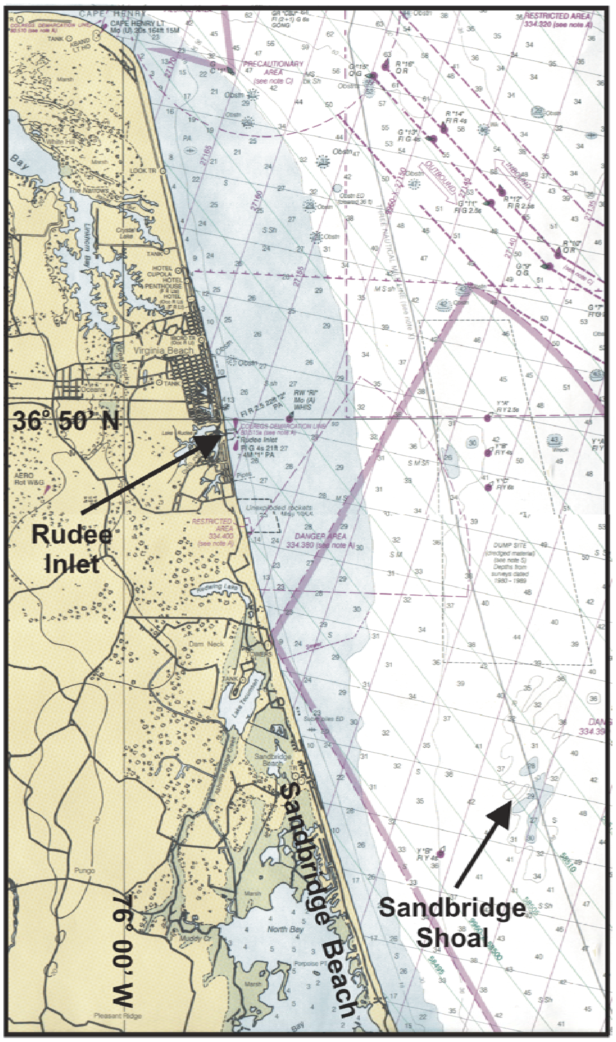
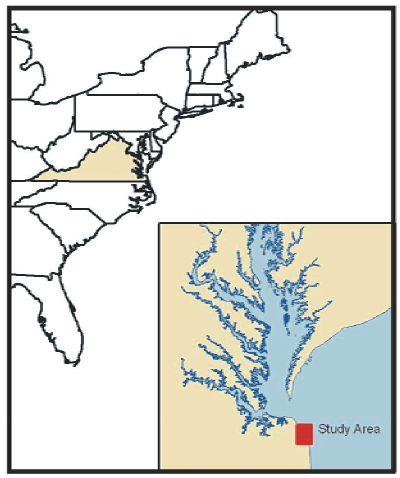
OCS Study
MMS 2005-056

Virginia Institute of Marine Science

Field Testing of a Physical/Biological Monitoring Methodology for Offshore Dredging and Mining Operations

Final Report





Cooperative Agreement

U.S. Department of the Interior
Minerals Management Service

Leasing Division, Marine Minerals Branch

Virginia Institute of Marine Science
College of William & Mary

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Field Testing of a Physical/Biological Monitoring Methodology for Offshore Dredging and Mining Operations

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ABOUT THE COVER

The figure on the cover is a portion of National Oceanic and Atmospheric Administration, National Ocean Survey, Coast Survey chart 12207, Cape Henry to Currituck Beach Light along with maps indicating the location of the study area. The locations of Sandbridge Shoal, Sandbridge Beach, and Rudee Inlet (all areas of importance to the study) and annotations of latitude and longitude have been added to the chart.

ACKNOWLEDGMENT

We gratefully acknowledge and thank Barry Drucker, the Contracting Officer's Technical Representative, who oversaw our work on this project, for his understanding, assistance, and cooperation.

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EXECUTIVE SUMMARY

The concept of a monitoring protocol for the environmentally sound management of federal offshore borrow areas along the U.S. east and Gulf of Mexico coasts is complex. In 2001 Research Planning, Inc. *et al.* developed such a protocol for the Minerals Management Service (MMS). The proposed protocol addressed six issues:

1: Bathymetric and Substrate Surveys
2: Sediment Sampling and Analysis
3: Wave Monitoring and Modeling
4: Shoreline Monitoring and Modeling
5: Benthic Communities and Their Trophic Relationships to Fish, and
6: Marine Mammal and Wildlife Interactions During Dredging.

The procedures, techniques, and tools advanced to examine these issues are fully appropriate for use in the study of each of the issues at specific sites and, if adopted as a mandatory element of dredging projects, should provide robust datasets.

The current project had the combined goals of exercising and evaluating parts of the draft protocol and of considering the actual circumstances of the test area, Sandbridge Shoal and Sandbridge Beach, Virginia.

The effort on Biological Monitoring and Evaluating the Biological Monitoring Protocol indicated that there was little discernable difference between areas that had been disturbed by sand mining and nearby areas that had not. Although substantial quantities of sand had been removed from the designated source areas, no negative environmental impacts have been observed for macrobenthos or demersal fishes. Also, although much of the suggested protocol proved valuable, there is a need to provide for a more mobile strategy that better facilitates responses to unanticipated changes in planned dredging activities. Finally, the cost and labor efficiencies of the various procedures need to be considered.

The Wave Monitoring and Modeling sections diverged from the draft protocol which advocated use of a wave gauge to record incident wave conditions inshore of the mining site. We preferred to develop a method that allowed consideration of wave conditions over an area as opposed to at a point. By collecting data on the areal distribution of wave characteristics, it should be easier to assess the validity of numerical models for wave transformation employed before dredging to predict what the actual wave conditions would be after dredging. Also, wave gauges can require intensive maintenance, removal of biofouling organisms, battery service, etc. The proposed radar observing/monitoring methodology that was developed as a major part of this project offers an alternative technique that overcomes some of the potential problems of the original protocol. In addition to providing guidance as to the characteristics needed in the actual radar system, the project also developed and provides a suite of software for data reduction and analysis.

Additionally, during the term of the project, the nationwide growth of coastal ocean observing systems has added additional options for monitoring physical conditions associated with areas of marine mining and of beach nourishment. Wave data from coastal ocean observing system stations could supplement and, perhaps, in some instances, supplant data from stations dedicated to obtaining data associated with the mining and nourishment projects. Agencies sponsoring or contemplating offshore mining and/or beach nourishment should give serious consideration to participating in the regional coastal ocean observing system. In addition to providing some funding, the participation could involve site selection so that newly placed stations could best serve the needs of the mining/nourishing project. Also the various coastal ocean observing system consortia are developing (inter)national standards for data presentation and storage that might suggest data management options for the entire monitoring protocol.

The analysis of the draft protocols for monitoring the shoreline and nearshore areas identified three major considerations: documentation of survey datums (metadata) is crucially important; an initial, preferably, pre-dredging, survey immediately offshore of the project beach and of the dredge site using some form of side-scan sonar or swath bathymetry is important as it will provide data with which to set parameters, such as profile spacing, for future surveys; and the actual tools and techniques of data acquisition are less important than the actual spatial distribution of points at which there is accurate and reasonably precise x-y-z bathymetric data. The monitoring protocol must be adaptive as every site is not the same as every other and as conditions at individual sites might change. The alongshore spacing of beach profiles needs to be close enough to capture the onshore consequences of nearshore bars and shoals.

In aggregate, a consistent set of criteria for a standard, minimum monitoring program appears to be beneficial for both broad and local analysis of the impacts of offshore sand mining and beach nourishment. Such a set of criteria, or protocol, needs to be adaptive in order to facilitate inclusion of new methods and the consideration of new questions. However the establishment of a standard protocol requires that another suite of questions be addressed. Why monitor at all? The basic reasons for the monitoring will define the dataset that needs to be acquired. Who pays? Obviously the tax payer is the ultimate payer, but the agency sponsoring the project likely would seek a smaller, shorter (less costly) monitoring program than would a permitting agency. What happens to the data? A robust monitoring system would benefit from uniform data formatting across projects and a continuing on-line availability of all data at a single URL, either in place or by link.

Reference Cited

Research Planning, Inc, W.F.Baird & Associated, Ltd, and Applied Marine Sciences, Inc, 2001. Development and Design of Biological and Physical Monitoring Protocols to Evaluate the Long-Term Impacts of Offshore Dredging Operations in the Marine Environment. Minerals Management Service, U.S. Department of the Interior, OCS Report MMS 2001-089. 116 p.

Benthic Resources and Habitats at the Sandbridge Borrow Area: A Test of Monitoring Protocols

Submitted

to

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March 2006

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Benthic Resources and Habitats at the Sandbridge Borrow Area: A Test of Monitoring Protocols

1. Introduction

The issues of coastline protection have become increasingly critical as erosion and coastal sediment transport have significantly altered or even eliminated ecologically, recreationally, and commercially important coastal habitats. Increased public use of beaches, development of coastal lands, and preservation of the limited and sensitive coastal ecosystems have all lead to an increase in the use of beach nourishment as the as the only engineered shore protection alternative that directly addresses the problem of a sand budget deficit by adding sand from outside the eroding system (National Research Council 1995). The sand resources suitable for economical beach nourishment are usually located in the near shore coastal zones adjacent to the project areas. However, ongoing and planned beach nourishment activities along the Atlantic and Gulf of Mexico coasts have identified sand sources located in Federal waters beyond the three nautical mile States' jurisdiction. The Department of Interior, Mineral Management Service (MMS) oversees all mineral resources (oil and gas, sand and gravel, industrial minerals, etc.) found in Federal waters on the outer continental shelf (OCS). The MMS's major legal mandates are the Outer Continental Shelf Lands Act, as amended in 1978 (OCSLAA) and the National Environmental Policy Act of 1969 (NEPA). An objective of both laws is to provide the information needed for balanced decision making. Both direct MMS to study the marine, coastal, and human environments and include guidance relative to information needs for rational decision making in utilizing mineral resources (for details see Drucker *et al*. 2003).

Environmental concerns that arise in connection with sand dredging from areas identified as suitable for beach nourishment focus on potential ecological impacts directly or indirectly associated with either removal of the sand from the OCS or placement of the sand on the beach. The configuration and location of the borrow site and the methods of handling the dredged material can be an important determinant in the level of impact. The level of potential impact would vary as a function of the characteristics of the material to be dredged, the exposure to currents and wave action, and the benthic resources (Thompson, 1973; Tuberville and March 1982; Hobbs, *et al*. 1985; Schaffner and Hobbs, 1992). Of the areas of concern associated with any beach-nourishment project, the sand source area and the beach nourishment area, MMS has focused on the OCS source area. With the likelihood of long-term use of Federal OCS sand resources for beach nourishment over broad areas of the OCS, MMS has developed a single set of protocols for assessing the effects of sand dredging to ensure that cumulative environmental damage does not occur. The biological and physical monitoring protocols developed focused on a broad range of effects and methods for assessing effects (Research Planning *et al.* 2001). There are four major components to the protocols:

- Development of field monitoring systems to evaluate the physical and biological impacts on a long-term basis.
- Examination of the feasibility, appropriateness, and desirability of putting these monitoring systems into place and identification of the need for collection of supplemental biological data or physical modeling information.
- Identification, review, and evaluation of environmental work or mechanisms (organizational,

economic) that may be needed to offset any potential adverse impacts.

- Identification of the need for and collection of any additional geological/geo-physical data to define available sand supplies for planned projects within the study areas.

This study is a field test of the biological protocols at Sandbridge, Virginia (Figure 1). The Sandbridge Shoal is 10 to 13 m deep, oriented north to south, and from 4.5 to 6.6 km off the coast in close proximity to developed ocean front beaches at Sandbridge and Virginia Beach. Estimated sand reserves are 20 million m^3 (40 million yd^3) (Hardaway *et al*. 1998). Sandbridge Shoal was first used in 1996 when 619,000 m^3 (810,000 yd^3) were dredged from Area B for shoreline protection of the Dam Neck Facility, U.S. Navy. In 1998, the City of Virginia Beach had 4,400,000 m^3 (1,100,000 yd^3) dredged from Area A for renourishment of the Sandbridge beach. Sandbridge beach was renourished again by the City of Virginia Beach in 2002 with 1,530,000 m^3 (2,000,000 yd^3) dredged from Area B. The Dam Neck facility was renourished by the U.S. Navy in 2003 with 535,000 m^3 (700,000 yd^3) yards taken from Area B. In summary, a total of 3,525,000 m^3 (4,610,00 yd^3) of sand has been removed for the Sandbridge Shoal.

1.1. Monitoring Protocols

In developing protocols for assessing and monitoring the effects of sand dredging in the OCS, Research Planning *et al.* (2001) goals were to have a monitoring program that would better understand the physical and ecological effects of sand dredging, and at the same time collect data or information relating to resource management decisions to allow for an adaptive management strategy. Stand-alone protocols were developed for six elements:

1. Benthic Communities and Their Trophic Relationships to Fish
2. Marine Mammals and Wildlife
3. Sediment Sampling and Analysis
4. Wave Monitoring and Modeling
5. Bathymetric and Substrate Surveys
6. Shoreline Monitoring and Modeling

For this study, only element 1 was evaluated. Details on all the elements can be found in Research Planning *et al.* (2001).

The philosophy that guided the benthic protocols was similar to that used in ecosystem-based fisheries management, which aims at for a more effective and holistic management approach by considering ecosystem functioning in managing fisheries (Pikitch *et al*. 2004). The ecosystem function emphasized in the protocols is trophic transfer from benthos to fishes (Research Planning *et al.* 2001). To estimate trophic transfer data are needed on secondary production of the benthos (which can be estimated from abundance, biomass, and taxonomic data), utilization of benthos by fishes (from stomach content analysis or stable isotope analysis), and abundance of fishes (from trawls or remote sensing). To assess acute and long-term effects of sand dredging the protocols rely on before and after dredging sampling and temporal sampling after a dredging event. An approach

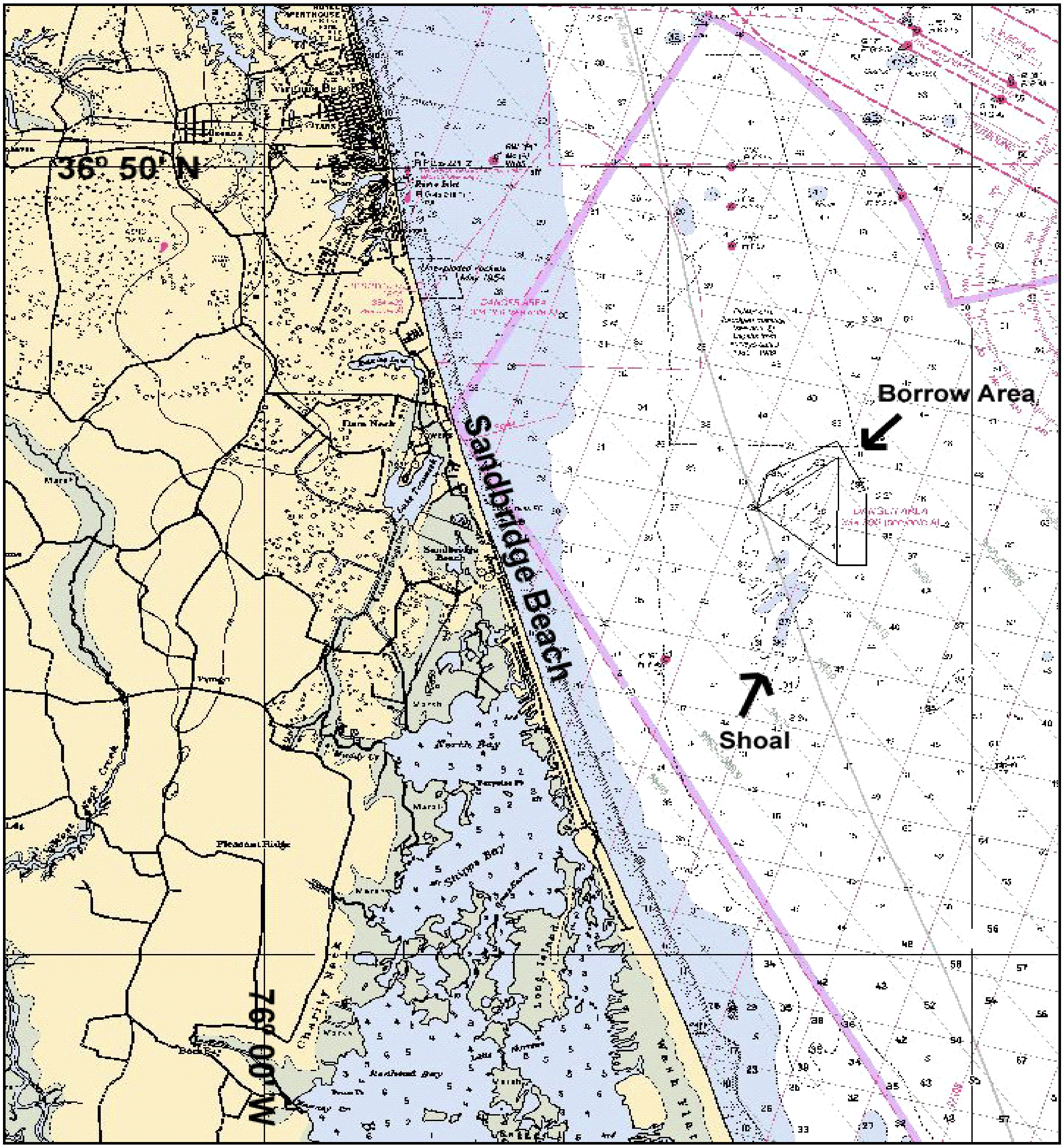

Figure 1. Location of the Sandbridge Shoal study area..

to impact assessment referred to as before-after, control-impact (BACI). In a BACI design, impact site observations are matched to simultaneous observations on one or more “Control” sites, expected to be unaffected by the alteration (Stewart-Oaten and Bence 2001). The protocols also include consideration of stratification of the study area to minimize extraneous variability, with strata acting as reference areas when appropriate.

