C1 exhibited the least variability.

The sediment traps largely collected fine grained materials (e.g. silt/clay) which are more easily suspended than the sand and calcium carbonate fractions (Figure 3.7). Even if significant sediment movements were occurring at the study sites, the sediment traps would not have been likely to capture those movements since the mouth of the traps was approximately 1 m above the bottom. Instead, the traps were deployed to determine if higher silt loads were apparent in the water column near the ODMDS, and for analysis of sediment signatures (see Chapter 4). As suspected, traps closer to the ODMDS did have a greater percentage of silt/clay compared to sites EB and reference area C1.

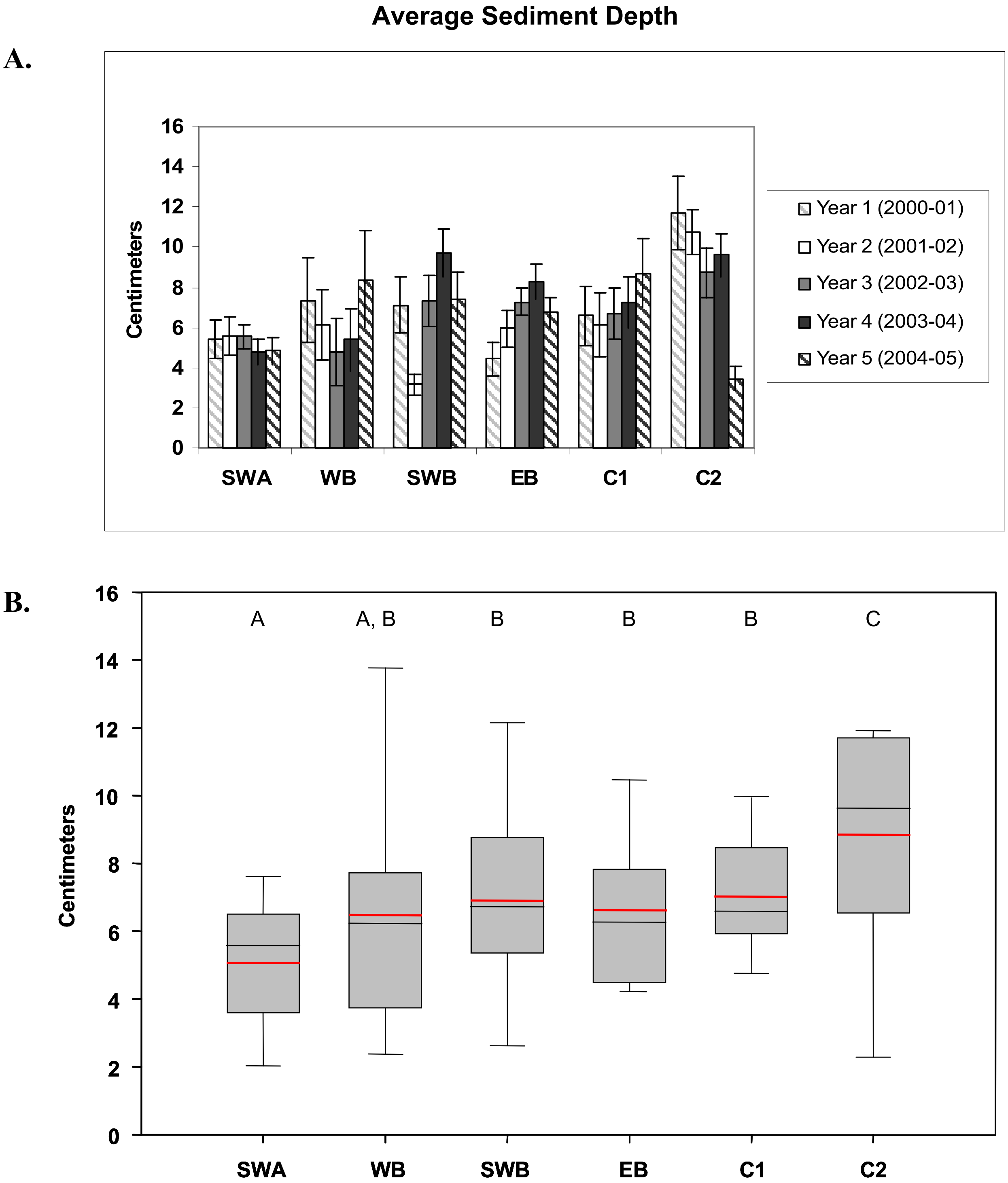


Figure 3.6. A. Mean sediment depth per study year. B. Summary of sediment depth. The boxes show the 25th and 75th percentiles and the error bars show the 10th and 90th percentiles. Red lines represent mean values. Sites are listed along the x-axis with increasing distance from the disposal site. Letters represent significant differences between study sites; similar letters represent no significant difference. Data represent all study years combined.

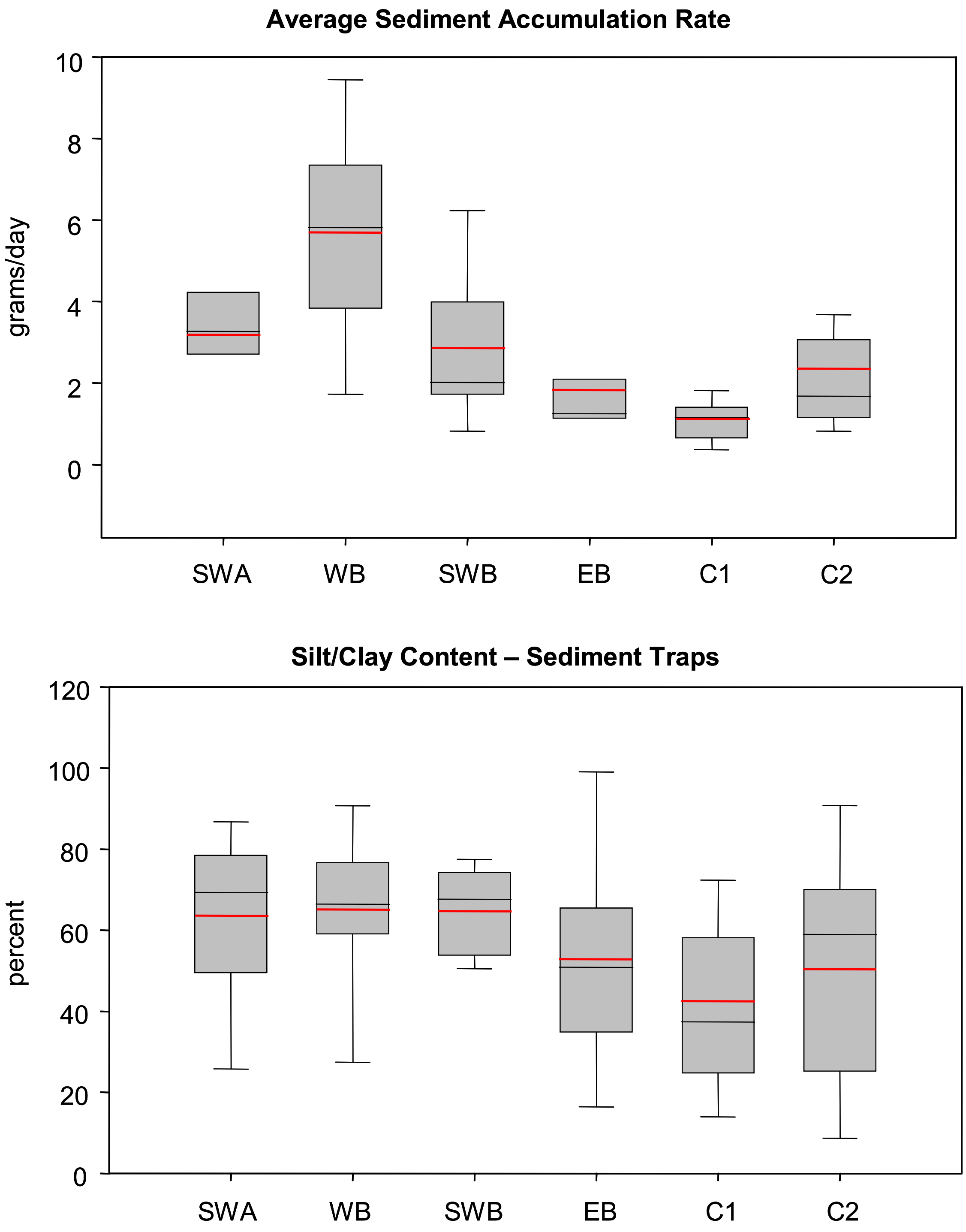


Figure 3.7. Summary of sediment accumulation rate and the percent silt/clay in sediment traps. Fall 2001 sedimentation rates were excluded from averages because of long deployment times where rates are likely inaccurate (see text). The boxes show the 25th and 75th percentiles and the error bars show the 10th and 90th percentiles. Red lines represent mean values. Sites are listed along the x-axis with increasing distance from the disposal site. Data represent all study years combined.

At site SWB, silt/clay was the dominant trap component in all sampling periods, while sites WB, SWA, and EB showed silt/clay dominance in most sampling periods, and the reference areas, C1 and C2 were quite variable over the five year period (Figure 3.7). In all cases, sand was the dominant trap constituent when silt/clay was not.

In most cases, sediment accumulation rates in the traps were consistently highest at the inshore sites. This could be a result of the proximity of these areas to the disposal area and/or the deposition of fine-grained materials entering the nearshore system as a result of tidal flow from Charleston Harbor. A study of the isotopic signature of sediments collected in traps and cores at each reef site was conducted in spring and fall 2004 (see Chapter 4 for details) to better understand the relative contribution of these two sediment sources. Study results suggest that additional sediment sources such as dredged material disposal or density driven plumes are not increasing sediment deposition at reef study sites or reference areas.

Video Survey Data

Finfish Surveys

Fishes observed included serranids (black and bank sea bass), sparids (scup, sheepshead), labrids (slippery dick), and haemulids (tomtate). Although we observed seasonal differences at some of the sites, there were no consistent seasonal trends. Consequently data was examined by study year to simplify analysis. The maximum mean abundance of fishes (82 fish/transect) was observed at site EB in fall 2003 (year 4; horizontal survey), and the minimum mean abundance (0 fish/transect) was observed at site C2 in the fall 2004 (year 5) during both horizontal and vertical surveys (Figure 3.8). The mean number of families collected per sampling period ranged from 0 to 4 families per transect (Figure 3.9).

Site EB had the overall highest mean abundance of fish on vertical surveys in year four of the study (Figure 3.8A). All sites were quite variable throughout the study period, although reference area C2 consistently had low mean abundances. Vertical surveys (with the camera held perpendicular to the seafloor) often resulted in lower overall abundances because they captured more individual bottom dwelling fish as opposed to schools of fish in the water column. Significant differences were observed in the mean abundance of fish on vertical surveys among sites within sampling periods. Study site EB had significantly higher abundances than reference area C2 during all sampling periods ($p = 0.008$). There were no significant differences between the reference areas, C1 and C2. There was no noticeable decline in abundances during vertical surveys between earlier sampling seasons and later sampling seasons at any of the study sites.

Overall, higher abundances were recorded during horizontal surveys than vertical surveys (Figure 3.8 A, B). Reference area C1 had the highest recorded abundances during horizontal surveys, followed by sites EB and WB. SWB and C2 consistently had the lowest abundances, although all sites were quite variable throughout the study period. Significant differences were observed in the mean abundance of fish on horizontal surveys among sites within sampling periods. Reference area C1 had significantly higher abundances than study site SWB and reference area C2 during all sampling periods ($p = <0.001$). Although there were minor seasonal differences noted during the horizontal surveys at some study sites, finfish abundances were not substantially reduced during the course of the study.

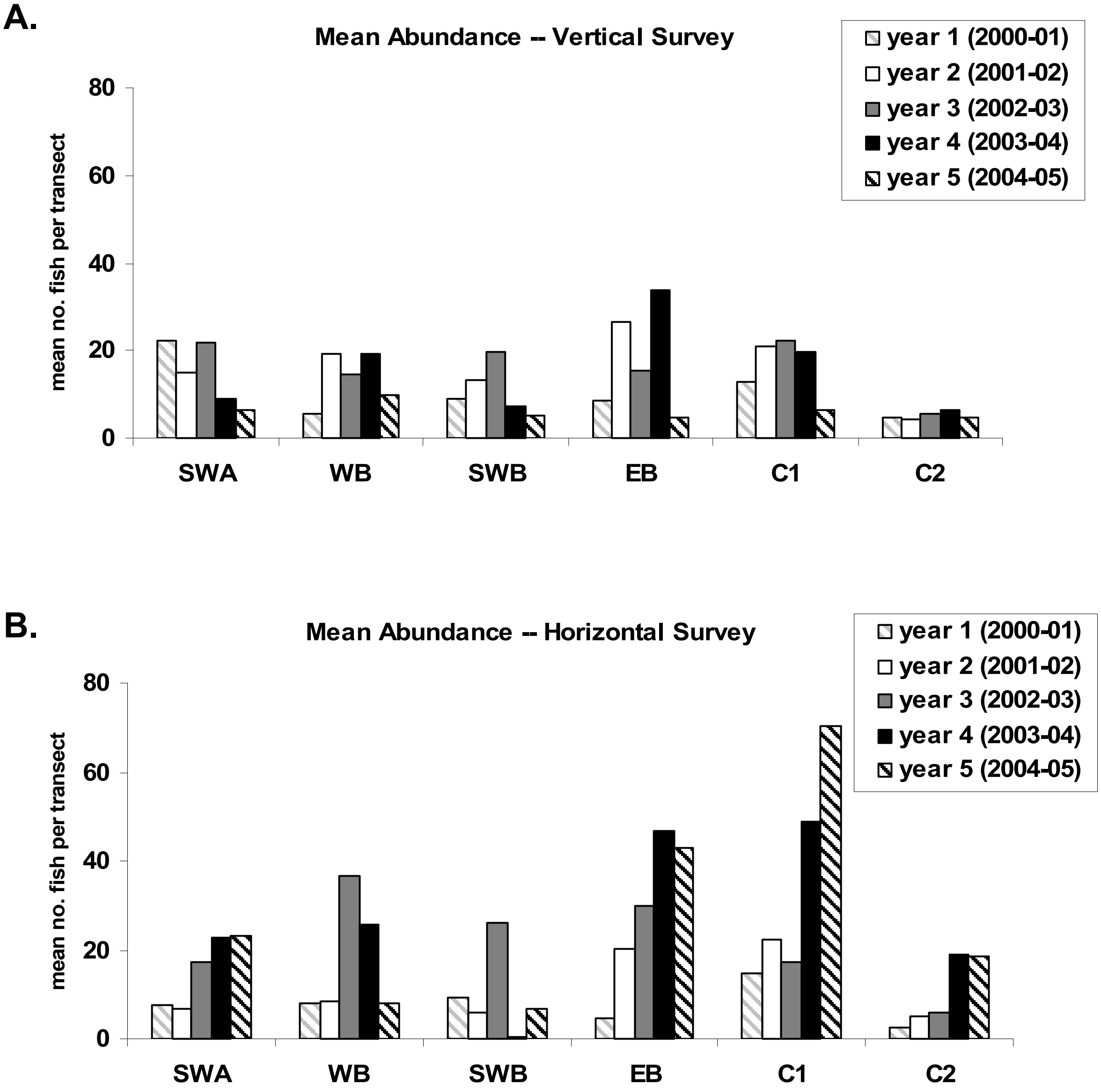


Figure 3.8. A. Mean abundance of fish observed per study year during vertical surveys. B. Mean abundance of fish observed per study year during horizontal surveys. Sites are listed on the x-axis with increasing distance from the ODMDS.

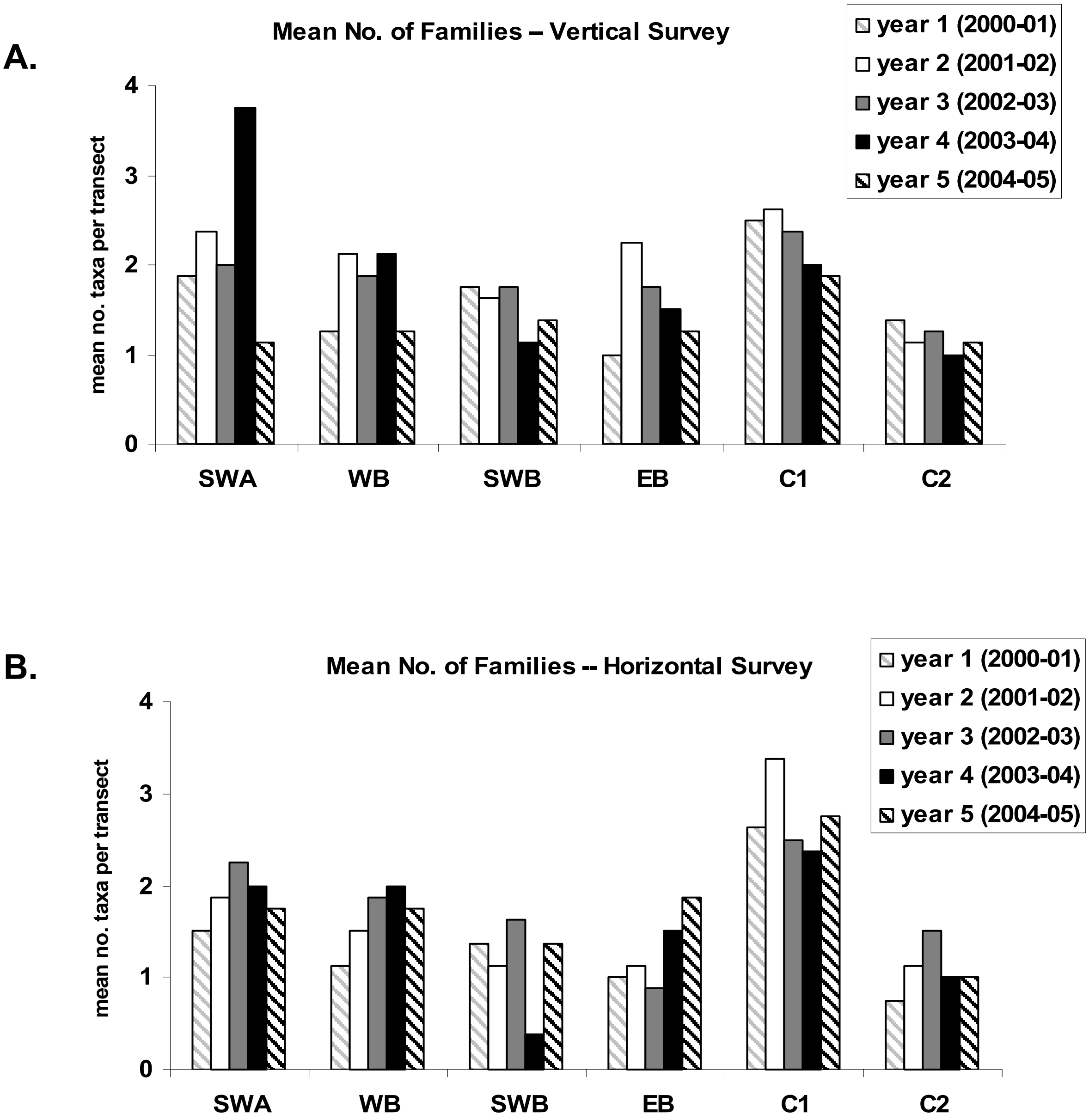


Figure 3.9. A. Mean number of fish families observed per study year during vertical surveys. B. Mean number of fish families observed per study year during horizontal surveys. Sites are listed on the x-axis with increasing distance from the ODMDS.

At reference area C1 and site SWA the mean number of fish families observed during vertical surveys was generally higher than all other study sites (Figure 3.9A). The lowest mean abundances were observed at C2. No significant differences were observed among the vertical surveys at sites SWA, SWB, and WB, or at reference area C1. Within all sampling periods, significantly more finfish families were observed at C1 and SWA than at the reference area C2 ($p = 0.002$). C1 also had a significantly higher number of taxa than EB ($p = <0.05$). The only seasonal differences observed were at C2 and EB (not shown), where some of the earlier sampling seasons had significantly more finfish families than later sampling periods, although the intermediate seasons were quite variable. Among the horizontal surveys, C1 consistently had the highest values during the study period. The lowest mean number of fish families observed was usually at the reference area C2, the furthest site from the disposal area. During all sampling periods, significantly more families were observed at the reference area C1 than all other study sites ($p < 0.001$). Also, significantly more finfish families were observed at SWA than the reference area C2 ($p < 0.001$). There were no significant seasonal differences observed at any site, with the exception of WB, where there were more finfish taxa observed during the spring 2005 sampling period than in fall 2000.