1.2. Study Area

The study area offshore Virginia was centered on the Sandbridge Shoal (Figure 1). This shoal is 10 to 13 m deep, oriented north to south, and from 4.5 to 6.6 km off the coast in close proximity to developed ocean front beaches at Sandbridge and Virginia Beach. Previous descriptions of the study region include geological and geotechnical descriptions of the Virginia inner continental shelf by Williams (1987), Berquist and Hobbs (1988), and Kimball and Dame (1989). Dauer (1981), Ranasinghe *et al*. (1985), and Cutter and Diaz (1998) described benthic communities in this area.

2. Methods

2.1. Field Design

To address element one of the protocols (Benthic Communities and Their Trophic Relationships to Fish) it was recommended that the focus be on long-term rather than short-term impacts with data collection directed at determining trophic transfer between infauna and fishes and how sand dredging would impact trophic relationships. Emphasis by the protocols on long-term impacts implies multiyear sampling with sampling at 1, 3, 5 and 7 years out from a sand dredging event. Thus long-term data on infauna and fishes needed to be collected For infauna data on abundance, biomass, carbon and nitrogen stable isotopes, and taxonomic composition were needed. For fishes data on abundance, stomach content, carbon and nitrogen stable isotopes, and taxonomic composition were needed. To address these data requirements, we executed a stratified random design. The area around Sandbridge Shoal was stratified based on location relative to the shoal and the designated borrow area for a total of four strata; east of the shoal (designated as East), west of shoal (West), dredged area B (Area B) on northern end of the shoal, and the top of the shoal that was not dredged (Shoal) (Figure 2).

To address the long term and BACI nature of the protocols, data were collected from the four strata over a four year period:

1. June 2002 about 6-months prior to dredging 1,530,000 m^3 (2,000,000 yd^3) of sand from Area B between January and May 2003,
2. August 2003 about 4-months post-dredging and prior to dredging of another 535,000 m^3 (700,000 yd^3) of sand from Area B from January to April 2004,
3. June 2004 about 2-months post-dredging from the last dredging in Area B,
4. June 2005 about 14-months post-dredging in Area B.

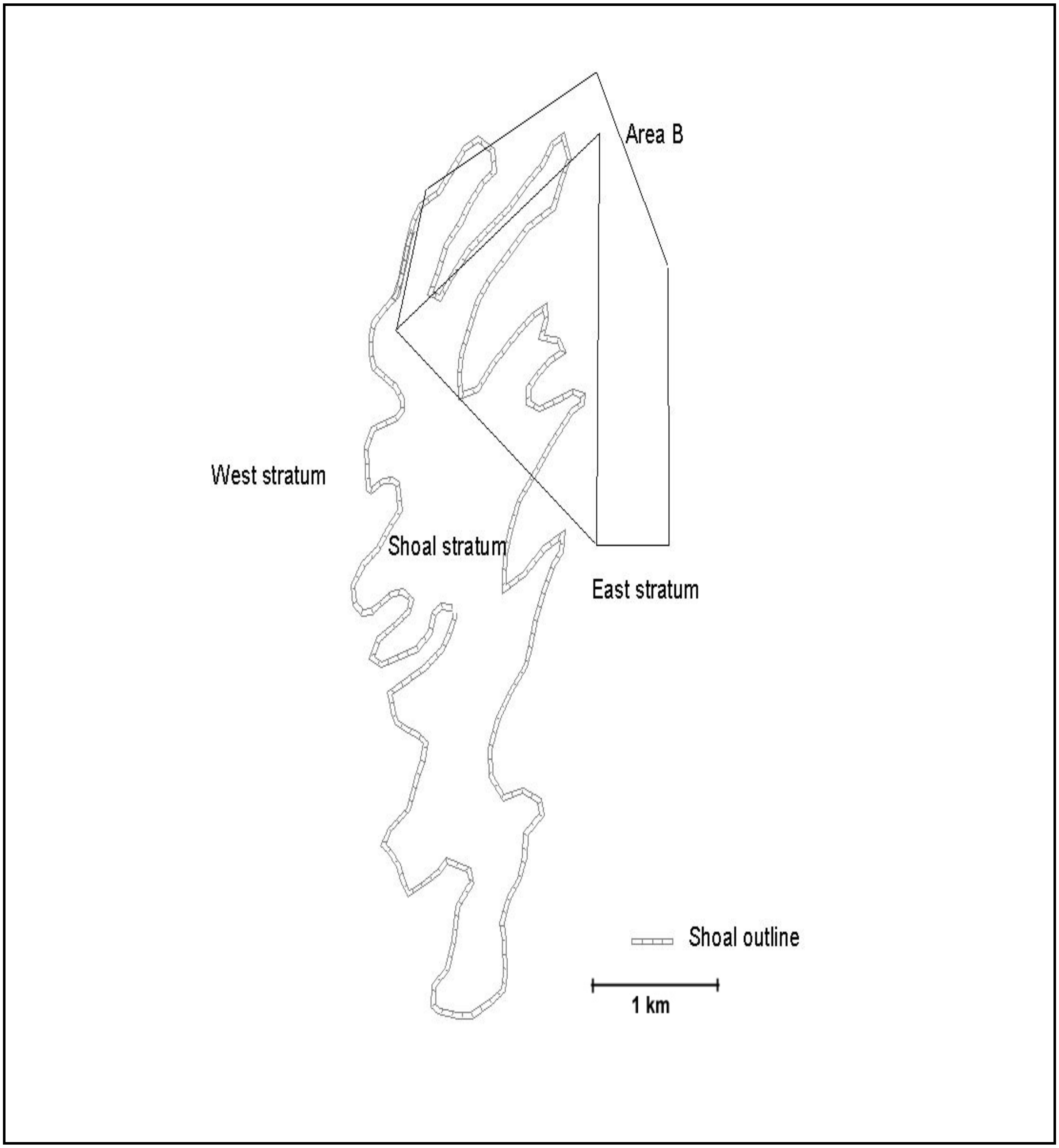

Figure 2. Sandbridge Shoal strata boundaries.

Initially, the field design was to document Spring and Summer conditions, but the sand dredging event in Area B in January 2004 caused us to shift our design to document shorter and longer term effects by sampling at 6-months and 18-months after sand dredging. The focus on Spring conditions kept seasonal effects to a minimum.

The initial location of grab and trawl stations within a stratum was random, determined by random generation of latitude and longitude coordinates within each of the defined stratum. These same locations were resampled on subsequent cruises (Figures 3 and 4). Sediment profile camera stations were both random and nonrandom (Figure 5). Video sled transects were also nonrandom and directed primarily at Area B (Figure 6).

2.2. Field Gear and Methods

To test the benthic protocols benthic community data were collected with a 0.1 m^2 Smith-MacIntry grab in 2002 and 2003. In 2004 and 2005, a 0.04 m^2 Young modified Van Veen grab was used. At each station two grabs were collected, one for community structure and the other for sediment grain-size and organisms for stable isotope analysis. The community structure grab was sieved in the field using 0.5 mm sieves and preserved in 10% to 15% Formalin. From the second grab, about 50 grams of sediment was removed for grain-size analysis and the reminder sieved and sorted in the field for a selection organisms for stable isotope analysis. Stable isotope samples were placed on ice and frozen on return to the laboratory.

Fishes were sampled with a 4.9 m (16-foot) otter trawl having 2.5 cm (1 in) stretched mesh body with a 0.5 cm (3/16) mesh liner. All trawls were pulled for a period of 10 minutes. The start and end points of each trawl were located with GPS, which were used to calculate total length of each trawl for standardizing catch to unit area. In 2002, a total of 10 trawls were completed using the 19 m (65 ft) long R/V Bay Eagle. For station 307, one trawl was pulled through Area B and three trawls just west of Area B. Two trawls were pulled at each of the other strata around and on the shoal (West of shoal station 394, East of shoal station 390, and On shoal station 356). In 2003, a total of 13 trawls were completed using the13 m (44 ft) R/V Langley. Four trawls were pulled through the area west of Area B (station 307) and two trawls in the West stratum (stations 394), three trawls in the East stratum (station 390), and four trawls in the On shoal stratum (station 356). In 2004, a total of 10 trawls were completed also using the R/V Langley. Four trawls were pulled through Area B (stations 307, 500, 501, and 502) and two trawls pulled at each of the other three strata around and on the shoal (stations 394, 390, and 356). All individuals (fishes and crustaceans) were identified to species and length (total length for fishes, carapace width or length for crustaceans) measured. After a representative sample was removed for stable isotope analysis, up to 25 individuals of each species were preserved for gut content identification. The remaining individuals collected in the trawl were measured and returned to the water. Fish were preserved in 10 % formalin for later gut removal and laboratory analysis. If an individual fish was too large to preserve in formalin (*i.e.* ray), the gut was removed and preserved while the carcass discarded. A representative sample for stable isotope analysis was taken from each trawl (this was up to five individuals of each species and size class). The whole body was saved of individuals measuring less than 100 mm by sealing in muffled foil and placing on ice. For the larger fish, a leather punch was

Figure 3. Location of grab samples on and around Sandbridge Shoal.

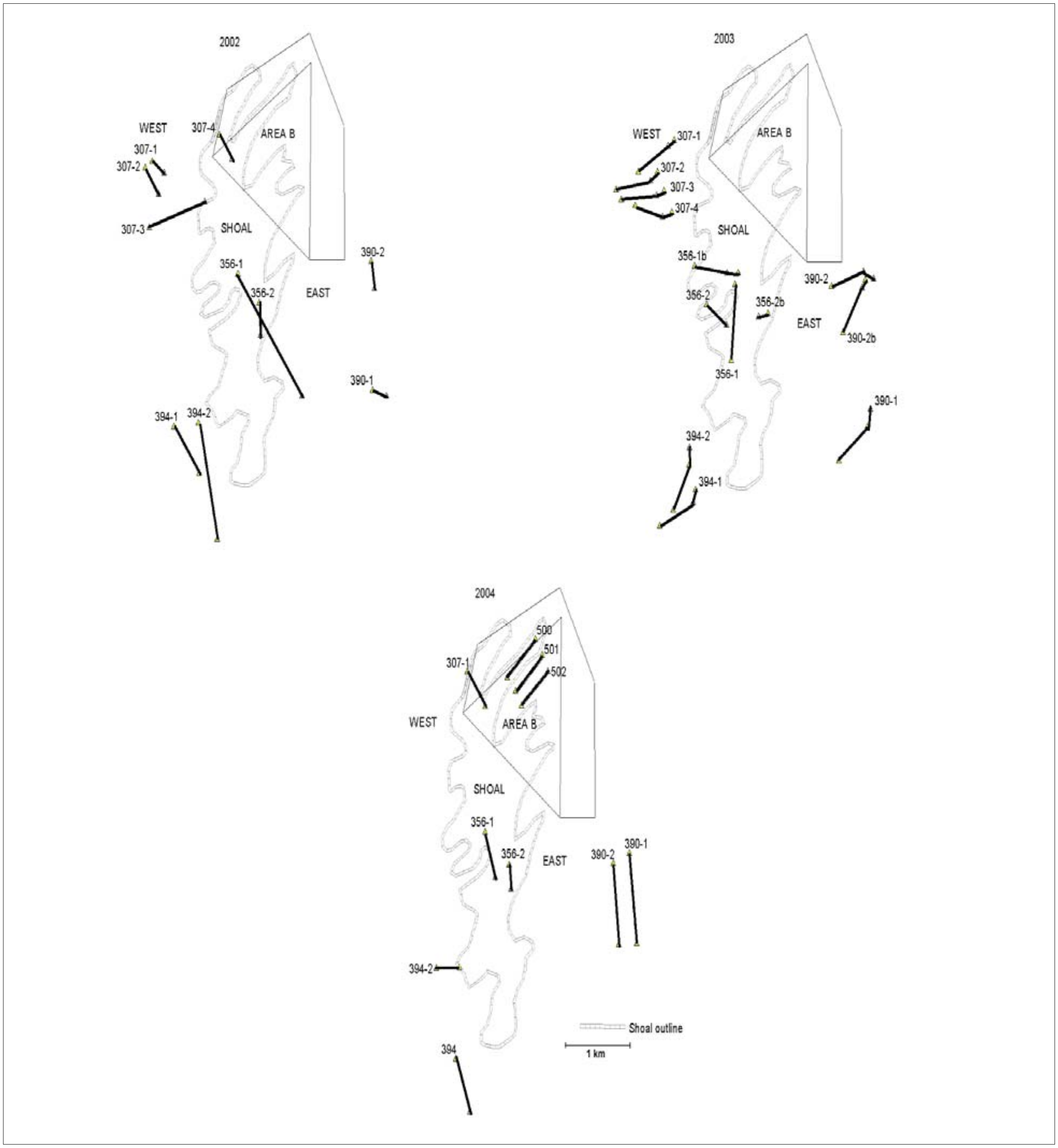

Figure 4. Location of demersal trawls on and around Sandbridge Shoal.