Overall, our findings do not indicate that reef fishes have been negatively affected by disposal activities at the disposal site. The number of individual fish as well as the number of species observed at hard bottom reef sites may be affected by a number of factors such as fishing pressure and hydrographic parameters (Sedberry *et al*. 1998). A study by Sedberry and Van Dolah (1984) examining fish assemblages in the South Atlantic Bight found that fish were more abundant on midshelf reefs (23-38m) than inshore reefs (16-22m) during the warmer months, and attributed this to more stable hydrographic conditions. It is probable that the variation in observed finfish abundance within or between study sites and sampling periods during the five year study period is due to natural fluctuations in conditions such as water temperature or salinity, or the effects of fishing pressure among sites, which have not been documented. There was no trend in declining fish stocks over the five year period that might reflect adverse effects from the disposal area. However, the monitoring technique used in this study has many limitations that may skew results, including low visibility, schools of fish which swim back and forth in front of the surveyor's camera, and possible disturbance of fish by diver activity.

Invertebrate Surveys

The percent of intervals per year with hard bottom reef, *Titanideum*, *Leptogorgia*, massive sponges, and encrusting sponges for each site and study year are presented in Figures 3.10 through 3.12. These taxa were the dominant erect growth forms in the study areas. The abundance of these taxa and the presence/absence of hard bottom habitat were also analyzed by study year since no clear seasonal trends were evident.

The mean percentage of intervals where hard bottom was present over all sampling dates was highest at the SWA (79%) and SWB (75%) sites, followed by EB (68%) and WB (61%) sites (Figure 3.10). The reference areas had the lowest percentages of intervals with hard bottom reef habitat (C1=53%, C2=40%).

At the reference area C1, and study sites SWA, SWB, and WB, there were no significant differences in the percent of intervals with hard bottom observed within the site among study years. Significant differences in the percentage of intervals with hard bottom habitat were observed at C2 and EB (Figure 3.10). At C2, there was a significant decline in the percentage of intervals with hard bottom reef observed from study year 3 through study year 5 ($p < 0.05$). There were also significantly more intervals with hard bottom in year 3 than in year 2 ($p < 0.05$). Site EB exhibited significantly lower reef coverage in year 4 than in year 2 of the study ($p < 0.05$). Overall, all sites show a general trend of decreasing percentages of hard bottom habitat over the entire study period. There is a similar or greater amount of decline in hard bottom habitats at the reference areas when compared the study sites which indicates that degradation of hard bottom habitat is not necessarily occurring due to disposal material migrating from the ODMDS. This assumes that the reference sites are beyond the realm of influence from the ODMDS, which we believe is a reasonable assumption based on other study components.

Overall, the presence of the soft coral *Titanideum* varied substantially throughout the study period (Figure 3.11). At sites C1, C2, SWB, and EB, there were significantly more intervals with *Titanideum* present in year 1 of the study than year 3 ($p < 0.05$). However, during the sampling periods in year 3, we noticed that some of the transect lines were possibly damaging soft coral specimens in the study areas when being washed about by storm activity. There were no significant differences in the percent of intervals of *Titanideum* at sites WB and SWA during the study period.

The presence of the soft coral *Leptogorgia* was also quite variable. At sites SWB, WB, and EB, the percentage of intervals with *Leptogorgia* was significantly higher in year 4 than most of the earlier study years ($p < 0.05$). Site WB had the highest average percentage of intervals with *Leptogorgia* throughout the entire study period. There were no significant changes in the percentage of intervals with *Leptogorgia* at C1, C2, or SWA, the closest site to the disposal area, throughout the study period.

Sponges, both massive and encrusting, were generally much less abundant along survey transects than soft corals (Figure 3.12). Sponge populations were quite variable at all sites during the study period. At SWA, the site with the highest overall abundance of massive sponges, there were a significantly higher number of intervals with massive sponges in year 2 than year 3. It is likely that sponges at this site disappeared as a result of predation or damage from a transect line due to storm activity, since sponges are long term growth forms and do not usually cease to exist abruptly. There was no significant change in the value of massive sponges at C1, C2, WB, EB, or SWB.

Encrusting sponge populations were generally similar to massive sponge populations at the study sites. However, at two sites, SWB and C2, no encrusting sponges were observed during some of the study years. The percentage of intervals with encrusting sponges was significantly higher in year 3 than all other study years at sites EB and C2 ($p < 0.05$). At sites WB and SWA, significantly fewer intervals with encrusting sponges were observed in year 5 and year 3, respectively, than year 3 ($p < 0.05$). No significant differences were observed with regard to encrusting sponges at reference area C1 or SWB. Overall, there was no clear trend within any of the study sites to indicate that the percentage of intervals with massive or encrusting sponges was decreasing over the course of the study period due to disposal activities.

Over the five years of sampling conducted, some general trends in the presence/absence of sessile invertebrates have been observed. The sites located near the disposal area do not appear to have lost significant overall reef habitat, particular species of soft corals, or sponge morphotypes. In many cases, the percent of reef habitat is greater at sites near the disposal area than at reference areas; these differences appear to represent dissimilarities in abundance and composition of invertebrates among sites that have existed throughout the study and are not likely related to disposal activities.

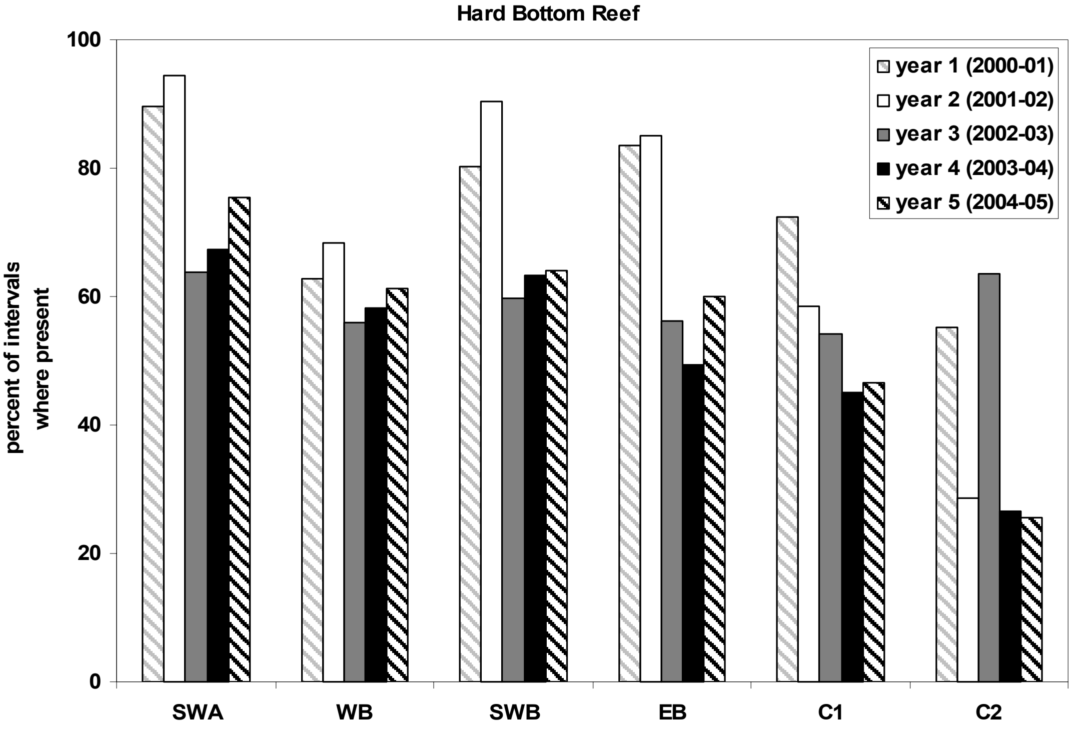
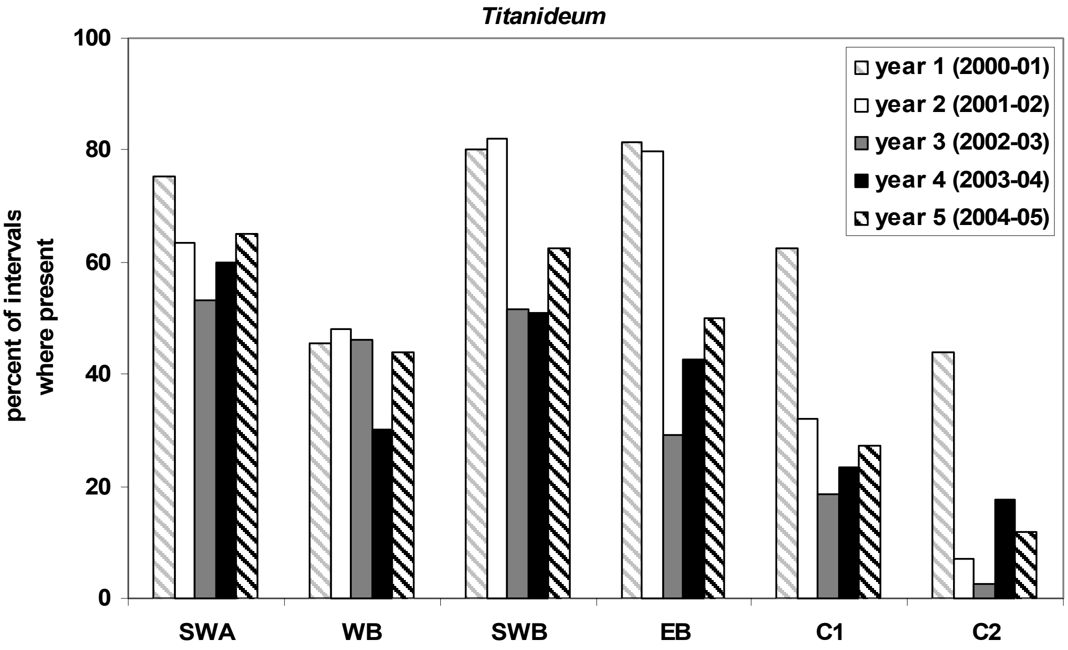


Figure 3.10. Average percent of 10 second video intervals with hard bottom reef present per study year. Sites are listed on x-axis with increasing distance from the disposal site.



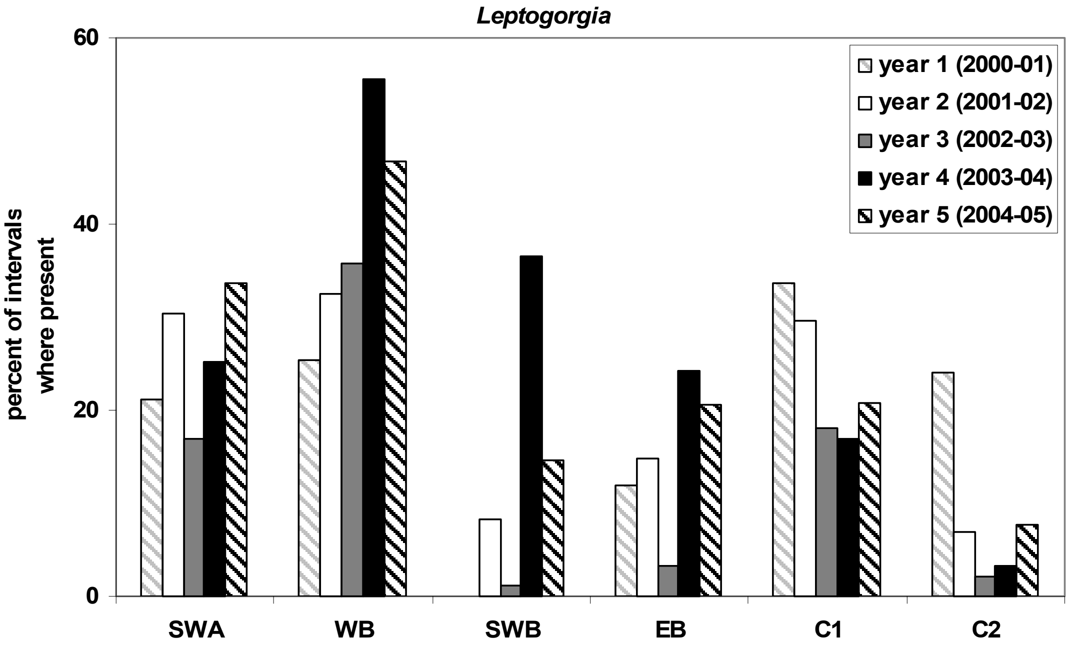
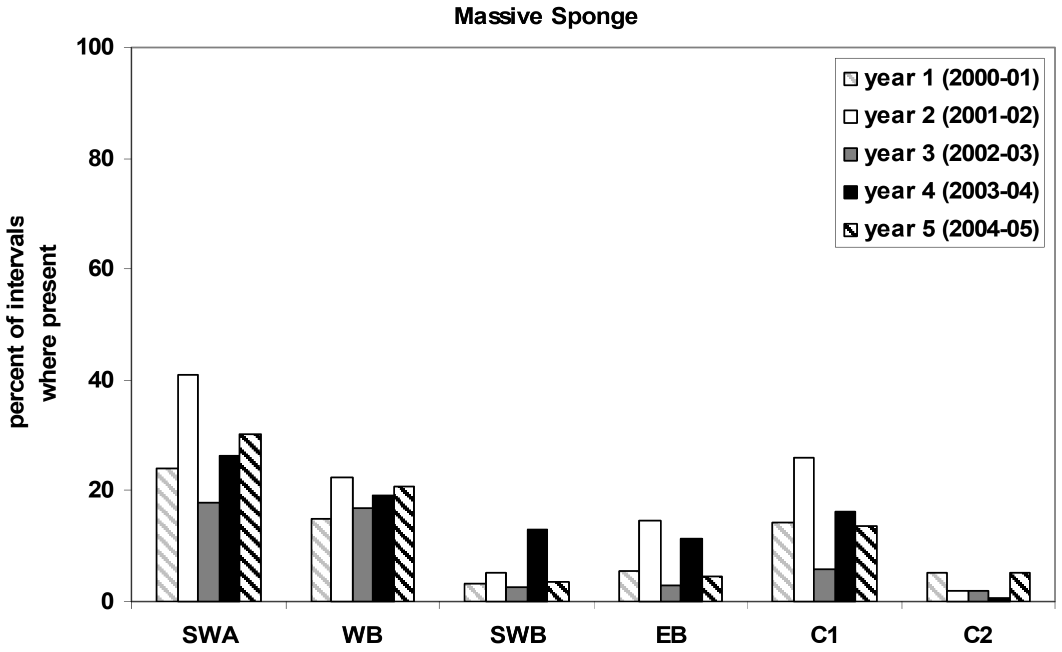


Figure 3.11. Average percent of 10 second video intervals with *Titanideum* and *Leptogorgia* present per study year. Sites are listed on x-axis with increasing distance from the disposal site.



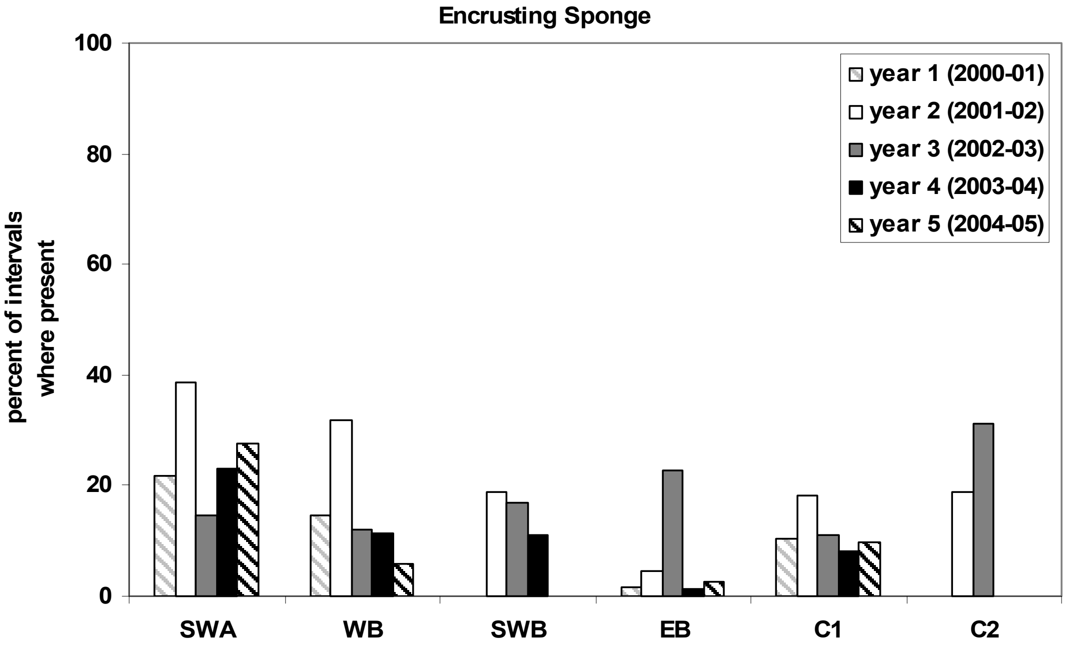


Figure 3.12. Average percent of 10 second video intervals with massive and encrusting sponges present per study year**.** Sites are listed on x-axis with increasing distance from the disposal site.

CHAPTER 4:

Utilizing Gamma Isotope Tracers to Determine Sediment Source at Reef Sites Near the Charleston ODMDS (Phase II)

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During the fourth and fifth year of the Hard Bottom Reef study, an analysis of the isotopic signature of sediments collected from the bottom and from the sediment traps at each reef site was conducted. Additional samples were also collected using a bottom grab in Charleston Harbor and various tributaries. The goal of this study component was to determine the relative contribution of disposal materials from the Charleston ODMDS versus tidally transported sediment from Charleston Harbor.

4.1 INTRODUCTION

A companion monitoring program was initiated by the SCDNR in 2000 to study possible impacts to natural hard bottom reef communities in the vicinity of the Charleston ODMDS. Six hard bottom reef sites surrounding the Charleston ODMDS (Figure 4.1) were established, and have been assessed during spring and fall field seasons to document changes in sedimentation rates, condition of biological communities, and areal extent of hard bottom reef habitats.

Higher sedimentation rates have been documented at the inshore reef sites, which may be due to their proximity to the ODMDS (Jutte *et al*. 2003). However, another potential source of sedimentation at the inshore reef sites is density driven or tidal transport of estuarine sediments. An analysis of the isotopic signature of sediments collected by divers and sediment traps at reef sites, in addition to samples collected by a vessel-deployed sediment-grab sampler in Charleston Harbor and various tributaries was conducted as part of Year 4 and 5 monitoring efforts of the hard bottom reef communities in the vicinity of the Charleston ODMDS. The goal of this study was to determine the relative contribution of disposal materials from the Charleston ODMDS versus tidally transported or density driven sediment from Charleston Harbor.

Coastal marine sediments have many commonly found isotopes associated with them, as well as occurrences of rarer isotopes such as beryllium-7 (^{7}Be) and cesium-137 (^{137}Cs; IAEA, 2000). The isotopic signature of sediments has been successfully used by the Center for Applied Isotope Studies (CAIS) at The University of Georgia, to trace the placement and subsequent migration of dredged material placed at the Charleston ODMDS (Noakes 2003). Evaluating isotopic signatures to identify the relative contribution of sediments deposited at natural reef sites is a novel use of this technique and could prove to be an important tool in future assessments.