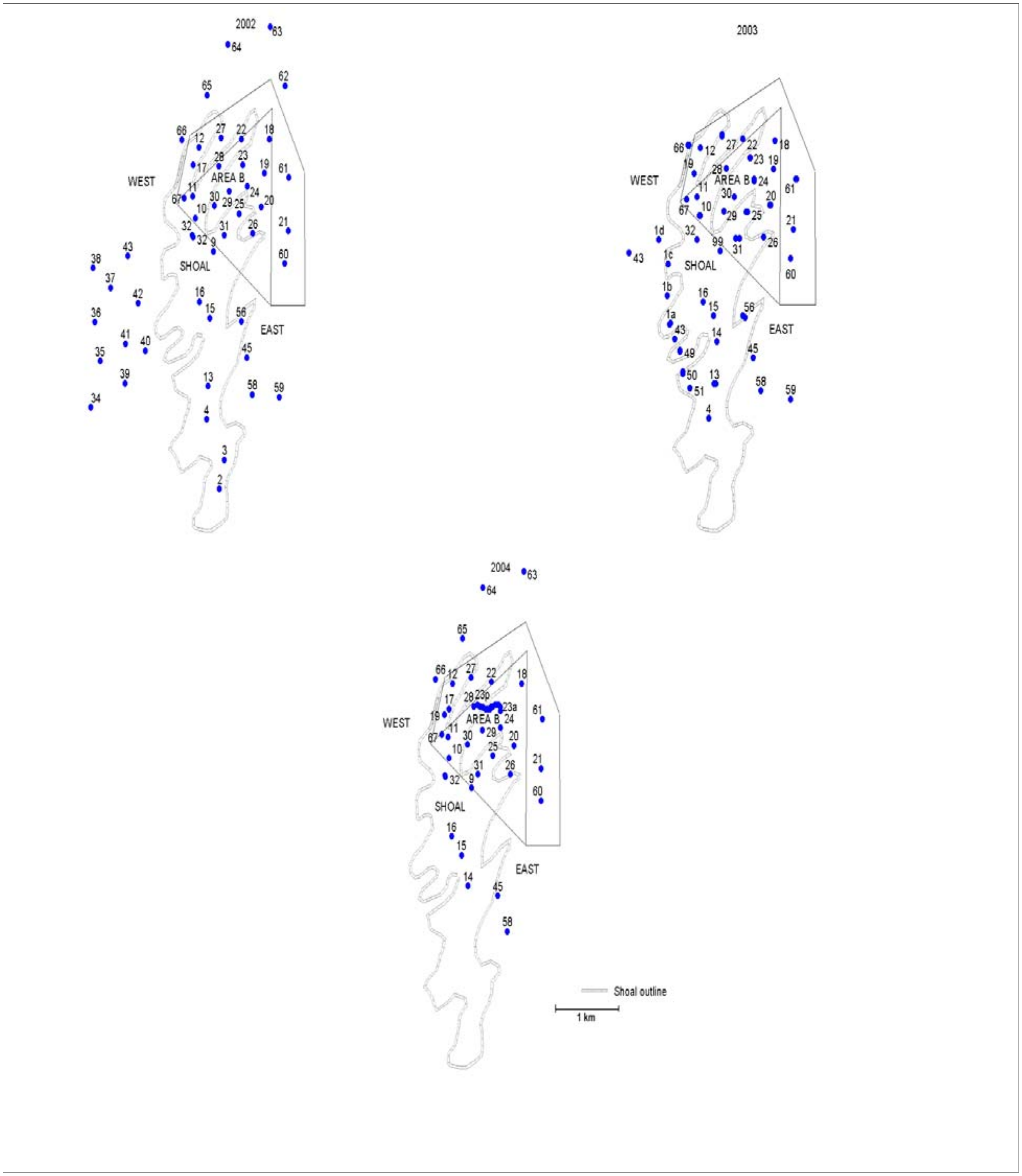

Figure 5. Location of sediment profile images on and around Sandbridge Shoal.

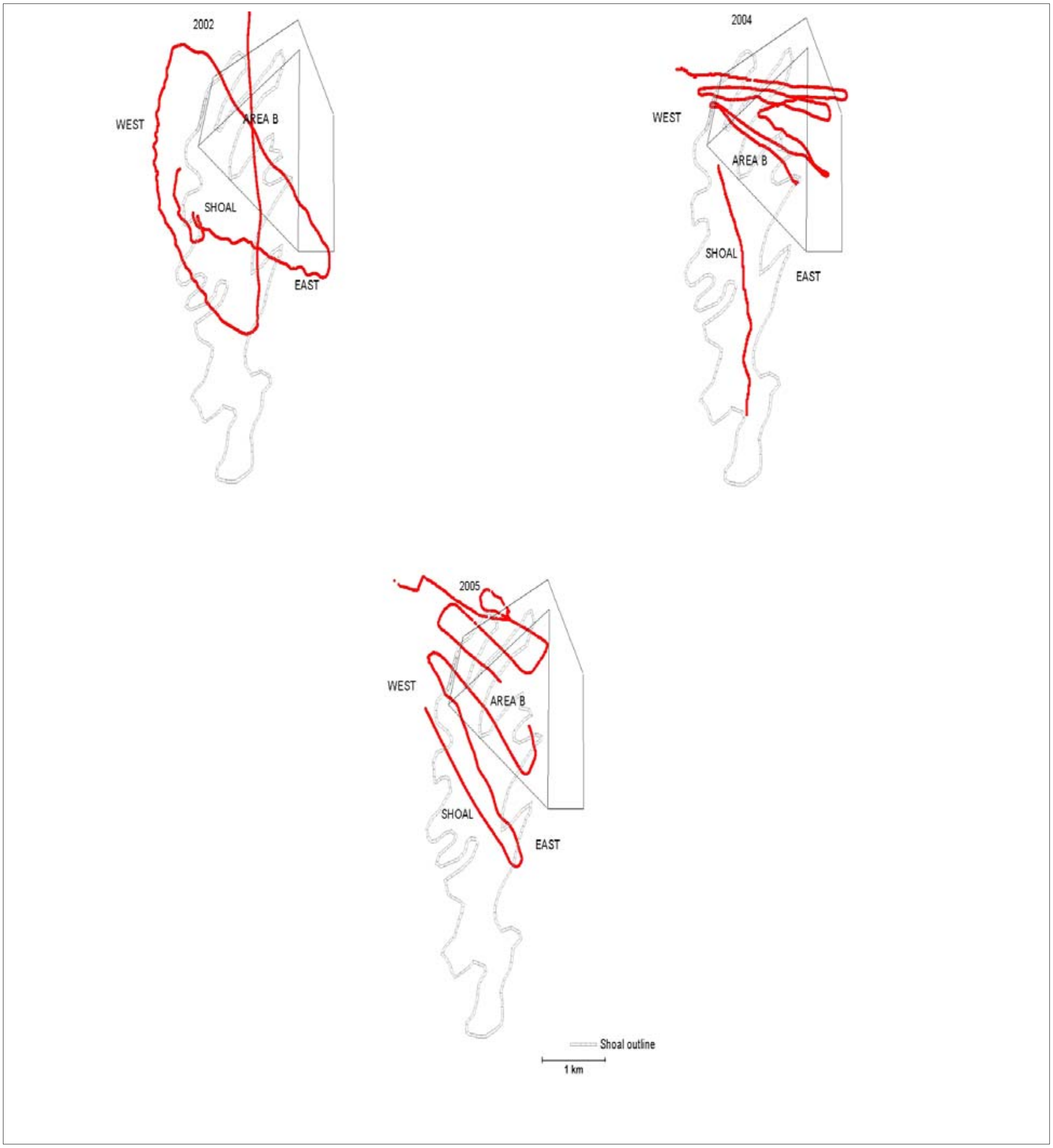

Figure 6. Location of video sled track on and around Sandbridge Shoal

used to take a sample of muscle tissue and the skin was removed with a scalpel. All tools were rinsed with DI water between samples and the tissue was placed in muffled scintillation vials for iced transport back to the lab.

A video sled was used to assess the association of fishes with the substrate and for classifying benthic habitats. The underwater video sled was equipped with forward and downward facing digital video cameras (Panasonic model GP-KR222) and was towed between 2 and 3 knots on the bottom. To reduce the effects of turbidity, the sled was equipped with video strobes (Perkin-Elmer model MVS-5004). The forward facing camera was mounted 0.2 m off the bottom at an oblique angle of 20° to provide a close-up view of bottom morphology and to detect the presence of biological features from 0.5 to 2.0 m^2 in front of the sled. The downward facing camera was mounted perpendicular to the bottom at a distance 0.15 m from the sediment surface with a field of view of 588 cm^2. The information collected from the cameras was recorded onto digital videotape with georeferenced data superimposed on the video using an onboard DGPS.

Small-scale surface and sub-surface sediment information from strata was collected using a digital sediment profile camera. Sediment profile images (SPI) were used to characterize benthic habitat similarly to the video images. The sediment profile camera works like an inverted periscope, taking cross-section images of the upper 20 to 30 cm of the seafloor (Rhoads and Cande 1971). The SPI camera used a Minolta Dimage-7i 5.2-megapixel digital camera. The camera was set to ISO 200, white balance to flash color temperature, contrast to normal, saturation to normal, maximum image size of 2560x1920, and saved using super-fine jgp compression. A video feed from the digital camera to the surface vessel allowed monitoring of the profile camera operation in real time. The camera was triggered from the surface about 1-sec after bottom contact and after the prism stopped penetrating the sediment. Approximately 100 kg of lead were added to the camera frame to improve prism penetration.

SPI allowed a relatively rapid determination and assessment of benthic habitat characteristics and capability for broad areal sampling coverage. Grabs allow detailed determination of benthic biological community characteristics. Together, SPI and grab sampling provide complementary data that are capable of forming the basis for resource maps. Grab data may serve as the basis for confirming inferences made about biological and physical habitat characteristics using SPI data. SPI data may be used to produce habitat coverage maps that when combined with secondary production data can represent the potential limits of trophic resources.

2.3. Data Processing

2.3.1. Laboratory processing and analyses

2.3.1.1. Grab

In the laboratory, grab samples were processed to obtain secondary production estimates and organismal densities and biomasses. Organisms were sorted into major taxa and enumerated. Samples that retained a large amount of sand which would not pass through 500 mm sieves were elutriated and the organisms then extracted for sorting. Counts and biomass were converted to m^{-2} by multiplying by 10 for Smith-MacIntry grabs and 25 for Young grabs. Processing for secondary production calculations involved resieving the sorted taxa through a series of nested sieves (8.0, 5.6, 4.0, 2.8, 2.0, 1.4, 1.0, 0.71, 0.5 mm), then counting the organisms in each size fraction. For organisms retained on the 5.6 mm and smaller sieves, allometric equations from Edgar (1990) were used to convert abundances to AFDW. Ash free dry weight (AFDW) was measured for each specimen retained on the 8.0 mm screen and for all taxonomic groups not specified by the sieve method of Edgar (1990). Individuals were dried for 48 hours to a constant weight at 60º C then combusted at 550º C for 4 hours.

Community production was calculated using the model of Edgar (1990):

$$P = 0.0049\ B^{0.80}\ T^{0.89}$$

Where P = daily average production in ug day^{-1}, B = ug AFDW individual biomass, and T = water temperature in °C. This general allometric equation is based on a regression calculated from the published production rates of 41 marine and estuarine invertebrate species ranging in size from 10^{-5} to 1 g and valid for temperatures from 5 – 30 °C. Combined weights from all size classes allowed determination of biomass and production for each taxa per sample.

2.3.1.2. Trawl

Guts were removed from the preserved fish collected during each of the trawls and placed into vials containing 70 % ethanol. The contents were removed and identified to the lowest taxonomic level. After identification, gut contents were enumerated and wet weight was measured. If the gut material was unidentifiable due to digestion or other factors, it was characterized as tissue. Data were organized and presented as frequency of occurrance, mean percentage by number, and mean percentage by weight.

2.3.1.3. Stable Isotope

Species were verified at the lab prior to processing the stable isotope samples. Individuals and tissue samples were dried for 48 hours to a constant weight at 60º C. Samples were then ground into a fine, flour-like powder using a mortar and pistol. Both mortar and pistol were cleaned and dried between each sample with DI water and 10 % HCl to prevent cross contamination. The ground powder was placed in muffled 1 dram shell vials and acidified with 10 % HCl to remove all carbonate. After acidification, samples were dried at 60º C for 48 hours. A microgram scale was used to weigh 1 mg of ground animal tissue which was placed in a 5 x 9 mm tin capsule. Capsules were crimped and sealed in 96-well microtitre plates for shipment to the University of California at Davis, Stable Isotope Facility for analysis. All capsulation instruments were rinsed with acetone between samples to avoid cross-contamination. The samples were analyzed on a Europa Hydra 20/20, which is a continuous flow isotope ratio mass spectrometer used for high precision analysis of combusted solid samples at natural abundance and for analysis of trace gases (H_2, CO_2, CH_4, NO, N_2O).

2.3.1.4. Video

Benthic habitat was characterized from the underwater video by analyzing images from recorded videotape using an editing deck and high-resolution video monitor. Images were analyzed at each 2 min interval of towing with the video sled. If video images were not visible at the 2-minute interval, because of poor near-bottom visibility, images from the last instance the bottom was visible and the first moment the bottom reappeared were analyzed. For analysis and archiving, 20-second video clips were captured around the sampled videotape times using Apple program iMove. Each video sample from the forward camera was 2 to 4 m^2, depending on turbidity levels, and 0.25 m^2 for the down camera. All fish and megafauna observed were identified to the lowest possible taxon, and physical and biological features of the benthic habitats at the instance the fish was noted were recorded. For each image, the substrate was classified for the presence or absence of physical and biological characteristics related to bottom relief, substrate particle size, biogenic structures, and shell hash. The classification system was similar to that described by Diaz *et al*. (2003). Broad-scale data on substrate and surface characteristics, both physical and biological, were collected over 17 km of track line in 2002, 15 km in 2004, and 8 km in 2005 (Figure 6).

2.3.1.5. SPI

All sediment profile images were evaluated visually with data of all features recorded in a pre-formatted spreadsheet file. Images selected for analysis were digitally processed to enhance contrast and color using a Red-Green-Blue (RGB) color space. Each image was histogram equalized and trimmed from 0.2 to 2.0% using the image program Adobe PhotoShop®. Steps in the computer analysis of each image were standardized and data sequentially saved to a spreadsheet file for later analysis. Details of how these data were obtained can be found in Diaz and Schaffner (1988) and Rhoads and Germano (1986). A description of parameters measured and evaluated follows.

2.3.1.6. Prism Penetration

This parameter provided an estimate of sediment compaction with the profile camera prism acting as a dead weight penetrometer. The further the prism entered into the sediment, the softer the sediments, and likely the higher the water content. Penetration was measured as the distance the sediment moved up the 23-cm length of the faceplate.

2.3.1.7. Surface Relief

Surface relief or boundary roughness was measured as the difference between the maximum and minimum distance the prism penetrated. This parameter also estimated small-scale bed roughness, within the view of the 15 cm width of the prism faceplate, which is an important parameter for predicting sediment transport and in determining processes that dominate surface sediments. The origin of bed roughness can be determined from visual analysis of the images.

2.3.1.8. Sediment Grain Size

Grain size is an important parameter for determining the nature of the physical forces acting on a habitat and is one of the major factors in determining benthic community composition particularly on the dynamic and sandy inner continental shelf (Rhoads, 1974; Snelgrove and Butman, 1994). The sediment type descriptors used for image analysis follow the Udden-Wentworth classification as described in Folk (1974) and represent the major modal class for each image. Maximum grain size was also estimated. Grain size was determined by comparison of collected images with a set of standard images for which mean grain size had been determined in the laboratory.

2.3.1.9. Surface Features

These parameters included a wide variety of physical (such as bedforms or flocculent sediment surfaces) and biological features (such as biogenic mounds, shell, or tubes). Each contributes information on the type of habitat and its ability to support benthic organisms. Surface features were visually evaluated from each image and compiled by type and frequency of occurrence.