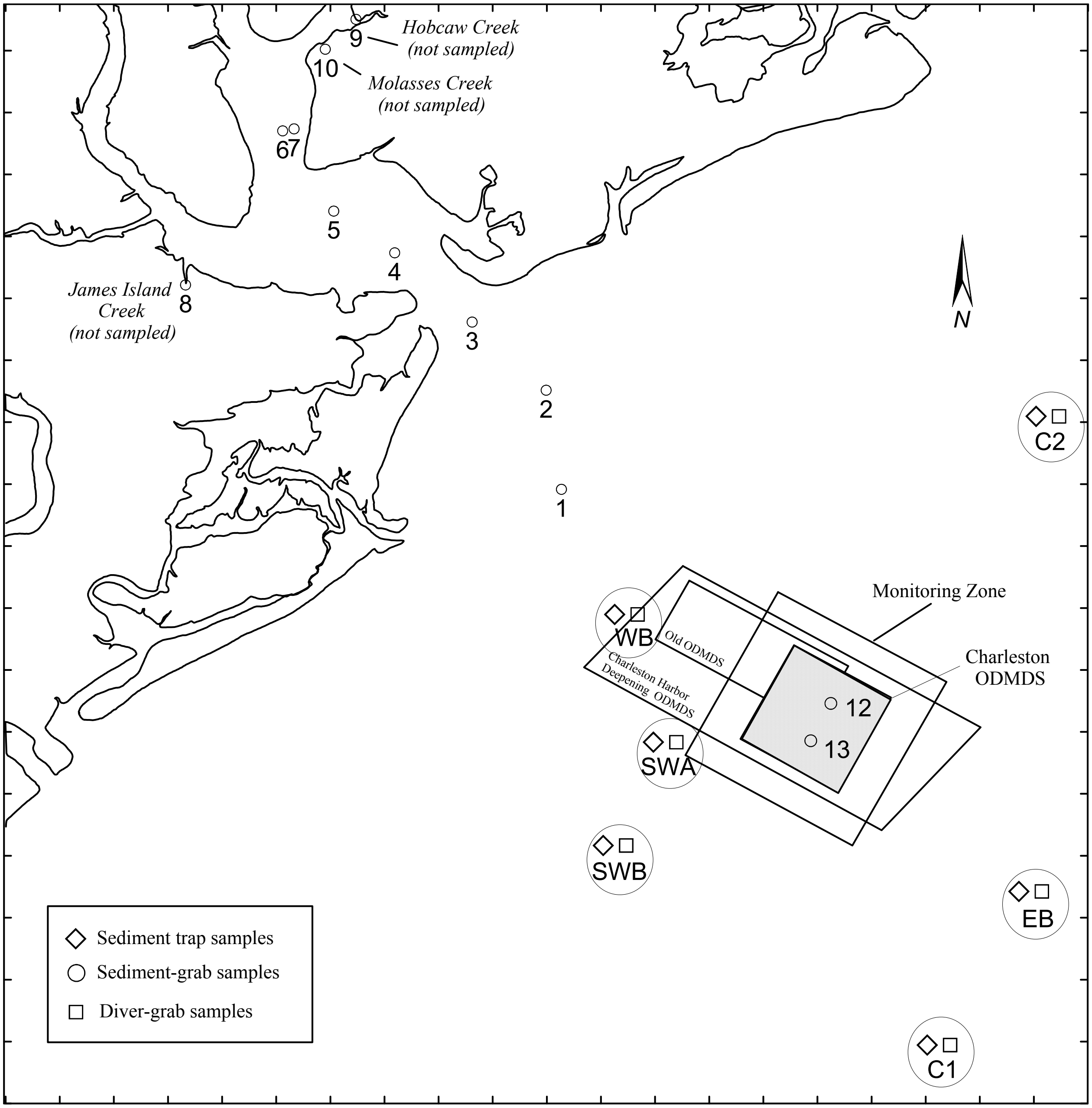

Figure 4.1. Charleston ODMDS, sediment sampling stations, and hard bottom reef monitoring stations (WB, SWA, SWB, EB, C1, and C2).

Several isotopes were evaluated in the current study. The occurrence of ^{137}Cs is directly related to the atomic bomb testing era when this isotope was distributed throughout the world by atmospheric fallout. As a result of the cessation of atomic bomb testing, there is very little ^{137}Cs present in the atmosphere today. ^{7}Be has a cosmogenic origin and is uniquely associated with atmospheric fallout. What makes ^{7}Be a particularly good tracer is that it has a relatively short half-life of only 53 days. Therefore, ^{7}Be tends to disappear quickly from the marine sediment if there is not a constant source. The presence of ^{7}Be and ^{137}Cs isotopes in the marine environment would be expected at low levels, with higher levels typically found in estuarine sediments due to erosion of terrestrial sediments. When estuarine sediments are dredged and placed in offshore disposal areas, ^{137}Cs would be expected to persist, but due to its short half-life, very little ^{7}Be would be present for extended periods of time.

In addition to ^{7}Be and ^{137}Cs, uranium (^{238}U), thorium (^{232}Th), and potassium (^{40}K) were also analyzed as part of this study. These isotopes are considered pathfinder isotopes and are generally indicative of the nature of the seafloor (Jones *et al.* 1988). ^{238}U reflects the uranium content of phosphatic deposits often found in the coastal regions, ^{232}Th is associated with heavy mineral deposits, and ^{40}K is often found in fine-grained clay sediments.

For this study, sediment samples were collected in the Charleston Harbor and along a transect leading towards the ODMDS. Additionally, two samples were collected within the ODMDS for a representative sample of dredged material deposited at the site. The primary purpose of the samples collected during this study was to measure the gamma activity of various isotopes (1) in estuarine sediments, (2) in areas where tidal deposition was expected, and (3) at the hard bottom reef sites in the vicinity of the ODMDS. The isotopic signature of sediments at the hard bottom reef sites in the vicinity of the ODMDS could then be used to identify the contribution of tidal and density driven transport to the sediment budget at these sites.

4.2 METHODS

A total of nine sediment-grab samples were collected in November 2004 from Charleston Harbor; the Cooper River; several near shore sites along a transect leading towards the disposal area; and the ODMDS (Figure 4.1). These samples were collected using a stainless steel sediment-grab sampler deployed from a surface vessel. Only the surficial sediment (~2 cm) was removed from the sampler to best represent recent deposition. Diver collected sediment-core samples were also collected in November 2004 from the surficial sediment at each of the six hard bottom reef monitoring stations (Figure 3.1). These sediment samples were dried according to standard operating procedures, and submitted for gamma analyses. Additionally, replicate sediment traps were deployed at the six hard bottom reef monitoring stations to collect a representative sediment sample from material settling on each monitoring site. Upon collection, SCDNR analyzed the trap sediments for composition and total dry weight and then shipped the samples to CAIS for gamma analysis.

The sediment samples (sediment-grab, diver-grab, and sediment-trap) were analyzed in the CAIS laboratory using a High Purity Germanium (HPGe) gamma radiation detector and pulse height-analyzer. Once dried, the sample was packed into a tared 0.5-L Marinelli beaker and weighed. Preliminary gamma analysis was completed on all the samples immediately after drying to obtain results for ^{7}Be, which has a relatively short half-life of only 53 days. The samples were then reanalyzed approximately two weeks later to obtain results for the ^{238}U, ^{232}Th, and ^{40}K which require a holding time for the ingrowth of the gamma-emitting U and Th daughter products. The sample was placed in an HPGe radiation detector for a counting time of 12,000 s. In addition to ^{7}Be and ^{137}Cs, the results for ^{238}U, ^{232}Th, and ^{40}K were recorded and converted to picocuries per kilogram (pCi/kg).

4.3 RESULTS

The results for the gamma analyses were plotted in bar graph format to aid comparison of the data. The U, Th, and K ratios for all the samples were very similar, which make it difficult to use these isotopes as definitive indicators for sediment transport. In addition to U, Th, and K isotopes, ^{7}Be and ^{137}Cs were also plotted on the graphs. To achieve a better concept of the distribution of both ^{7}Be and ^{137}Cs in the Charleston study area, the isotopes were plotted by stations in relation to relative activities (Figures 4.2 and 4.3). The data from these gamma analyses is presented in Table 4.1.

No samples were collected in the small tributaries associated with the Cooper River during the fall sampling. However, the tributary samples collected in spring 2004 all demonstrated a strong presence of both ^{7}Be and ^{137}Cs (Noakes 2004). These sediments were primarily from recently deposited terrestrial sediment eroded from the surrounding marshes.

Sediment samples were collected along a transect from the entrance channel inward to the Cooper River (Figure 4.1). All of the sediment-grab samples collected in the entrance channel, harbor, and Cooper River had nearly identical ^{40}K activity (Figure 4.4). However, the ^{238}U and ^{232}Th activities varied according to the amount of phosphatic and mineral sands present in the sample. Sample 1, located furthest out in the entrance channel, had the highest concentration of sand versus clay. The ^{238}U and ^{232}Th activity decreased into the harbor until Sample 4 where the ^{238}U activity increased considerably indicating a potential phosphatic deposit which is commonly found in the Charleston area. Samples 6 and 7 were located in the Cooper River near the most recent dredging activities and were very similar in gamma activity to the ODMDS samples (12 and 13). It should be noted that Samples 6 and 7 were located immediately east of the Cooper River channel and not exactly where the dredging was occurring.

The ^{7}Be activity in the sediment-grab samples identified an area of mostly fine-grained sediment near the mouth of the harbor. No ^{7}Be or ^{137}Cs were detected in Sample 1 (nearshore) indicating that terrestrial sediment either was not transported or at least was not deposited that far from the mouth of the harbor (Figures 4.2 and 4.3). Absence of ^{7}Be or ^{137}Cs does not rule out the possibility that fine-grained sediment containing either isotope could remain suspended in the water column and be deposited further offshore. Detectable levels of ^{7}Be were shown starting at Sample 2 with ^{7}Be gamma activity increasing considerably in Samples 3 and 4. Samples 3 and 4 were located at the harbor

Table 4.1. HPGe Gamma analyses on collected sediment.

Sediment-grab Samples

Station	Isotope (pCi/kg)				
	^{238}U	^{232}Th	^{40}K	^{7}Be	^{137}Cs
1	2623	2564	7084		
2	1035	536	6216	29	
3	632	238	6430	237	14
4	2884	311	6538	154	
5	712	440	7398		
6	2747	731	7171	25	
7	1949	497	6815	105	
12	1861	322	6971		16
13	1361	337	7610		48

Sediment-trap Samples

Station	Isotope (pCi/kg)				
	^{238}U	^{232}Th	^{40}K	^{7}Be	^{137}Cs
SWA	1221	384	9285	1561	42
SWB	1305	328	8799	2166	
C1	409	319	11280	3476	
C2	668	243	11600	3153	30
EB	369	185	11110	4034	25
WB	746	417	9596	1854	23

Diver-collected Samples

Station	Isotope (pCi/kg)				
	^{238}U	^{232}Th	^{40}K	^{7}Be	^{137}Cs
SWA	640	1916	4259		
SWB	388	167	4714		
C1	372	218	5254		
C2	362	166	3677		
EB	444	306	5541		
WB	322	112	3646	21	