2.3.1.10. Subsurface Features

These parameters included a wide variety of features (such as infaunal organisms, burrows, water filled voids, gas voids, or sediment layering) that reveal a great deal about physical and biological processes influencing the bottom. For example, habitats with grain-size layers or homogeneous color layers are generally dominated by physical processes while habitats with burrows, infaunal feeding voids, and/or visible infaunal organisms are generally dominated by biological processes (Rhoads and Germano, 1986; Diaz and Schaffner, 1988; Valente *et al*., 1992; Nilsson and Rosenberg, 2000). Subsurface features were visually evaluated from each image and compiled by type and frequency of occurrence.

2.3.2. Statistical Analysis

Analysis of variance or t-Test was used to test for differences between factors with quantitative parameters. Normality was checked with the Shapiro-Wilk test and homogeneity of variance with Bartlett's test (Zar 1999). Data were log10 (x + 1) transformed when necessary or Welch ANOVA, which allows for unequal variances, was used to test for differences. For qualitative data, odds and odds ratios were tested with the Fisher Exact test, and Mantel-Haenszel or Cochran-Mantel-Haenszel statistics were used for assessing differences among categorical parameters (Agresti 1990).

3. Results

3.1. Overview

Data collected on each of the four cruises is summarized in Table 1. Emphasis was on grab samples, which were collected on all four cruises. SPI and trawl data were not collected June 2005 due to weather problems. Video was not collected in August 2003 due to weather and high levels of turbidity near the bottom. The areas around Sandbridge Shoal were stratified into four areas based on location relative to the shoal and borrow Area B. The area east of the shoal was designated as East stratum, west of shoal was West stratum, the dredged area was Area B located on northern end of the shoal, and the top of the shoal that was not dredged was Shoal stratum (Figure 2). The locations of all stations by year and strata boundaries are presented in Figures 3 to 6.

Table 1
Summary of Data collected on Each Cruise to the Sandbridge Shoal Study Area

Cruise	Date	Stratum	Grabs Infauna	Grabs Grain-Size	Demersal Trawls	SPI	Video Sled Track
1	June 2002	Area B	3	3	1	13	X
		On Shoal	7	7	2	15	X
		East of Shoal	5	5	2	10	
		West of Shoal	5	5	5	12	X
2	August 2003	Area B	3	3	0	26	
		On Shoal	7	7	4	36	
		East of Shoal	3	3	3	12	
		West of Shoal	5	5	6	10	
3	June 2004	Area B	6	6	4	29	X
		On Shoal	6	6	2	11	X
		East of Shoal	4	4	2	8	
		West of Shoal	4	4	2	2	
4	June 2005	Area B	5	5	0	0	X
		On Shoal	7	7	0	0	X
		East of Shoal	1	1	0	0	
		West of Shoal	4	4	0	0	

3.2. Substrate and Sediments

Based on SPI, physical processes dominated the sediment surfaces throughout the study area. Bedforms occurred at 100% of the SPI stations (Appendix A). None of the sediment surfaces appeared to be structured by biological processes. Table 2 summarizes some of the SPI data. Evidence of biological processes in the form of tubes appeared in 15% (28 of 184 stations) SPI images with the August 2003 data having a highest proportion of biogenic structures at 61% (17 of28 stations, for example see Figure 7). The higher proportion of images with tubes in August verses June did suggest a seasonal effect but the trend was not significance (Odds Ratio of 2.0, p = 0.100). The only other biogenic structure observed in the SPI from the three cruises were protuberances of sand that rose above the sediment surface about 1 cm and may have been foraminiferans (Figure 7). The odds of sand protuberances occurring was significantly lower in the dredged area stratum (Area B) compared to the other three strata (East, West, and Shoal strata), (Cochran-Mantel-Haenszel Test, p = 0.046). The recent dredging within Area B is the likely cause, as storms or other natural disturbances would have reworked the entire shoal.

Physical processes were predominant in structuring sediment surfaces for all stations in all years (2002, 2004, and 2005). Pure sand sediments, indicative of high kinetic energy bottoms, were seen at all stations for all years, except station 40 in 2002 that had a layer of silt-clay sediments under fine-sand surface sediments (Figure 8). Modal grain-size over the study area was primarily a mixture of fine-sand (0.125 to 0.25 mm grains, 2 to 3 Phi) and medium-sand (0.25 to 0.5 mm grains, 1 to 2 Phi), and occurred at 84% of all stations (154 of 184). The remaining stations were coarse-sands (16% or 29 stations) with one fine-sand-silt station (station 40). Maximum sediment grain-size ranged from gravel (2 to 4 mm grains, -1 to -2 Phi) at 13% of stations to fine-sand at 9%. Most of the stations had a maximum grain-size of medium-sand or coarse-sand (0.5 to 1.0 mm grains, 0 to 1 Phi).

Table 2
Summary of Sediment Profile Image Data by Strata for Sandbridge Shoal

		Number of SPI in Each Modal Sediment Class						
Strata	N	Fine-Silt-Sand	Fine-Sand	Fine-Medium-Sand	Medium-Sand	Medium-Coarse-Sand	Coarse-Sand	Very-Coarse-Sand
West of shoal	24	1	11	3	5	0	2	2
Area B	68	0	4	32	20	2	10	0
On Shoal	62	0	0	26	27	0	9	0
East of Shoal	30	0	3	14	9	1	3	0

		Penetration		Surface Relief		Tubes	*Diopatra* Tubes
Strata	N	Mean (cm)	SD (cm)	Mean (cm)	SD (cm)	Mean (#/image)	Mean (#/image)
West of shoal	24	3.6	2.5	1.5	0.8	0.6	0.0
Area B	68	6.7	2.3	1.5	1.0	0.1	0.1
On Shoal	62	5.7	3.0	1.4	1.1	0.3	0.0
East of Shoal	30	5.6	2.9	1.7	1.5	1.6	0.4

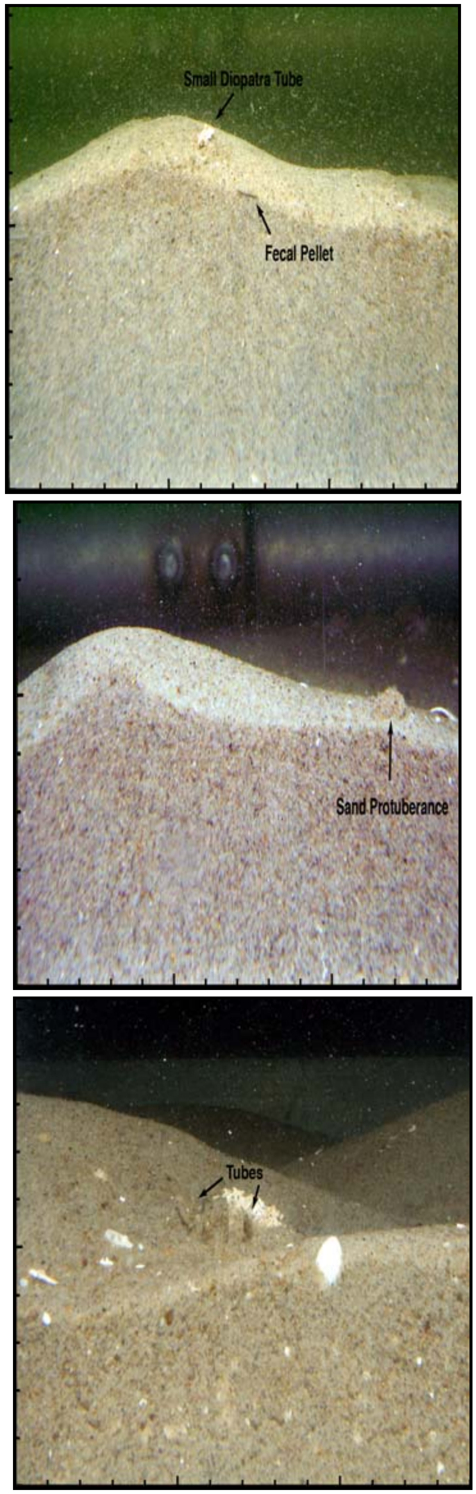

Figure 7. Examples of physical and biological processes structuring surface sediments. Scale around image is cm units.

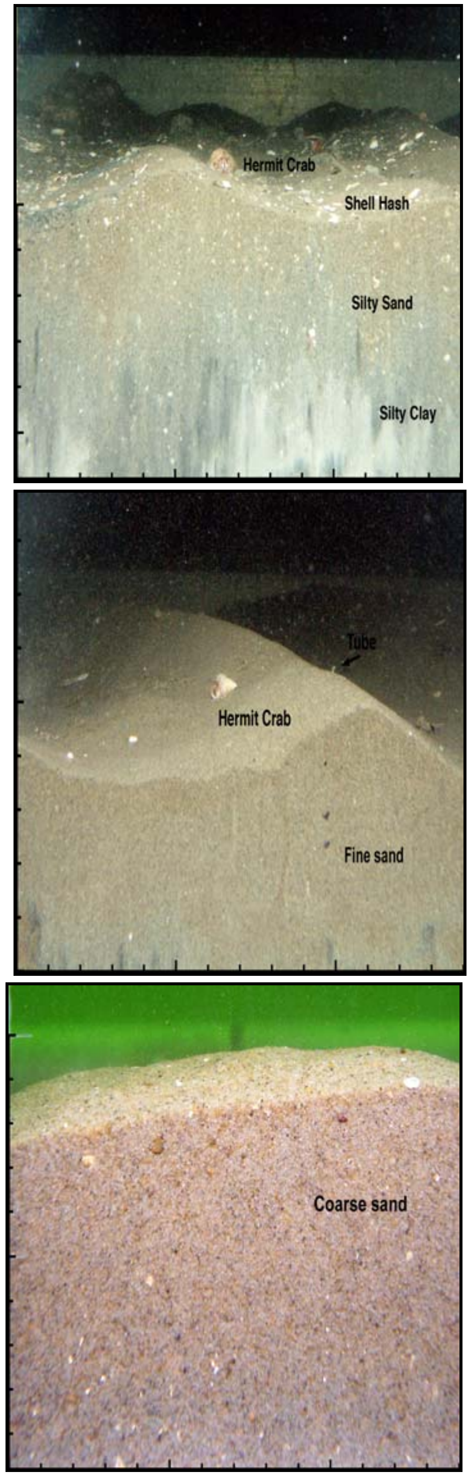

Figure 8. Examples of grain-size from Sandbridge Shoal. Scale around image is cm units.

The West stratum had significantly finer sediments than the other three strata (Mantel-Haenszel Test, Chi Square = 16.98, df = 3, p = 0.0007). Fine-sand sediments occurred at 50% of West stratum stations with the other 50% of stations having a mixture of fine-sand to coarse-sand sediments. The Shoal stratum had the coarsest sediments with no fine-sand stations observed in the SPI. Area B on the northern end of Sandbridge Shoal was similar to the Shoal stratum in the proportion of fine-medium to coarser sand stations but did have some fine-sand stations. The East stratum was most similar to Area B in sediments (Table 3). If the West stratum was removed from the comparison of strata, there were no significant differences between the other three strata.

Grain-size analysis of sediments from grab samples showed a similar pattern, both spatially and temporally (Appendix B), to SPI derived grain-size data. From 2002 to 2005, there was little variation in grain size either at a station or within a stratum. The largest difference in median grain size between years occurred at station 353, in the West stratum, which ranged from coarse-sand in 2003 to fine-sand in 2005. All other stations had <1 Phi difference between years (Table 3). The West stratum had significantly finer grained sediments than the other strata (ANOVA, strata df = 3, p = <0.0001, year df = 1, p = 0.111, interaction p = 0.960) and on average were fine-sand (median Phi of 3.1) with 6% silt-clay. The other three strata were significantly coarser in grain size, being on average medium-sand with the Shoal stratum have slightly coarser sediments than Area B and East strata (Figure 9). Silt-clay content of these three strata was also significantly lower than the West stratum (Welch ANOVA, df = 3, F = 9.00, p = 0.001).

Sediment compaction (lower prism penetration harder sediments) was significantly higher in the West stratum compared to the other three strata (ANOVA, df = 3, F = 8.09, p = <0.0001). Sediments in the West stratum were well to very-well sorted compact fine-sands while the other three strata were moderately to moderately-well sorted (Table 3). Bed roughness (surface relief measured across width of prism window) was consistent between strata with no significant differences (ANOVA, df = 3, F = 0.54, p = 0.657). For all stations, the bed roughness was due to small sand ripples or bedforms, which were an indication of the dominance of physical processes in structuring surface sediments, and averaged from 1.4 to 1.7 cm for the four strata. Biogenic structures of benthic organisms were not prominent and had little influence on bed roughness.

3.3. Benthic Community Composition

Total abundance of macrofauna averaged by year for all grab sample stations declined from a high of 3,700 individuals/m^2 in 2002 to 2,300 individuals/m^2 in 2005 (Figure 10, data in Appendix C). The lowest abundances were in 2004, which was significantly lower than 2002 (ANOVA, log transform, df = 3, F = 4.80, P = 0.004). In 2005, there were two outlier (stations 332 and 361), both in the West stratum, with abundances >6,800 individuals/m^2 (Figure 10). The most abundance major taxonomic group was polychaetes that represented 73% of all organisms collected. The other 27% of individuals were amphiods (9%), bivalves (7%), lancelets (3%), and other groups (8% for decapods, nemerteans, echinoderms, anemonies, isopods, gastropods, phoronids, and tunicates). When evaluated by strata and year, there were significant differences between strata over time (ANOVA, log abundance, strata df = 3, p = <0.0001, year df = 1, p = 0.0019, interaction p = 0.472). The West stratum consistently had significantly higher abundances relative to the other three strata for all four years (Figure 11). There were no significant differences between the East, Shoal, and

Area B strata in the abundance indicating that sand dredging within Area B had no or no long-term impact on macrofaunal abundance. There was, however, a regional reduction to total abundance in 2004 that carried into 2005 with the exception of the West stratum, which increased to 2002-2003 abundances in 2005.

The community composition on and around Sandbridge Shoal for 2002-2005 was similar to previous work in the area. Cutter and Diaz (1998) found polychaetes (54% of individuals), amphipods (20%), decapods (8%), bivalves (5%), sand dollars (5%), and lancelets (4%) to be the dominant groups in 1996 and 1997. Average macrofaunal abundance in 1996 and 1997 was lower relative to 2002 to 2005 with an average of 1500 individuals/m^2. This was 1.5 to 2.5 times lower than 2002-2005, but there were no significant differences between any of the four strata. Overall, these taxonomic groups, in about the same proportion, are typical of sandy shallow continental shelf habitats along the Atlantic Coast. For examples see studies by Boesch (1979) off the coasts of New Jersey and Maryland, Maurer *et al*. (1976) off Delaware, Dauer (1981) off the mouth of Chesapeake Bay just north of Sandbridge, and Day *et al*. (1971) off North Carolina. These authors reported similar taxa composition for similiar depths and sediment types.

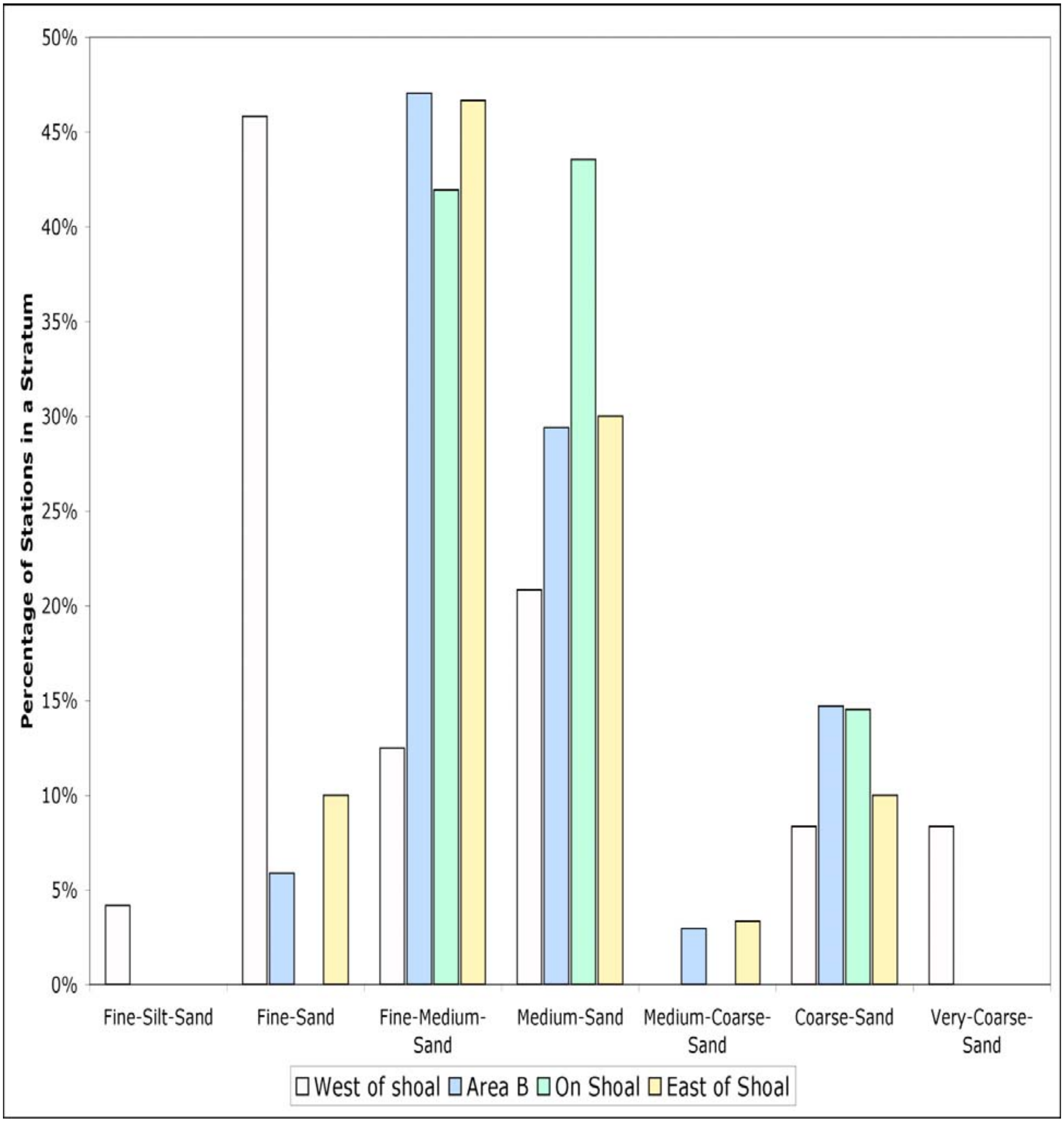

Figure 9. Grain size analysis of sediments from Sandbridge Shoal grab samples.

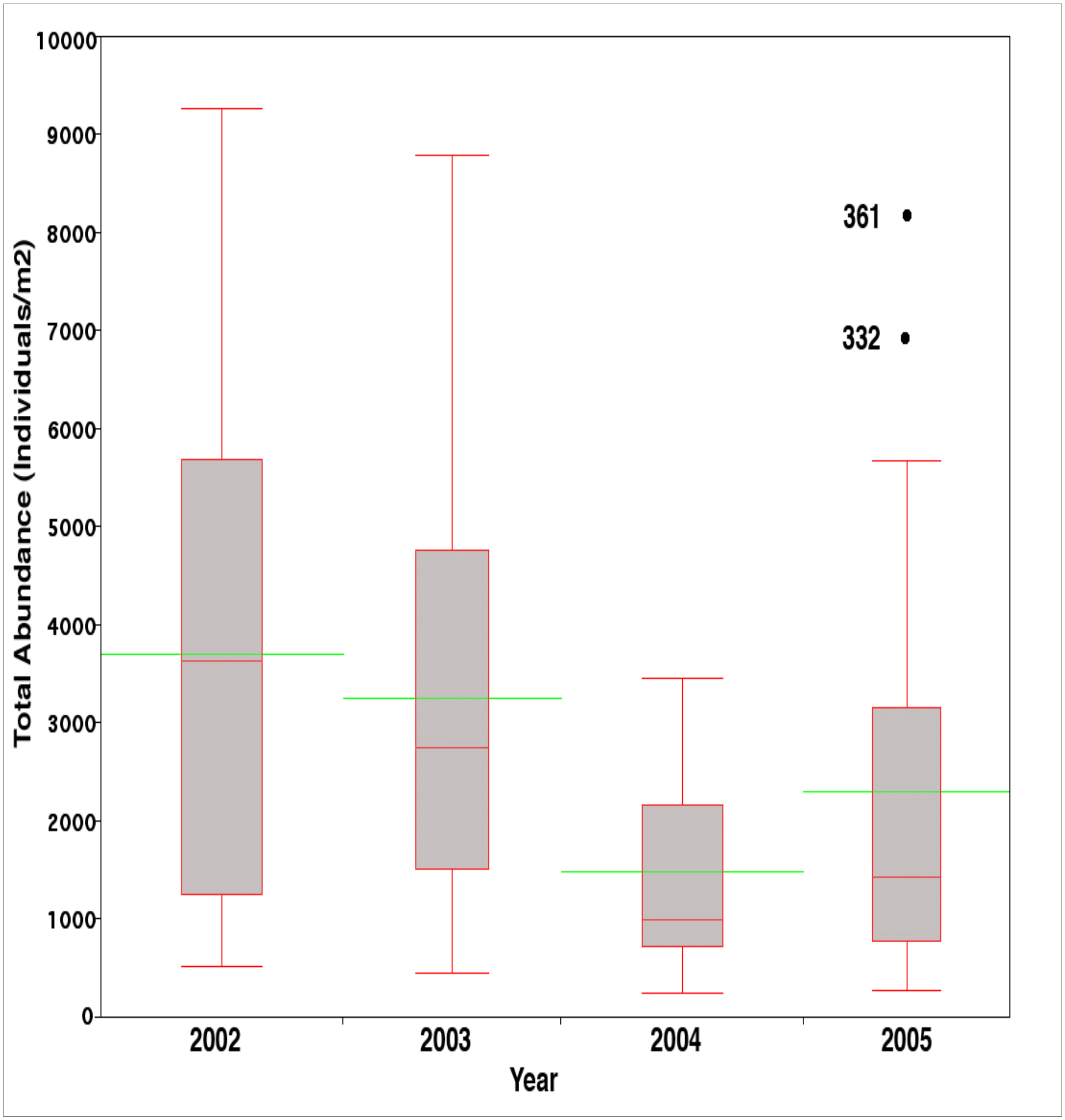

Figure 10. Total abundance of macrofauna for Sandbridge Shoal strata by year. Stations 361 and 332 were high outliers in 2005. Box is interquartile range (IR, 25^{th} to 27^{th} percentiles), whiskers are 1.5xIR, bar in box is median, bar extending out of box is mean. Width of box is proportional to sample size.

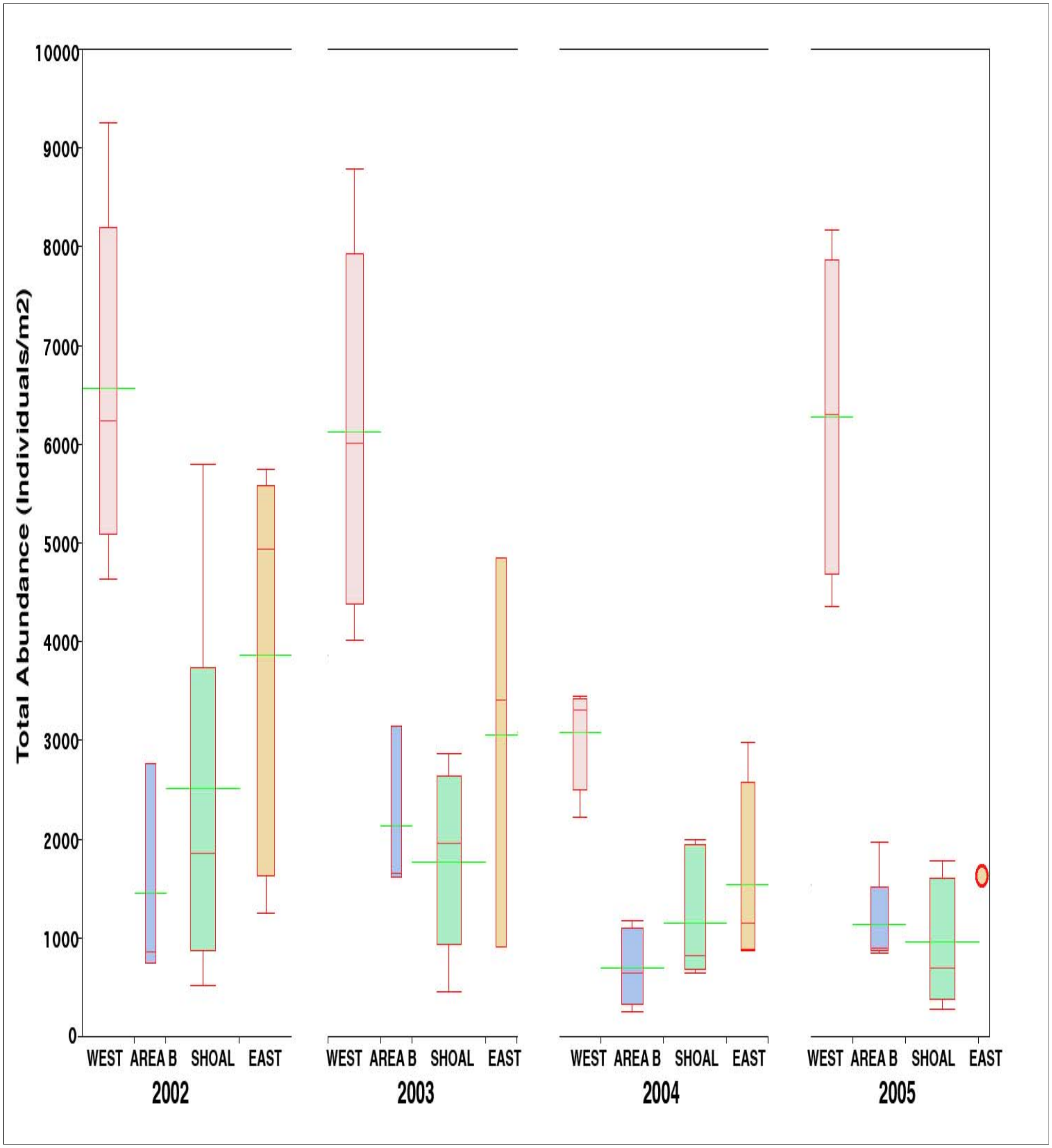

Figure 11. Total abundance for macrofauna by year for all Sandbridge Shoal stations. Box is interquartile range (IR, 25th to 27th percentiles), whiskers are 1.5xIR, bar in box is median, bar extending out of box is mean. Width of box is proportional to sample size.

Table 3
Summary of Sediment Grain Size by Station and Strata for Sandbridge Shoal

Strata	Station	N of Years Sampled	Phi Min	Phi Max	Phi Mean	Phi SE	% Sand+Gravel
West of Shoal	332	4	3.3	3.3	3.3	0.01	95
	342	2	3.4	3.4	3.4	0.00	92
	353	4	0.6	3.3	2.3	0.65	95
	361	4	3.3	3.3	3.3	0.01	95
	372	4	3.2	3.3	3.3	0.02	93
Area B	307	4	1.4	1.9	1.6	0.10	99
	308	4	1.1	2.0	1.6	0.20	99
	318	4	1.7	1.9	1.9	0.04	98
	500	2	1.3	1.7	1.5	0.21	100
	501	2	1.9	1.9	1.9	0.02	100
	502	1	1.6	1.6	1.6	.	99
On Shoal	297	3	1.2	1.3	1.2	0.04	99
	316	4	1.4	2.0	1.7	0.12	98
	336	4	1.2	1.7	1.5	0.10	99
	347	4	1.6	1.9	1.7	0.07	99
	356	4	1.5	2.1	1.8	0.12	99
	365	3	1.7	2.2	1.9	0.14	98
	385	3	1.2	2.1	1.6	0.27	99
	504	1	1.4	1.4	1.4	.	99
	509	1	1.6	1.6	1.6	.	100
East of Shoal	329	2	1.4	1.9	1.6	0.25	99
	360	2	1.3	1.7	1.5	0.21	99
	377	4	2.5	2.7	2.6	0.04	93
	390	3	0.8	1.7	1.3	0.27	99
	396	2	2.5	2.6	2.6	0.03	98

3.4. Benthic Community Biomass and Secondary Production

Biomass (B) and mean individual weight (w), important factors in determining the potential food resources available to bottom feeding fish and crabs (Diaz and Schaffner 1990), were used to estimate secondary production based on the equations of Edgar (1990). The size spectra of the benthos (Class interval lower limits were 0.5, 0.7, 1.0, 2.0, 2.8, 4.0, 5.6, >8 mm) followed a pattern typical for marine communities, where most of the biomass was in the larger size classes and most of the individuals were in the smaller size classes (Appendix D). When summarized by major taxa, polychaetes accounted for 31% of the daily production followed by bivalves (17%), amphipods (13%), lancelets (12%), and echinoderms (11%). Gastropods, decapods, and nemerteans combined accounted for 14% and the remaining 2% being miscellaneous taxa.

Total macrobenthic production monotonically declined over the study period by a factor of about four from a high of 46.2 mg AFDW/m^2/day (SE = 12.3) in 2002 to a low of 12.8 mg AFDW/m^2/day (SE = 3.1) in 2005. There were also significant differences between the strata with the East and West strata having significantly higher production relative to Area B and Shoal strata by a factor of about 2.5 (Figure 12). These differences in production between strata were consistent through time as evidenced by the nonsignificant interaction term in the analysis of variance (ANOVA, log production, strata df = 3, p = <0.0001, year df = 1, p = 0.0005, interaction p = 0.526). The lack of interaction between strata and years supports the hypothesis that differences between strata were not related to sand dredging in 2004. Had any event in 2004, or any other year, altered macrobenthic production in one stratum relative to the others, the interaction term would likely have been significant.

The taxonomic composition of the production varied with time and strata. The production of polychaetes and bivalves was different by year and strata (Figure 13). For both taxonomic groups, production declined from 2002 to 2005. For polychaetes, daily production was higher in the West stratum than the East stratum, which were both higher than the two top of the shoal strata (Area B and Shoal). Lower productivity of polychaetes on the top of the shoal was in part due to the smaller body size of individuals on the shoal vs off of it. Bivalves had higher production in the West stratum than in the other three strata. For both bivalves and polychaetes, higher production in the West stratum was likely related to the finer grained sediments that occurred there as well as larger body size in the West stratum. For amphipods, decapods, and gastropods production was not significantly different through time, but strata were different with the West and East strata being higher than both Area B and Shoal strata. The other taxa groups were not significantly different (Table 4). The consistently lower macrofaunal production on Sandbridge Shoal (both West and Shoal strata) points to the dynamic nature of sandy shoal environments. Similar patterns in on and off shoal productivity were observed on and around Fenwick Shoal, MD (Diaz and Cutter 2000).