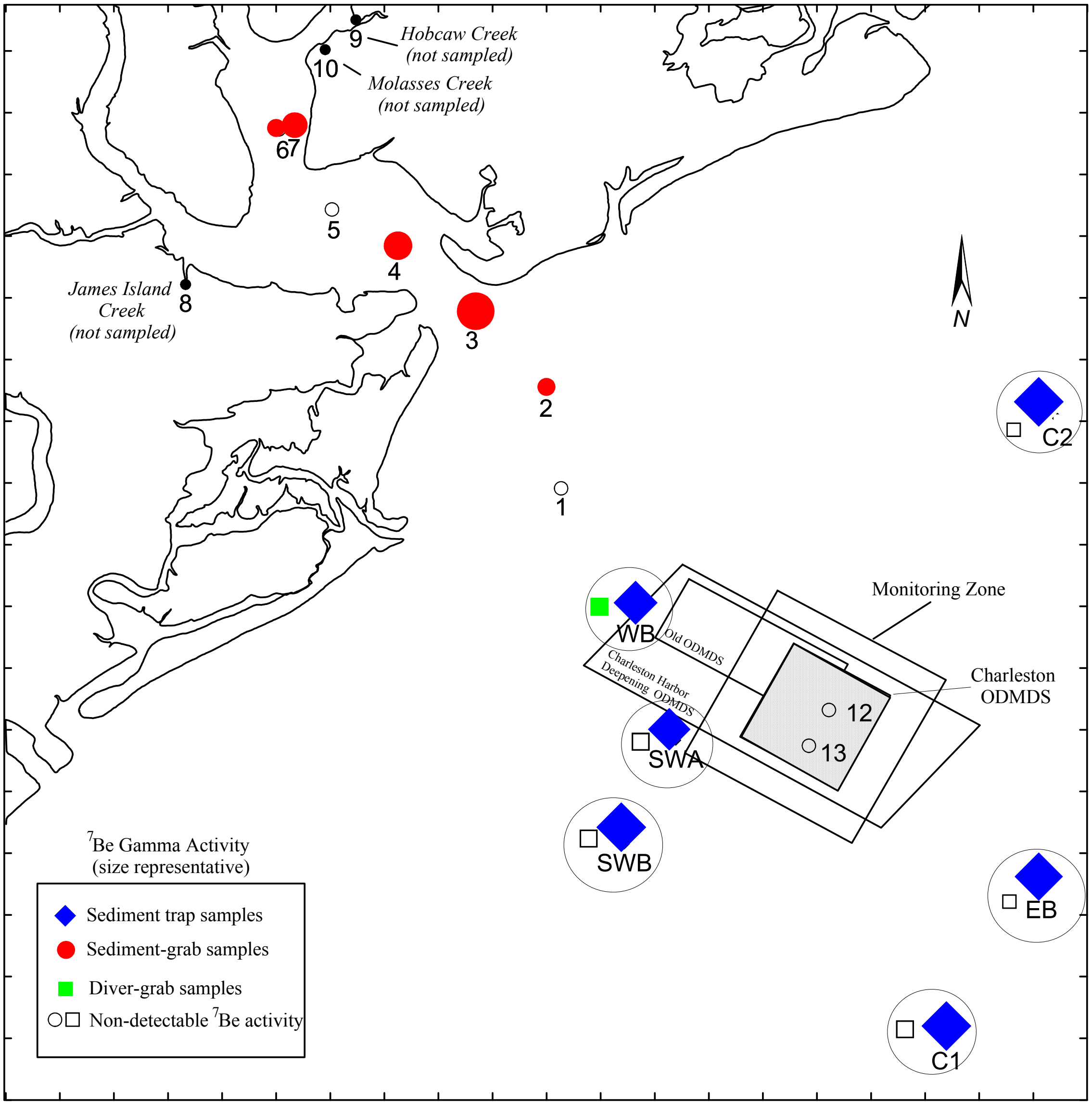

Figure 4.2. ^{7}Be gamma activity (size representative).

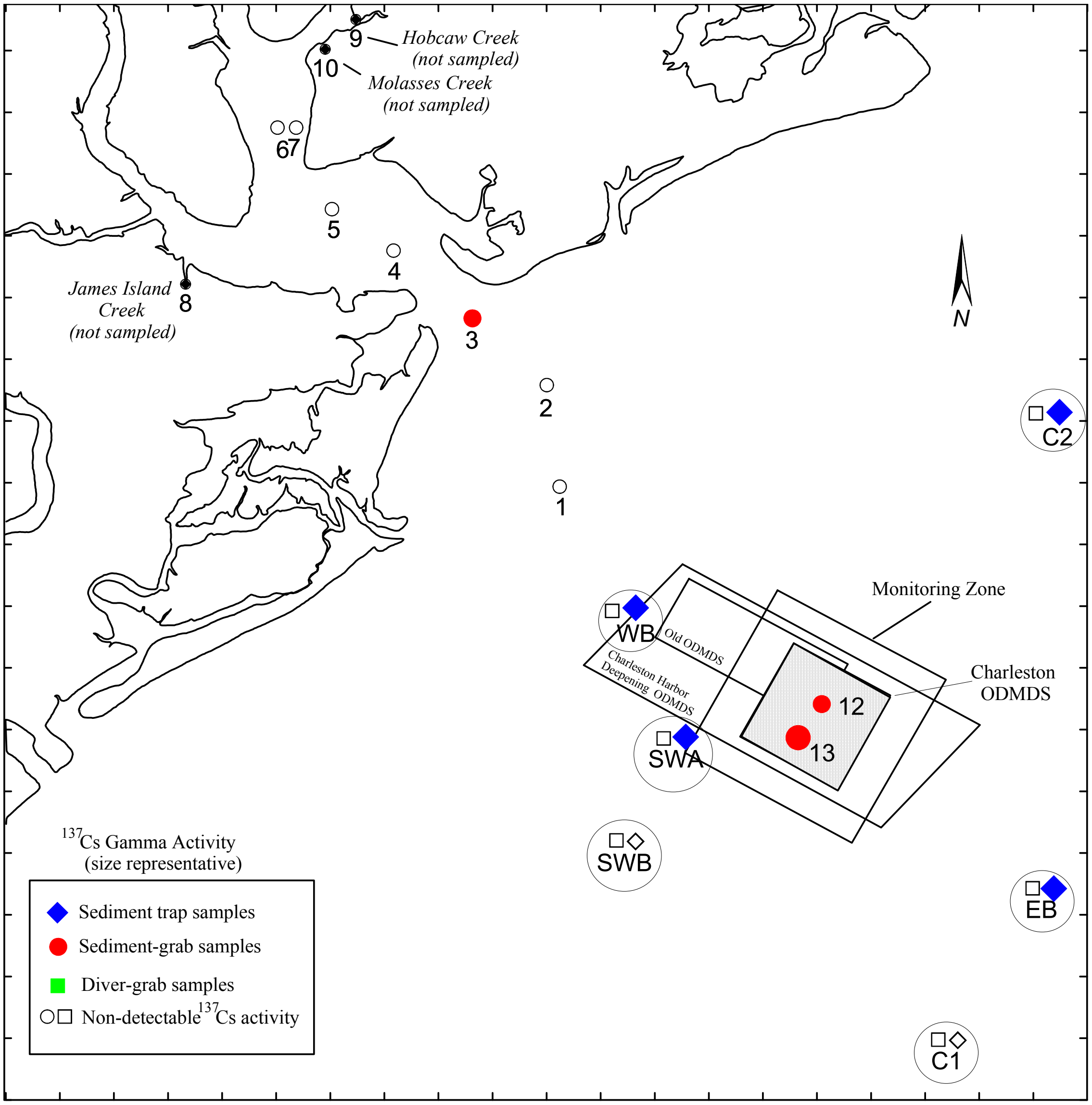

Figure 4.3. ^{137}Cs gamma activity (size representative).

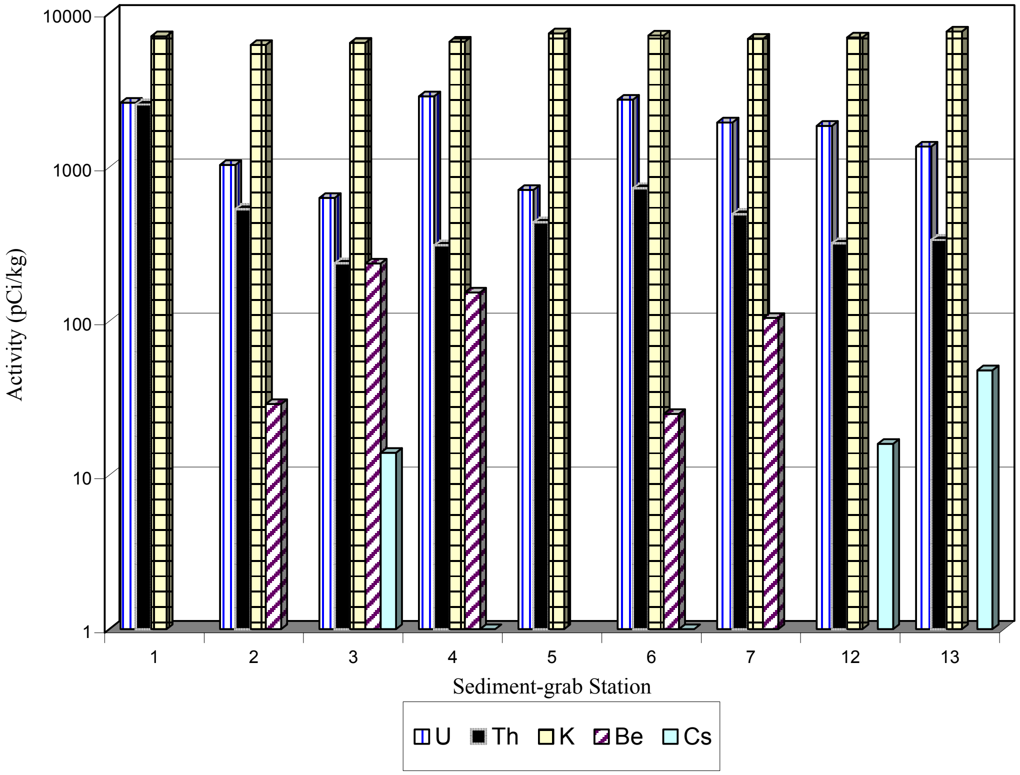

Figure 4.4. Sediment-grab stations in Charleston Harbor, Cooper River and ODMDS.

entrance and immediately inside the harbor, clearly indicating a major depositional zone. Similar to the spring 2004 sampling, no ^{7}Be was detected in Sample 5 which was located in the inner harbor area. Samples 6 and 7, located immediately east of the Cooper River channel, did have detectable levels of ^{7}Be. Sample 3, located in the mouth of the harbor, was the only channel/harbor sample that had ^{137}Cs present. The remainder of the samples, located in the entrance channel, inside the harbor, and Cooper River, did not indicate any ^{137}Cs. As expected, ^{238}U, ^{232}Th, and ^{40}K activities were similar across all sampling stations.

Two additional sediment-grab samples (12 and 13) were collected in recently deposited dredged material within the Charleston ODMDS. At the time of sample collection, dredging was actively taking place near the Highway 17 Bridge which spans the Cooper River. Samples 12 and 13 had similar gamma signatures to Samples 6 and 7 (Cooper River). Both of these samples had ^{137}Cs present, but not ^{7}Be. The absence of the ^{7}Be in the dredged material samples can be explained by the depth below surface that the sediments were being dredged. ^{7}Be would be expected in the surficial sediments, but not in the deeper dredged sediments. ^{137}Cs activity would be expected in sediments dating back to the 1950s when atomic bomb testing spread airborne particulate matter worldwide.

The gamma activity levels for the sediment-trap samples were all very similar (Figure 4.5). All of the sediment-trap samples also had considerable ^{7}Be activity present. Elevated ^{7}Be in the traps would be expected primarily due to the preferential sampling of fine-grained sediment by the traps. ^{7}Be is associated with the fine-grained clay particles and organic matter in the water column. As this particulate matter settles to the seafloor, the sediment traps collect the particles and prevents them from leaving the trap. The fine-grained particulate matter that reaches the seafloor is continuously resuspended into the water column, some of which is collected by the sediment traps. This process works the seafloor over and over again effectively keeping the fine-grained sediment from accumulating on the seafloor. However, when an unusually high volume of fine-grained sediment is introduced into the water column as would be the case from dredged material disposal or rain events, sufficient fine-grained sediment can reach the seafloor and remain until the winnowing process eventually transports the sediment away.