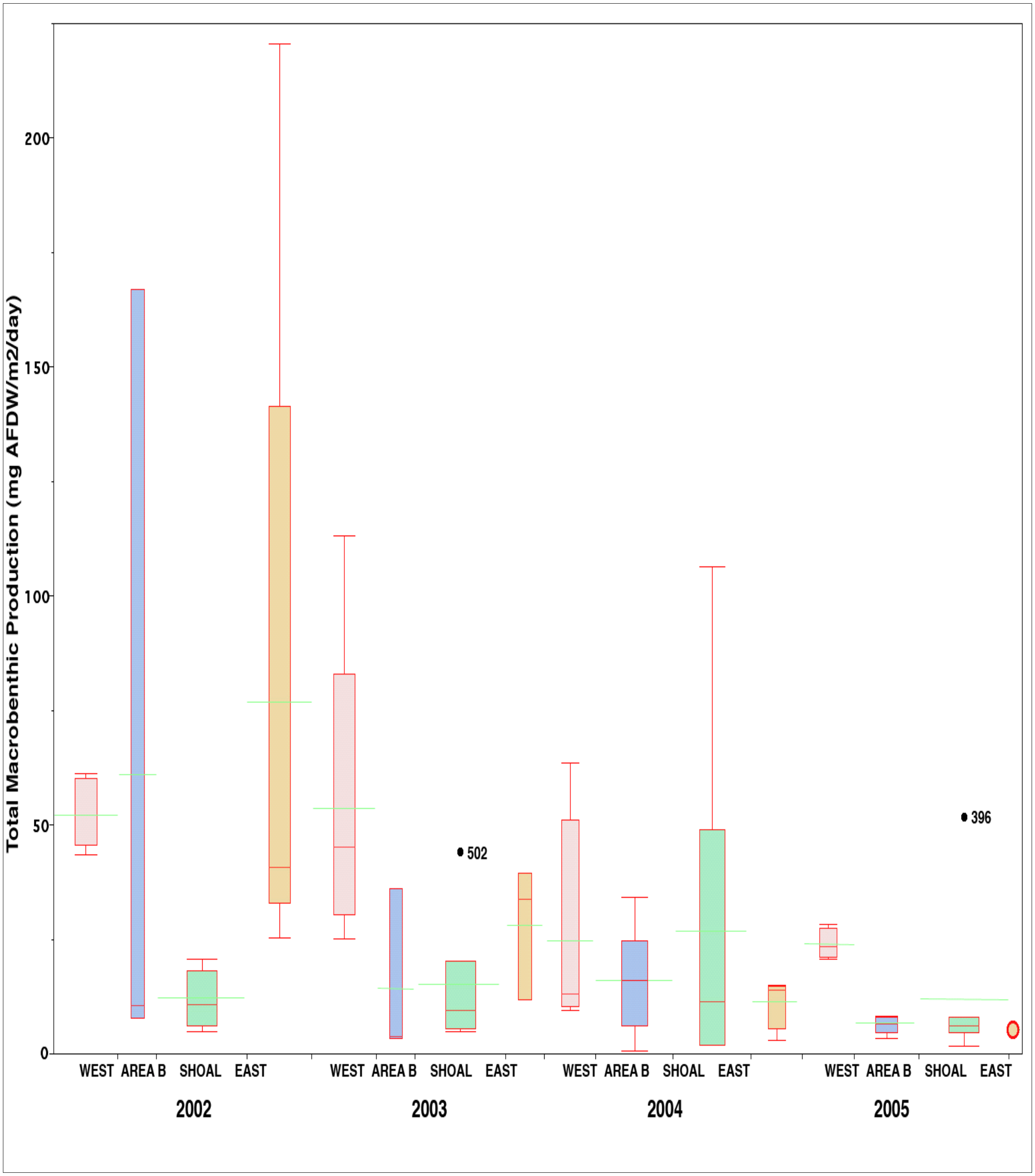

Figure 12. Total macrobenthic production by year for all Sandbridge Shoal stations. Stations 502 and 396 were high outliers in 2003 and 2005 respectively. Box is interquartile range (IR, 25th to 27th percentiles), whiskers are 1.5xIR, bar in box is median, bar extending out of box is mean. Width of box is proportional to sample size

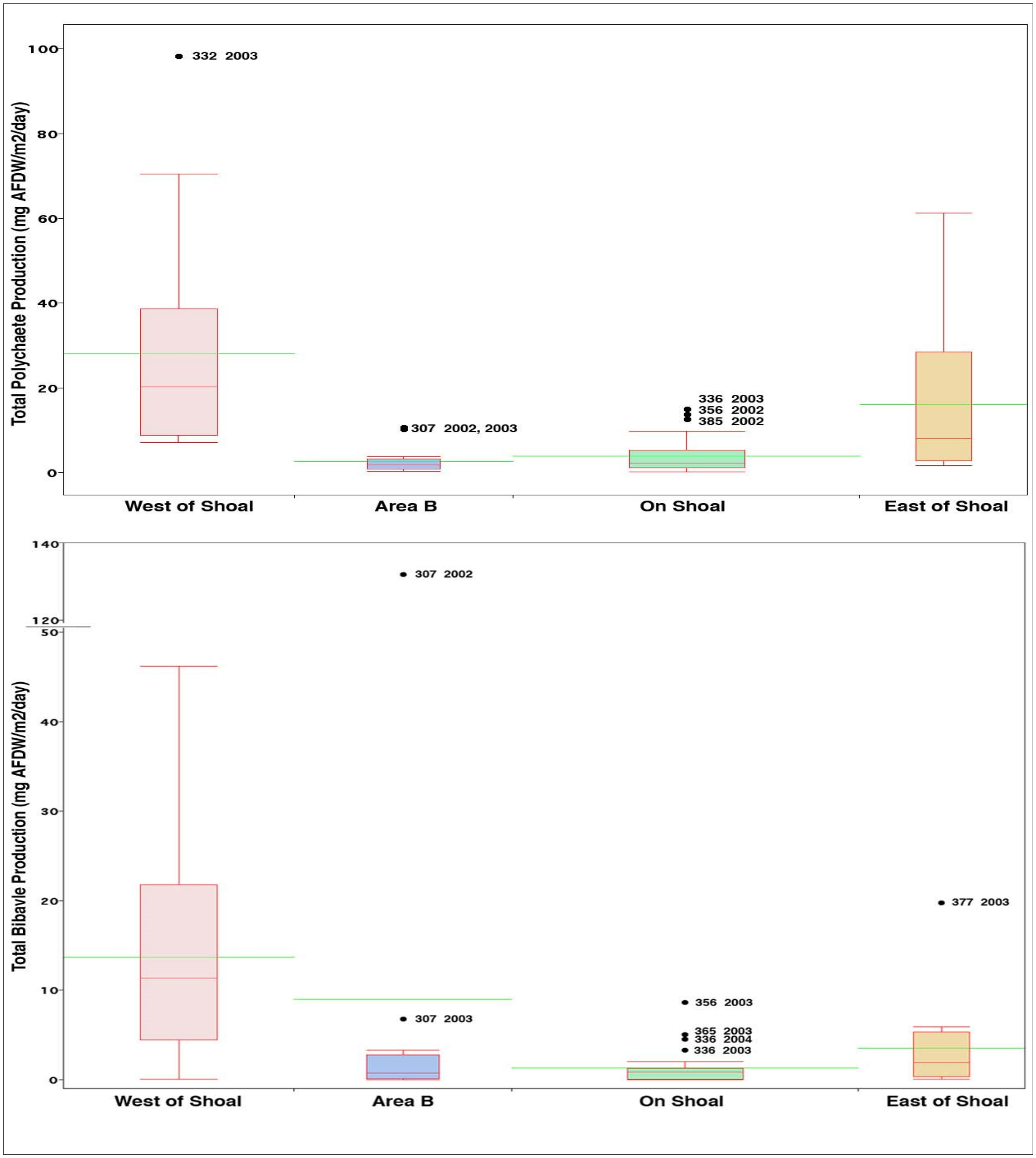

Figure 13. Total production for polychaetes and bivalves by strata at Sandbridge Shoal. Box is interquartile range (IR, 25th to 27th percentiles), whiskers are 1.5xIR, bar in box is median, bar extending out of box is mean. Width of box is proportional to sample size.

Table 4
Summary of ANOVA Tests for Daily Production for Major Taxa by Strata and Year

Mean Differences Were Tested Using Tukey-Kramer HSD
Strata with Solid Underlined Are Not Significantly Different.
W Is West of Shoal, E Is East of Shoal, B Is Borrow Area B, and SIs Top of Shoal

Taxa	Source	df	F Ratio	P value	Means Different
Polychaete	Year	1	10.01	0.002	
	Strata	3	33.44	<0.001	W E B S
	Year*Strata	3	0.65	0.586	
Bivalve	Year	1	4.95	0.029	
	Strata	3	14.34	<0.001	W E B S
	Year*Strata	3	0.99	0.402	
Lancelet	Year	1	0.12	0.732	
	Strata	3	2.25	0.090	W E B S
	Year*Strata	3	1.40	0.251	
Amphipod	Year	1	0.27	0.603	
	Strata	3	5.04	0.003	W E B S
	Year*Strata	3	1.08	0.364	
Echinoderm	Year	1	0.31	0.580	
	Strata	3	1.43	0.243	W E B S
	Year*Strata	3	0.65	0.586	
Gastropod	Year	1	0.22	0.642	
	Strata	3	6.42	0.001	W E B S
	Year*Strata	3	0.69	0.559	
Decapod	Year	1	0.28	0.601	
	Strata	3	2.80	0.046	W E B S
	Year*Strata	3	0.57	0.639	
Nemertean	Year	1	0.41	0.526	
	Strata	3	0.32	0.810	W E B S
	Year*Strata	3	1.04	0.381	
Isopod Year	1	0.00	0.981		
	Strata	3	1.54	0.211	W E B S
	Year*Strata	3	0.10	0.959	
Other Year	1	0.29	0.590		
	Strata	3	1.04	0.383	W E B S
	Year*Strata	3	1.00	0.397	
Crustacean Other	Year	1	0.00	0.991	
	Strata	3	2.76	0.049	W E B S
	Year*Strata	3	0.13	0.944	

3.5. Demersal Fish and Megafauna

For the three sampling times (2002, 2003, and 2004), a total of 1600 fishes and skates representing 12 taxa were collected at the four strata along with 1000 invertebrates representing 12 taxa. When scaled to individuals/1000 m^2 the average density of fishes and skates was 48 and 25 for all invertebrates (Table 5). The lower number of invertebrates was due to the larger net mesh relative to the body size of the invertebrates. Also, in 2002 there may have been problems with proper net set on the bottom because of the vessel used.

In terms of occurrence and abundance, the most common fishes were the sea robins, *Prionotus* spp., which occurred in all strata every year and accounted for 32% of all fishes. Spotted hake, *Urophycis regia*, was the second most abundant and accounted for 26% of the fishes even though it did not occur in any trawl in 2002. Butterfish, *Peprilus triacanthus*, were 16% of the fishes and also did not occur in 2002. Pinfish, *Lagodon rhomboides*, and smallmouth flounder, *Etropis microstomus*, occurred in all but one strata-year combinations and were 16% and 6% of the fishes, respectively. Other flounders, mostly summer flounder (*Paralichthys dentatus*), and black sea bass (*Centropristis striata*) were about 1% of the fishes. In all, the 11 fish taxa collected along with the clear nose skate, *Raja eglanteria,* are common members of the shallow continental shelf fish assemblages (Able and Fahay, 1998). The trawl also collected many mobile and sessile invertebrates (Table 5) that were not collected quantitatively by the grab. The most abundant being hermit crabs, *Pagurus* spp., and sand shrimp, *Crangon septemspinosa*, followed by squid, which were all the Atlantic brief squid *(Lolliguncula brevis)* except one individual of the Atlantic bobtail squid (*Rossia* sp.).

There were no significant differences between the four strata or between the three years in the abundance of sea robins, smallmouth flounder, or pinfish, which were the fishes with broadest occurrence on and around Sandbridge Shoal (Table 5). Variation in abundance between years and strata was large and the principal factor that lead to the lack of significant differences for the common species. Coefficient of variation (standard deviation divided by mean) for these three species was 227%, 165%, and 125% respectively. The largest variations in catch were between 2002 data and 2003-2004 data. It is likely that these catch differences were due in part to the use of different vessels that fished the trawl with different efficiencies. In 2002 a larger vessel was used, which made it harder to keep the trawl on the bottom. In 2003 and 2004 a smaller vessel was used (see methods section).

Spotted hake, which was not collected in 2002 but was common in 2003 and 2004, were more abundant in 2004 relative to 2003 but there were no significant differences between strata (2-Way ANOVA, no replication, log abundance, year $p = 0.043$, strata $p = 0.702$). Squid were the only broadly occurring invertebrate taxa to be significantly different between years with higher abundances in 2004 relative to 2002 and 2003, but there were no significant strata differences (2-Way ANOVA, no replication, log abundance, year $p = 0.006$, strata $p = 0.696$). These results assume there was no interaction between strata and years, which could not be tested because of lack of replication. While the initial trawl location within a stratum was randomly selected the replicate trawls, usually three or four, were not random and data from all trawls within a stratum were summed to provide a single stratum estimate of fish and megafauna abundance per year sampled.

Table 5
Summary of Demersal Trawl Data by Strata Around Sandbridge Shoal
All Abundances Are Standardized to Individuals/1000 m^2 Trawled

		2002					2003				2004			
Scientific name	Common name	West	West B	Area B	Shoal	East	West	West B	Shoal	East	West	Area B	Shoal	East
Fishes														
Centropristis striata	Black sea bass	22	0	0	0	31	0	0	2	0	2	1	0	0
Cynoscion regalis	Weakfish	0	0	0	0	0	2	0	0	0	0	14	1	0
Etropis microstomus	Smallmouth flounder	1	0	17	9	5	4	12	5	5	4	87	69	26
Hippocampus erectus	Sea horse	0	3	0	0	0	0	0	5	0	0	0	0	0
Lagodon rhomboides	Pinfish	10	5	8	21	108	212	0	16	15	37	110	79	2
Paralichthys spp.	Flounder	0	12	0	0	15	0	0	1	0	0	1	0	0
Peprilus triacanthus	Butterfish	0	0	0	0	0	4	33	46	145	21	172	218	5
Prionotus spp.	Sea robin	11	26	166	79	792	9	14	11	15	64	9	70	2
Syngnathus fuscus	Northern pipefish	1	0	0	0	0	0	0	0	0	0	0	0	0
Synodus foetens	Lizardfish	0	0	8	0	0	0	0	0	0	0	0	0	0
Urophysis regia	Spotted hake	0	0	0	0	0	12	10	9	0	396	80	323	210
Total		45	45	199	108	951	244	70	95	181	524	474	759	244
States														
Raja eglanteria	Clear nose skate	0	0	8	2	5	0	1	5	0	0	5	0	0
Cephalopod														
Lolliguncula & *Rossia* spp.	Squid	0	0	0	2	5	2	0	1	0	56	143	108	14
Decapods														
Cancer sp.	Cancer crab	1	0	0	0	0	19	1	3	1	0	0	0	0
Crangon septimspinosa	Sand shrimp	0	0	0	0	0	0	7	0	0	96	220	66	27
Libnia emarginata	Spider crab	2	4	0	0	0	0	0	0	0	0	0	0	2
Menippe sp.	Stone crab	0	0	0	0	0	0	0	0	0	4	0	0	6
Ovalipes spp.	Lady crab	0	0	0	2	0	0	2	0	0	0	10	0	0
Pagurus spp.	Hermit crab	0	1	0	12	23	240	13	208	73	9	98	14	36
Total		3	5	0	13	23	259	23	211	74	109	328	81	71
Echinoderms														
Asterias sp.	Starfish	0	0	0	0	0	0	0	0	0	0	0	0	2
Melita quinquiesperforata	Sand Dollar	0	0	0	9	0	0	0	5	22	0	0	0	0
Total		0	0	0	0	0	0	0	0	0	0	0	0	2
Gastropods														
Marginella apicina	Snail	0	0	0	0	0	0	0	0	1	0	0	0	0
Nassarius sp.	Mud snail	0	3	8	4	0	0	19	0	7	0	0	0	0
Polinices duplicatus	Moonsnail	0	1	0	0	0	0	2	0	0	0	0	0	0
Total		0	4	8	4	0	0	21	0	9	0	0	0	0

Also, because trawl data was not collected all years within the Area B stratum, for the purpose of analyzing trawl abundance all trawls in and just to the west of Area B were combined. This problem was related to not knowing the exact location of Area B boundaries in June 2002. Three of four trawls intended for the Area B stratum ended up being located too far to the west (Figure 4). Trawl data were also standardized to an area of 1,000 m^2 trawled using the starting and ending GPS coordinates to get total distance trawled and 4.8 m as the width of the trawl.