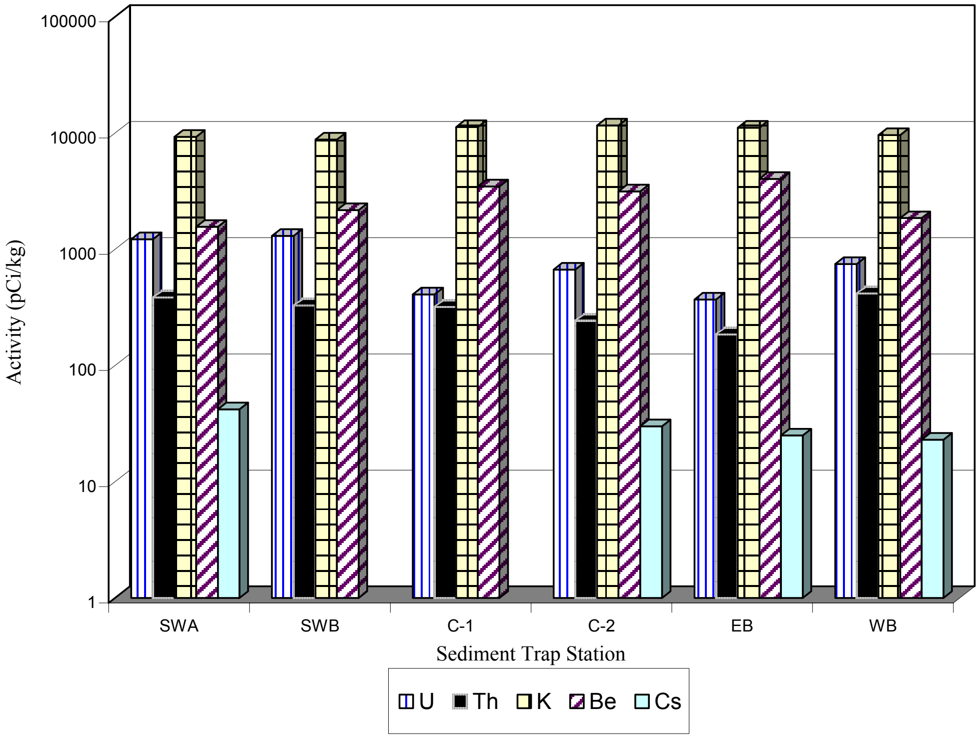

Figure 4.5. Sediment-trap stations at the Charleston ODMDS.

Four of the six sediment-trap samples had detectable ^{137}Cs: WB, SWA, C2, and EB (Figure 4.5). However, none of the diver-grab samples (Figure 4.6) had any detectable ^{137}Cs present indicating resuspension and winnowing as discussed in relation to the ^{7}Be. The two sediment grab samples collected in the recently deposited dredged material did have ^{137}Cs present (Samples 12 and 13). Since the dredged material was deposited in greater volume to the ODMDS seafloor than the particulate matter collected in the reef sediment traps, it was expected to find ^{137}Cs in the fine-grained bottom sediment. It was also anticipated that ^{137}Cs would be detected in sediment-trap samples for both WB (potentially affected by the sediment plume from the harbor) and SWA (located near the ODMDS). However, it was not expected that ^{137}Cs would be detected in either C2 (considered a control site) or EB (furthest offshore). Since ^{137}Cs is no longer present in atmospheric fallout, any ^{137}Cs detected offshore would have originated from eroded terrestrial sediment and transported either by tidal action, density driven transport or dredged material deposition. Levels of U, Th and K were similar across all diver-grab samples collected at the hard bottom reef sites (Figure 4.6), and were similar to levels observed in sediment grab samples.

WB, which was one of the six diver-grab samples, did have detectable ^{7}Be present (Figure 4.6). This station was the closest reef monitoring station to the coast and within reach of the sediment plume from the harbor (Figure 4.7). Since several of the other reef monitoring stations were closer to the ODMDS and did not have any ^{7}Be present, the ^{7}Be at WB may have been transported from the harbor through natural processes. In addition,

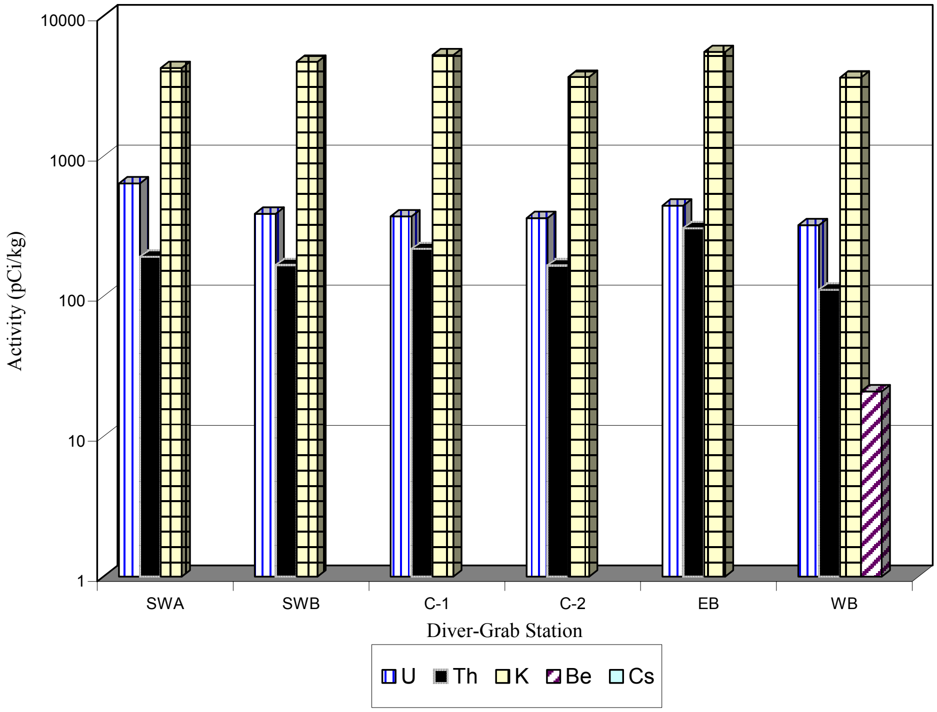

Figure 4.6. Diver-grab sediment samples at the Charleston ODMDS.

Figure 4.7. Satellite view of Charleston including the ODMDS and sampling stations. *Image courtesy of Earth Sciences and Image Analysis Laboratory (NASA 2003).

no ^{7}Be was detected in the recent dredged material deposited at the ODMDS. Since ^{137}Cs was detected in recently deposited dredged material at the ODMDS, it would be expected to find ^{137}Cs at some of the monitoring stations. However, none of the diver-grab samples had any ^{137}Cs present. Therefore, if fine-grained sediment was dispersed as a result of dredge material disposal at the ODMDS, it would have been at levels small enough to have been winnowed by natural forces.

4.4 DISCUSSION

The original intention for the fall 2004 isotope tracer sampling was to repeat the spring 2004 results (Noakes 2004). In the spring, there was a very clear indication of recent terrestrial sediment deposition (as indicated by ^{7}Be) at the offshore reef monitoring stations. However, the fall results were somewhat different from that of the spring. In contrast to the spring results when ^{7}Be was detected at four of the reef monitoring stations (diver-grab samples) only one fall collected diver-grab sample had ^{7}Be present. In addition, only one sediment trap collected in the spring had detectable ^{137}Cs while four sediment traps (fall collected) had detectable ^{137}Cs present.

There were similarities between the spring and fall results in that WB, the reef monitoring station closest to the entrance channel, had both ^{7}Be and ^{137}Cs present. WB had detectable ^{7}Be in the diver-grab sample and ^{7}Be and ^{137}Cs in the sediment-trap sample. Satellite photos have shown in the past that WB has been within range of the harbor sediment plume during rainfall events (Figure 4.7). The presence of both ^{7}Be and ^{137}Cs at WB for the spring and fall samples along with the satellite photo gave a good indication that the harbor sediment plume had extended to this reef monitoring site.

The remainder of the reef monitoring sites had similar ^{7}Be in the sediment-trap samples from spring versus fall. Other than WB, no reef monitoring sites had any detectable ^{7}Be present in the diver-grab samples. With similar ^{7}Be in the sediment-trap samples from spring versus fall and no additional accumulation on the seafloor, this would indicate that atmospheric ^{7}Be deposition rates were relatively constant and that additional sources such as dredged material disposal or density driven plumes were not adding significantly to the system to increase sediment deposition. The occurrence of ^{137}Cs at C2, EB, and SWA (fall sediment trap samples) indicate an increase of ^{137}Cs into the system. The additional ^{137}Cs that appeared at the reef monitoring site maybe from the dredged material deposited at the ODMDS. As discussed previously, the dredged material recently deposited at the ODMDS had detectable ^{137}Cs, but not ^{7}Be.

An additional factor that could create a difference in the spring versus fall sampling results was shown in the annual rainfall (NADP 2004; Figure 4.8). The precipitation plot clearly showed that considerably more rainfall was recorded in the fall as compared to the spring. The increased precipitation in the Charleston area was due to the unusually active hurricane season experienced during 2004 which produced several rain events during the fall. As a result of the increased precipitation, a greater volume of suspended sediment could be transported offshore by the river plume. However, the diver-grab samples did not reflect any ^{7}Be (other than at WB) which would indicate recent sediment deposition on the seafloor.

4.5 CONCLUSION

Analyses of the tributary and harbor sediments in the Charleston area have clearly shown that ^{7}Be and ^{137}Cs are associated with terrestrial sediment (Noakes 2004). The presence of ^{7}Be and ^{137}Cs in the offshore diver-grab and sediment-trap samples indicate that this sediment was also of terrestrial origin. The novel approach of utilizing ^{7}Be and

^{137}Cs as tracers in this study to identify the relative contribution of density driven sediment from the harbor versus disposal material migration suggests that some terrestrial sediment has been transported to a subset of the hard bottom reef monitoring stations through natural and anthropogenic processes.

As a result of this study, it would appear that the offshore reef monitoring sites have been affected by both density driven plumes as well as dredged material disposal. WB, as indicated by the spring and fall results and satellite photography, has been affected by the sediment plume from the Charleston Harbor. Indications are that the remaining reef monitoring sites may have been affected by the dredged material disposal. The presence of ^{137}Cs in the recently deposited dredged material at the ODMDS as well as several of the reef monitoring sediment trap samples would support the dredged material dispersion. However, with the absence of ^{137}Cs and ^{7}Be on the seafloor, it was clear that at the reef monitoring sites, most of the sediment settling from the water column was either resuspended or winnowed away and did not readily accumulate at the sites.