The overall odds of fish occurrence on Sandbridge Shoal (Shoal plus Area B strata) verses off the shoal (East plus West strata) were significantly different between years. For total fishes the odds of occurrence were about 2.5 times higher for fishes to be found off Sandbridge Shoal in 2002 and 2003. In June 2004 just 2-months post-dredging of 700000 cubic yards of sand from Area B, the odds shifted and fishes were about 2 time more likely to be found on the shoal (Cochran-Mantel-Haenszel test, df = 2, p = <0.0001). Butterfish, which did not occur in the trawls in 2002, were more likely to be off the shoal in 2003 and on the shoal in 2004 (Cochran-Mantel-Haenszel test, df = 1, p = <0.0001). Pinfish and sea robins followed this pattern except that in 2003 sea robins had on preference for on or off Sandbridge Shoal. Spotted hake was the only common species to significantly prefer being off the shoal in 2004 (Cochran-Mantel-Haenszel test, df = 1, p = 0.0004). Smallmouth flounder was the only commonly occurring fish species with no preference for being on the shoal or off of it for any of the years sampled.

In June 2004 two months after sand dredging, when on the shoal smallmouth flounder, pinfish, and butterfish showed no preference for either of the Shoal stratum or the Area B stratum. Spotted hake on the shoal showed a preference for the Shoal stratum over the Area B stratum (Test of Equal Proportions, df = 1, p = 0.002). Sea robins on the shoal preferred the Area B stratum the Shoal stratum (Test of Equal Proportions, df = 1, p = <0.0001).

Cluster analysis of the fishes by strata indicated that in 2002 the four strata grouped together primarily because butterfish and spotted hake were not collected in the trawls that year (Figure 14). Data from 2003 and 2004 formed a single group with strata and years mixed together. However, Area B in 2004 and the Shoal strata for 2003 formed a subgroup based on common occurrence of fish species (Table 5). The overall lack of a strong association of fishes between strata appeared to be related to the low variation in sediment grain-size between strata, and generally similar bed roughness and low occurrence of biogenic structure over the study area. There were no indications that fish assemblage using the Area B stratum was different than that in the other three strata.

3.6. Gut Content

Gut content of the more abundant fishes was analyzed to determine trophic linkages with invertebrate communities and to assess possible effects of sand dredging. Overall, Sea Robins had the most guts examined with 167 guts from fish that averaged from 62 to 106 mm fork length. A total of 123 guts from spotted hake that averaged 100 to 195 mm, 114 guts from pinfish that averaged 53 to 99 mm, 72 smallmouth flounder guts from fish that averaged 64 to 126 mm, and 49 guts from butterfish that were 42 to 45 mm fork length were examined. A smaller number of guts from black sea bass (16), weakfish (9), and other flounder (15) were also examined. All these

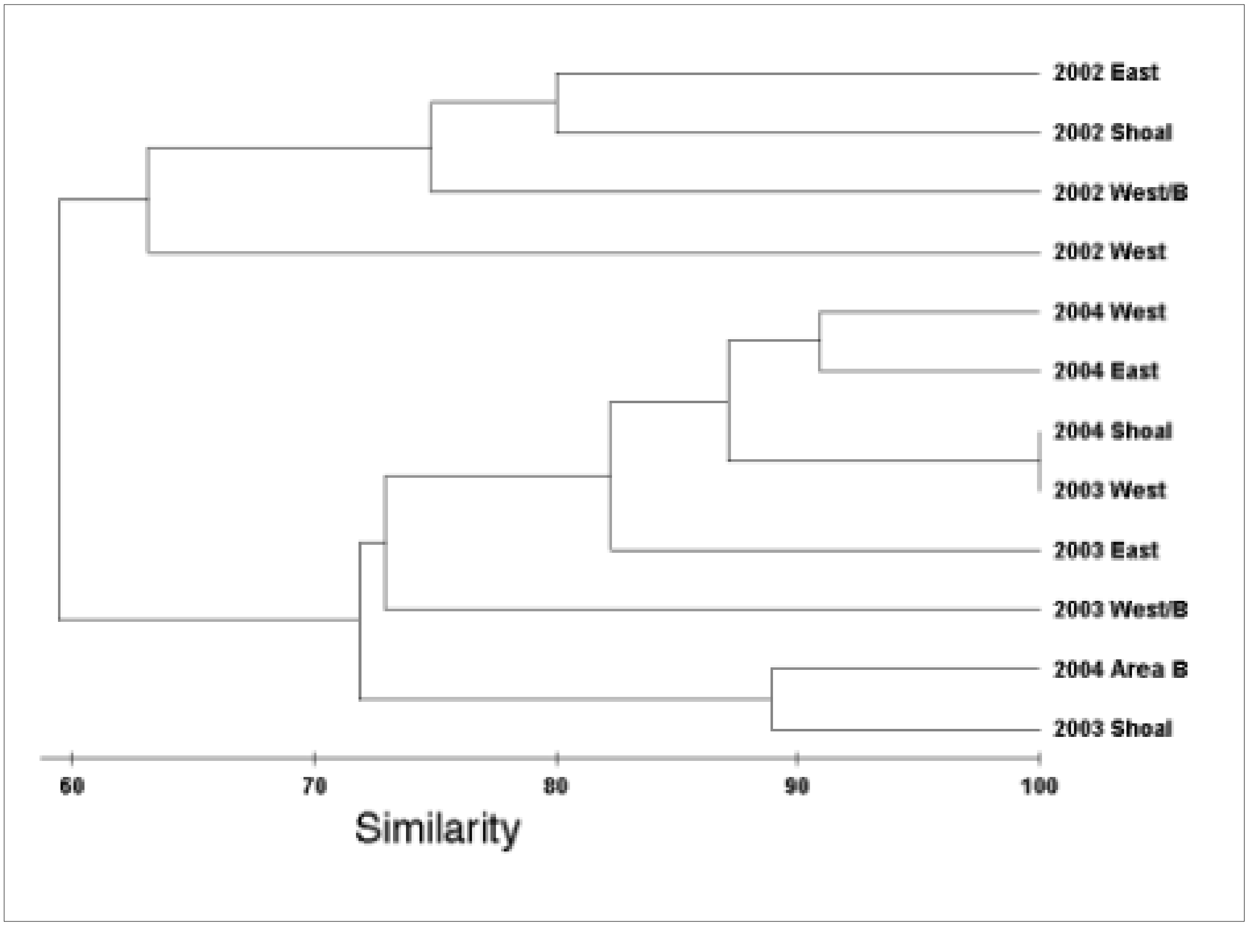

Figure 14. Cluster analysis of the fishes by strata at Sandbridge Shoal.

individuals represented young of the year or year class +1 individuals and were considered to be juveniles.

A total of 58 taxa were identified from the guts of these fishes (Appendix F) that were summarized into eight major taxa/life-history groups (Table 6). The most numerous food items were epifaunal or near surface infaunal species in the decapod, amphipod, and mysid taxonomic groups and accounted for 84% of all gut items and 59% of all gut biomass (Figure 15). About 3% of the food items and 27% of the gut biomass were grouped into a category called other, which consisted mainly of unidentifiable organic bits plus rarer taxonomic groups such as anemones and nemerteans.

There were differences between fish species in their diets even though mysids and other planktonic larvae were the most abundant food item for all species examined, except butterfish that ate about an equal proportion of mysids and other crustaceans (Table 7). Only pinfish and flounder obtained the majority of their food (biomass) from mysids and other planktonic forms. Decapods, mainly sand shrimp, were the bulk of the diet for spotted hake, black sea bass, weakfish, and sea robins. Polychaetes followed by lancelets and amphipods were most important in the diet of smallmouth flounder. Polychaetes and molluscs, mostly bivalves, were also important to black sea bass (Figure 15).

Differences in feeding patterns by strata were examined for 2004 data for spotted hake, sea robins, smallmouth flounder, and pinfish, as this was when the trawls were in Area B about two months after sand dredging and stomachs were analyzed from all four strata, except for pinfish that were not collected in the East stratum. Pinfish primarily ate mysids and other planktonic forms in all strata examined (Figure 15). For spotted hake, sea robins, and smallmouth flounder there were no significant differences in the percentage of biomass consumed by strata from the various taxonomic groups, but there were significant differences in what the fish species ate. Spotted hake consumed higher percentages of decapods (2-way ANOVA, no replication, arc sin transformation, $df = 2$, $p = 0.003$), sea robin consumed higher percentages of mysids and other planktonic forms ($p = 0.027$), and smallmouth flounder consumed higher percentages of polychaetes ($p = 0.014$) (Figure 15).

Epifaunal species, summarized as decapods and mysids primarily, were the most common food item in the stomachs of the fish examined indicating that benthic habitats with higher numbers of epifauna and crustaceans in general, would have higher resource value then habitats without epifauna. The presence of abundant epifauna, such as mysid shrimp and sand shrimp, would then attract fishes and provide more resource value relative to areas with little to no epifauna. The field design employed did not sample mysids at all but the trawls collected were adaquate for quantifying most of the decapods. The second most abundant food item was amphipods, mostly either surface tube builders like *Ampelisca* spp. or shallow free burrowing infaunal species like the haustorids. Amphipod population were adequately quantified with the grab samples.

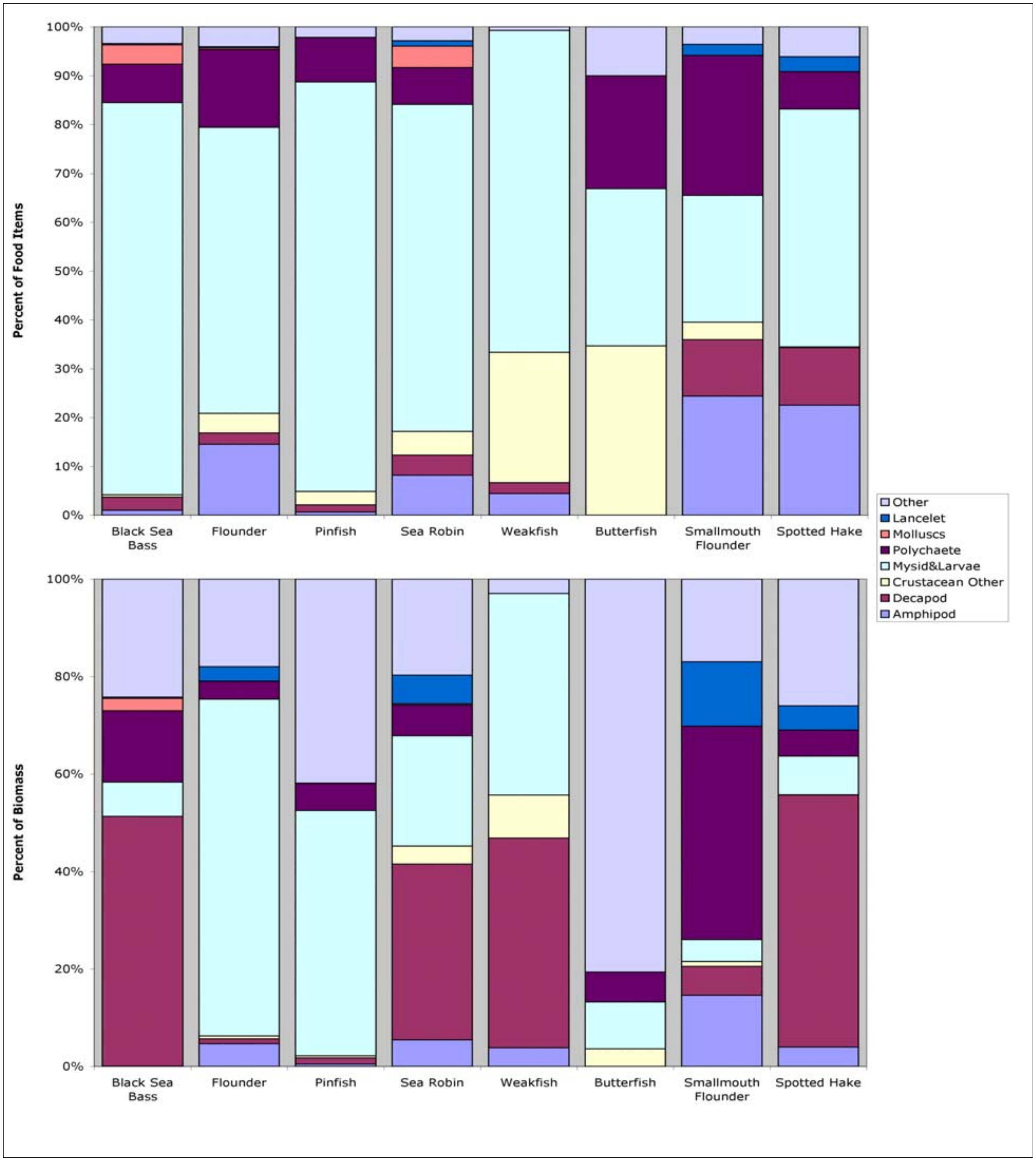

Figure 15. Gut content as percent of food items and percent biomass by species for common fishes trawled at Sandbridge Shoal.