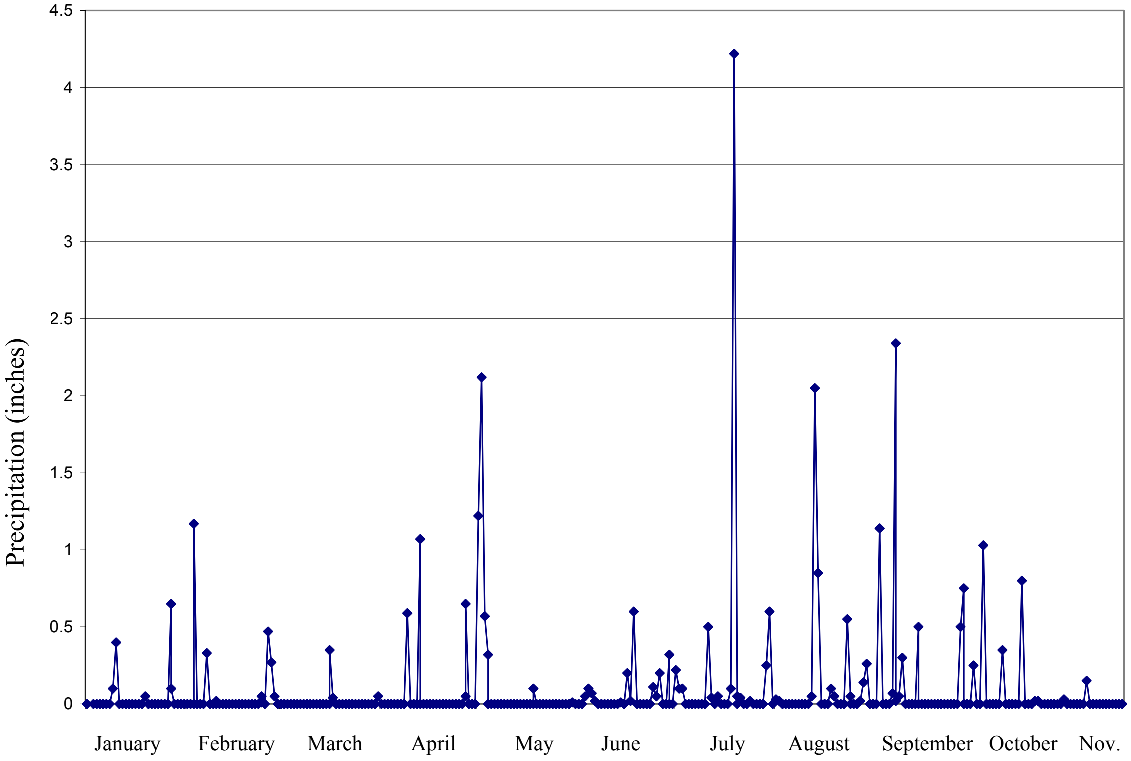

Figure 4.8. Charleston, South Carolina annual rainfall for 2004 (NADP 2004).

CHAPTER 5: SUMMARY

- The deepening of shipping channels throughout the Charleston Harbor was completed in April 2002 and placed an estimated 22 million cubic yards (mcy) of fine-grained sediments in the permitted disposal zone in the Charleston Ocean Dredged Material Disposal Site (ODMDS).
- The current report presents findings from detailed physical and biological assessments of the hard bottom reef habitats surrounding the ODMDS. There were several components of this project coordinated by the South Carolina Department of Natural Resources (SCDNR).

Large Scale Reef Assessment

- Four consecutive years of sidescan-sonar surveying (five years at site SWA) and five years of video data have been collected at the study sites. Net hard bottom change during the study period has been a small gain at all sites with the exception of SWA. With most net hard bottom changes being just a few percent, it is likely that sediment dumped at the ODMDS is not significantly changing the surrounding habitats.
- Comparisons between backscatter intensity, textural analysis, and coded video data suggest that a thin veneer of sand is sometimes capable of disguising hard bottom, especially since a much larger portion of each study area provided a hard bottom textural signature via sidescan sonar, which was not always supported by evidence of sessile invertebrate growth using the television sled.

Small Scale Reef Assessment

- Analyses of sand and $CaCO_3$ content found at the study sites and reference areas show that any changes observed within sites or between sampling periods are likely due to natural variability.
- In general, silt/clay was a minor component of sediment composition at all sites and any changes observed were probably attributable to seasonal rainfall or storm activity rather than significant movement of fine-grained material from the ODMDS.
- Changes observed in grain size of the sand fraction of sediment cores also do not appear to be related to movement of sediments from the disposal area.
- Surficial sediment depths/measurements at the sites in the vicinity of the disposal area have not been significantly altered, suggesting that migration of disposal area sediments has not been a major problem to date.
- Analyses of sediment trap contents suggest that there is a higher silt/clay load in the bottom waters near the ODMDS and at the inshore sites. These materials would not be expected to remain on the bottom when strong currents and storm events are present.
- The abundance of finfish individuals or species observed at study sites and reference areas does not appear to be affected by disposal activities during the five year survey period.

- The percent occurrence of selected sessile, erect growth forms at the sites studied also did not change significantly at most sites, and sites where significant changes did occur do not appear to be related to movement of disposal material.
- The presence of ^{7}Be and ^{137}Cs in the offshore diver-grab and sediment-trap samples indicate that this sediment was of terrestrial origin. The novel approach of utilizing ^{7}Be and ^{137}Cs as tracers in this study to identify the relative contribution of density driven sediment from the harbor versus disposal material migration suggests that some terrestrial sediment has been transported to a subset of the hard bottom reef monitoring stations through natural and anthropogenic processes.
- The presence of ^{137}Cs in the recently deposited dredged material at the ODMDS as well as several of the reef monitoring sediment trap samples would support the dredged material dispersion. However, with the absence of ^{137}Cs and ^{7}Be on the seafloor, it was clear that at the reef monitoring sites, most of the sediment settling from the water column was either resuspended or winnowed away and did not readily accumulate at the sites.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

In general, the hard bottom reef areas evaluated in this study showed no evidence of substantial degradation resulting from the possible movement of sediments from the Charleston ODMDS during the five year study period. There was no evidence of significant loss in the areal extent of hard bottom substrate at four sites located various distances from the ODMDS, the abundance of sessile biota and finfish at these sites were not severely altered, and sediments which did migrate from the ODMDS were not deposited in the reef areas in large enough quantities to detect a significant accumulation of sediment over the hard bottom.

While we didn't find substantial evidence of impacts to any of the above parameters, it should be noted that the inherent variability of the sites in this dynamic environment makes it difficult to detect subtle changes that may be occurring in the reef areas. The combination of video and side scan sonar surveys provide spatial characterization of changes in the extent and distribution of reef habitat over time, but confidence related to the presence or absence of sessile reef biota is relatively poor because these organisms don't provide good sonar signature returns. In contrast, the smaller scale diver observations at discrete locations provide information on the presence or absence of erect sessile fauna that should be representative of the rest of the reef and can be accurately reassessed over time, but this approach provides poor spatial evidence of changes in the overall reef habitat. The combination of the two approaches helps to overcome the limitations of each approach individually.

The geophysical analysis has provided a valuable approach to characterizing habitat and change of nearshore benthic environments. The aerial coverage also proved helpful in identifying dumping of dredged material outside the permitted disposal area. Throughout the project, additional video interpretation has become available that would be useful to update and refine the neural network discrimination algorithm for differentiating hard bottom for sand bottom habitats. Such an update should further increase the effectiveness and accuracy of identifying habitat and change for monitoring of the ODMDS site, potentially aid in eventual search for sites for expansion of the Charleston site and potentially others in the state.

In the vicinity of the ODMDS, relief is generally less than 1-meter high and spatial coverage of multi-beam systems are much less efficient than for offshore settings. As a result, analysis of backscatter has been the focus of habitat analysis. However, relief is a key parameter in determining the "quality" of habitat. As a result, incorporation of full swath-bathy mosaic, select site specific applications or some combination of approaches would greatly aid both physical as well as habitat assessments. Addition of relief-based parameters to the discrimination function for habitat can be expected to greatly improve the overall habitat interpretation and also allow for some quantification of "quality" of habitat. As vast areas of the South Carolina inner shelf are floored by patchily distributed low relief – low growth habitat, improved capability to search out and quantify quality of habitat has significant benefits to resource management.

Our study findings provide an opportunity to make some recommendations that should be considered in order to ensure that hard bottom reef habitats in the vicinity of the Charleston ODMDS continue to suffer limited, if any, harm from migrating sediments. First, due to the uncertainty of how well the berms located on the boundaries of the ODMDS will continue to contain the dredged material, especially following major storm events, the Corps of Engineers and EPA should support periodic surveys of the same index sites in the future, perhaps at 5 year intervals and certainly after the passage of any named storm through the area. These surveys should incorporate the use of improved neural net algorithms combined with television confirmation.

Second, the Corps should conduct, or support the conduct of future multibeam and bathymetric surveys similar to that conducted by the USGS and Coastal Carolina University to (1) define the condition and extent of the berms, including identification of any apparent breaches that may be present, and (2) obtain an estimate of the volume of sediment remaining in the ODMDS compared to the volume reported to have been dumped in that site during deepening and subsequent maintenance disposal. This would help to identify a rough assessment of the volume of material that may have migrated from the ODMDS and provide a better indication of the current capacity of the ODMDS for future disposal operations. The next survey should be conducted in the near future since the last survey is already 4 years old.

Traditional single-beam bathymetric survey along geophysical lines of survey provides a very coarse approximation of the bathymetry and change within and around the dumpsite. Through the cooperative with the US Geological Survey, inteferometric sonar coverage provided more continuous information for a portion of the ODMDS for one year. Broader multi-beam or inteferometric bathymetry should be incorporated into future studies. This will greatly aid documentation of gross disposed volumes as well as help resolve the distribution of material and ultimately maintenance of material within the disposal area.

Such acquisition could represent a significant cost to future studies. For the Charleston ODMDS, it may be possible to access federal vessels with multi-beam capabilities that are home-ported in Charleston to incorporate such imagery. This possibility is being pursued. In addition, CMWS presently has a large research equipment proposal pending with the National Science Foundation that would establish a multi-beam system at CMWS. If that proposal is acceptable, CMWS would incorporate swath bathymetry into subsequent habitat/mapping efforts directly.

Based on previous evidence of unauthorized dumps outside the designated ODMDS boundaries, the multibeam surveys should encompass both the inner and outer boundary areas to ensure that additional unauthorized dumps are not occurring. As a safety precaution, the Corps of Engineers should continue to implement strict disposal protocols that require barge track lines to not go over known hard bottom habitats, and require electronic records of all dump logs with respect to the beginning and end of barge openings.

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