Table 6
Summary of All Gut Content for Fishes from the Sandbridge Shoal

Percent of Food Items in Gut:

Fish	Amphipod	Decapod	Crustacean Other	Mysid&Larvae	Polychaete	Molluscs	Lancelet	Other Taxa
Black Sea Bass	1.0	2.7	0.5	80.3	7.9	3.9	0.2	3.4
Flounder	14.5	2.3	4.1	58.6	15.9	0.3	0.3	4.1
Pinfish	0.6	1.5	2.8	83.9	9.0	0.1	0.0	2.2
Sea Robin	8.2	4.1	4.9	67.0	7.6	4.4	1.1	2.8
Weakfish	4.4	2.2	26.7	65.9	0.0	0.0	0.0	0.7
Butterfish	0.0	0.0	34.7	32.2	23.1	0.0	0.0	10.1
Smallmouth Flounder	24.4	11.6	3.6	26.0	28.7	0.0	2.3	3.6
Spotted Hake	22.5	11.8	0.2	48.7	7.7	0.0	3.1	6.1

Percent Biomass of Food in Gut:

Fish	Amphipod	Decapod	Crustacean Other	Mysid&Larvae	Polychaete	Molluscs	Lancelet	Other Taxa
Black Sea Bass	0.0	49.6	0.0	5.9	13.3	11.3	0.4	19.5
Flounder	4.7	1.1	0.6	67.7	3.9	0.1	4.7	17.1
Pinfish	0.5	1.5	0.4	50.6	6.1	0.3	0.0	40.6
Sea Robin	5.1	37.7	3.6	20.4	6.2	1.4	8.5	17.2
Weakfish	3.6	46.4	9.0	38.4	0.0	0.0	0.0	2.7
Butterfish	0.0	0.0	4.0	9.8	6.8	0.0	0.0	79.4
Smallmouth Flounder	13.3	6.1	0.9	4.0	42.2	0.0	18.9	14.6
Spotted Hake	3.5	51.7	0.0	6.8	5.0	0.0	6.8	26.1

Mean Weight of Individual Food Item (mg AFDW/item):

Fish	Amphipod	Decapod	Crustacean Other	Mysid&Larvae	Polychaete	Molluscs	Lancelet	Other Taxa
Black Sea Bass	0.08	34.76	0.06	0.14	3.20	5.47	3.00	10.75
Flounder	0.23	0.35	0.11	0.83	0.18	0.17	11.75	3.02
Pinfish	0.39	0.51	0.08	0.30	0.33	2.08		9.33
Sea Robin	0.58	8.67	0.70	0.29	0.77	0.30	7.18	5.70
Weakfish	0.24	6.12	0.10	0.17				1.05
Butterfish			0.03	0.09	0.09			2.36
Smallmouth Flounder	0.66	0.64	0.32	0.19	1.79		10.07	4.97
Spotted Hake	1.11	31.40	1.17	1.01	4.70		16.01	30.55

Table 7
Summary of Nitrogen and Carbon Stable Isotope Ratios for Fishes, Skates, and Invertebrates Collected On and Around Sandbridge Shoal
All values are parts per mil (‰)

		Nitrogen				Carbon			
Taxa	N	Min	Max	Mean	SD	Min	Max	Mean	SD
Fishes and Skates:									
Black Sea Bass	6	11.4	13.2	12.4	0.8	-19.3	-17.8	-18.7	0.5
Butterfish	17	11.6	14.1	12.6	0.7	-22.1	-19.4	-20.7	0.8
Flounder	9	12.2	14.1	12.8	0.6	-19.7	-18.0	-19.0	0.5
Pinfish	25	11.6	14.3	12.6	0.8	-24.1	-17.7	-19.9	1.5
Sea Robin	47	10.9	14.0	12.5	0.8	-21.2	-17.2	-18.9	0.9
Skate	7	9.6	13.0	11.8	1.4	-18.0	-16.7	-17.1	0.5
Smallmouth Flounder	33	10.9	15.1	12.7	0.8	-21.5	-17.3	-18.5	1.1
Spotted Hake	36	11.4	15.1	13.3	0.8	-22.9	-17.3	-18.7	1.2
Weakfish	3	11.5	14.5	13.3	1.6	-19.9	-17.1	-18.8	1.5
Menhaden	1	11.8	11.8	11.8	.	-20.2	-20.2	-20.2	.
Pipefish	2	8.3	11.3	9.8	2.1	-19.1	-18.9	-19.0	0.1
Invertebrates:									
Amphipoda	56	5.0	11.1	8.2	1.5	-22.6	-17.3	-19.9	1.4
Anemone	1	10.7	10.7	10.7	.	-21.2	-21.2	-21.2	.
Bivalva	43	3.5	9.5	7.4	1.5	-22.4	-9.2	-18.3	3.2
Decapoda	117	8.0	15.0	11.0	1.4	-23.5	-16.0	-18.8	1.2
Echinoidea	11	1.3	13.4	8.7	3.1	-20.2	-9.6	-17.8	2.9
Gastropoda	38	2.2	21.8	11.3	3.0	-22.5	-9.0	-17.4	3.6
Hemichordata	1	12.2	12.2	12.2	.	-18.8	-18.8	-18.8	.
Holothuroidea	3	8.0	12.1	10.6	2.2	-19.1	-17.8	-18.6	0.7
Isopoda	7	8.4	16.0	11.0	2.7	-21.0	-17.6	-19.1	1.1
Lancelets	23	7.7	10.0	8.7	0.5	-20.9	-18.2	-19.7	0.8
Nemertean	2	10.5	12.4	11.4	1.3	-18.2	-17.8	-18.0	0.3
Polychaeta	91	7.0	16.5	11.5	1.7	-22.8	-15.7	-18.6	1.3
Squid	7	11.0	13.0	12.1	0.8	-20.7	-19.2	-19.8	0.5
Tunicates	2	6.0	9.0	7.5	2.1	-24.3	-21.0	-22.6	2.4

3.7. Stable Isotope Analysis

Stable isotope signatures of both carbon and nitrogen for the fauna on and around Sandbrige Shoal ranged broadly (Table 7). For fishes on average, pipefish had the lowest nitrogen ratios of 9.8 ‰ and spotted hake and weakfish the highest at 13.3 ‰. For invertebrates, bivalves had the lowest nitrogen ratios of 7.4 ‰ and squid the highest at 12.1‰. Lower values for nitrogen ratios would indicate the organism was depleted in nitrogen and closer to the bottom of the food web. Conversely, the higher nitrogen ratios would indicate enrichment in nitrogen and that the organism was higher up in the food web. For stable carbon ratios, the more negative the value the closer the organism is to the bottom of the food web and conversely the less negative the value the higher up the organism is in the food web (Peterson 1999). For stable carbon ratios, tunicates were most depleted at –22.6 ‰ and skates the most enriched at –17.1 ‰. Over the three years that stable isotopes were measured, none of the taxonomic groups had significant differences in both stable isotope ratios. There were also no significant differences between strata for either stable isotope ratios for the taxonomic groups. There were only two species that had significant differences between years for carbon ratios. Butterfish had higher more enriched (higher values) carbon ratios in 2004 relative to 2003, no butterfish were collected in 2002, (2-way ANOVA, no replication, year df = 1, p = 0.046, strata df = 3, p = 0.323) and sea robin had more enriched carbon ratios in 2004 relative to 2002 and 2003 (2-way ANOVA, no replication, year df = 2, p = 0.002, strata df = 3, p = 0.071). The implication of enriched carbon ratios would be that in 2004 butterfish and sea robins were eating higher on the food web relative to 2003. In 2004, sea robins ate significantly more biomass of mysids and other planktonic forms. Unfortunately, we did not collect mysids for any analysis.

The gut content analysis and general pattern of isotopic enrichment form invertebrates to fishes confirms that the demersal fishes on and around Sandbridge Shoal are feeding and relying primarily on epibenthic or surface dwelling invertebrates (Figure 16). Assessing the isotopic differences between the fishes and their diets, and applying a trophic enrichment factor can make an estimate of the trophic enrichment factor for nitrogen. For the Sandbridge Shoal data, there was an average enrichment in nitrogen of 3.3‰ from primary consumers, the filter feeding invertebrates represented by amphipods, bivalves, tunicates, and lancelets, to secondary consumers, the predatory invertebrates represented by decapods, gastropods, and nemerteans. If fishes at Sandbridge Shoal were assumed to obtain half their food form primary consumers and half from secondary consumers than their enrichment factor would be 3.2‰. These values are within the range of 3.0 to 3.8‰ for enrichment of nitrogen ratios found in other ecosystems (Hobson and Welch 1992, Melville and Connolly 2003). The trophic level (TL) of a consumer was than estimated from the nitrogen ratios (N) according to the relationship:

$$TL = 1 + (N - 5.4) / 3.2$$

Overall the trophic web for Sandbridge was short and it appeared that the primary consumers (TL 2) directly supported both the secondary consumers and fishes (TL 3, Table 9). The fishes in turn also preyed on the secondary consumers. The top trophic level species, spotted hake and weakfish, at TL 3.5 were likely preying on other fishes.

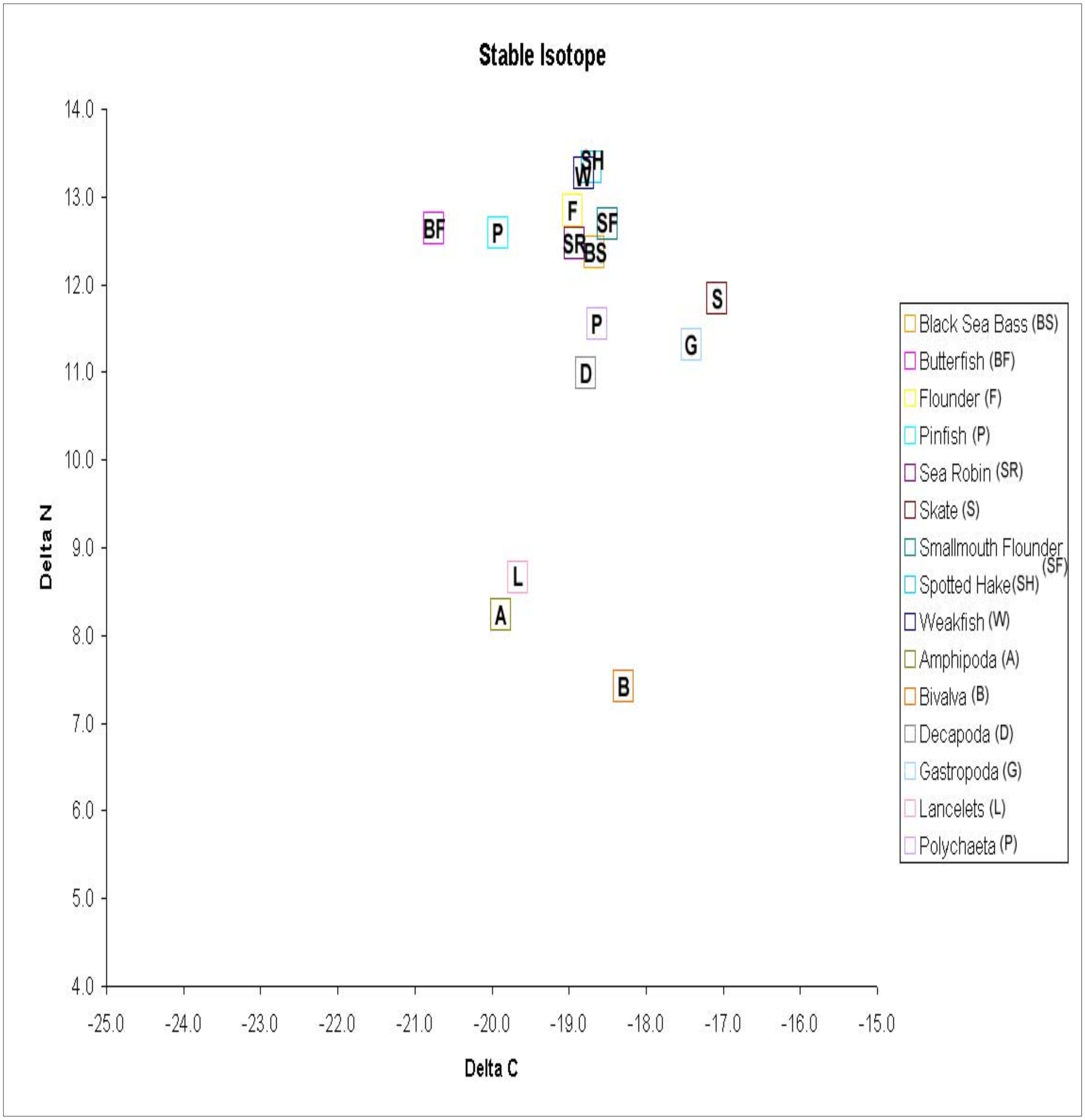

Figure 16. Stable isotope results for macrofauna and fishes from Sandbridge Shoal. Means for all years.

4. Discussion

4.1. Benthic Habitats Around Sandbridge Shoal

Sediment surface substrates on and around Sandbridge Shoal were all dominated by physical processes, primarily currents either wave or tidally induced, as evidenced by the universal presence of bedforms, primarily smooth-crested wave-orbital ripples. Substrates were predominantly fine to medium sands with little to no silt-clay content. The area to the west of Sandbridge Shoal had sediments that were finer sands and contained 6% silt-clay. The shoal itself and the area to the east had coarser sediments that averaged medium-sand. There was little evidence that biological processes structured surface sediments. Tubes and other biogenic structures were not encountered in high densities but occurred sporadically on and off the shoal. The area to the west of the shoal tended to have more biogenic structures, which was related to the finer sediments with a higher silt-clay content, but there did not appear to be any highly structured substrate surfaces in the area of Sandbridge Shoal, either biological or physical. This is in contrast conditions in 1996 and 1997 when Cutter and Diaz (1998) found biologically dominated habitats the west, east, and south of Sandbridge Shoal. It is likely that a combination of storm events, which periodically completely rework surface sediments, and benthic recruitment events, which when large and successful can structure surface sediments, are constantly shaping and reshaping the substrate.

The physically dominated substrates throughout the area were habitat to macrobenthic and fish populations. The relative uniformity of the substrate lead to about equal habitat value throughout the study area. There were few instances where one taxonomic group preferred one of the four strata over another. The four strata sampled were the area west and east of the shoal, and the top of the shoal divided into borrow Area B to the north and the rest of the shoal to the south (Figure 2). The area west of the shoal was the only habitat to have higher value to macrobenthos, as abundances in this habitat were significantly higher. There were also differences in macrobenthic production between strata with east and west areas having about 2.5 times higher production relative to the top of the shoal. Cutter and Diaz (1998) also found secondary production to be higher off the shoal relative to on shoal. There were also no big differences in dermersal fish habitat on and off the shoal. Fishes used all habitats, but the odds of fish being present on verses off Sandbridge Shoal varied through time. For total fishes the odds of occurrence were about 2.5 times higher for fishes to be found off Sandbridge Shoal in 2002 and 2003. In 2004, the odds shifted and fishes were about 2 time more likely to be found on the shoal. For the most abundant fishes (sea robins, smallmouth flounder, pinfish, spotted hake) there were no differences in habitat utilization. In all, the 11 fish taxa collected along with the clear nose skate are common members of the shallow continental shelf fish assemblages and have broadly preferences of various sandy habitats (Able and Fahay 1998, Diaz *et al.* 2003).

From year to year there appeared to be a regional trend in the total abundance of macrofauna in that populations would rise and fall across all strata. In 1996, abundance averaged 1,600 individuals/m^2 and in 1997, 1400 individuals/m^2 (Cutter and Diaz 2000). By 2002, abundances averaged 3,700 individuals/m^2 and declined to 2,300 individuals/m^2 in 2005. Overall, the community composition on and around Sandbridge Shoal for 2002-2005 was similar to previous work in the area (Cutter and Diaz 1998) and for the shallow continental shelf habitats along the Atlantic Coast (Day *et al.* 1971, Maurer *et al.* 1976, Boesch 1979, and Dauer 1981). These authors reported similar taxa composition for similar depths and sediment types.

4.2. Assessing Effects of Sand Dredging

In total, two sections of Sandbridge Shoal have been dredged four time from 1996 to 2003. Area A on the south end of the shoal had 841,500 m^3 (1,100,000 yd^3) dredged in 1998. Area B on the north end of the shoal had 619,500 m^3 (810,000 yd^3) dredged in 1996, in 2002 another 1,530,000 m^3 (2,000,000 yd^3) dredged, and in 2003 another 535,500 m^3 (700,000 yd^3). In summary, a total of 3,527,000 m^3 (4,610,00 yd^3) of sand has been removed for the Sandbridge Shoal with most of the sand taken from the northern end of the shoal (Area B).

In spite of these removals, no negative environmental impacts have been observed for macrobenthos or demersal fishes. Data collected in 1996 and 1997 by Cutter and Diaz (1998) indicated there were no differences in macrobenthos populations between borrow Area B and the rest of the shoal or habitats to the east and west. The biggest differences in benthos were related to the finer sediments found in the habitat to the west of the shoal. Similarly, macrobenthic data collected during this study from 2002 to 2005 did not find any differences due to dredging within Area B. The biggest differences in benthos were again related to the finer sediments found in the habitat to the west of the shoal.

Demersal fish data were collected from 2002 to 2004 and did not have a strong sand dredging signal. Prior to the last dredging event in Area B, fishes were broadly distributed over the area and more likely to be present off the shoal than on it. In June 2004 just 2-months post-dredging of 535,500 m^3 (700,000 yd^3) of sand from Area B, the odds shifted and fishes were about 2 time more likely to be found on the shoal. This pattern held for all the common species except spotted hake, which prefer being off the shoal in 2004, and smallmouth flounder, which had no preference for being on the shoal or off of it for any of the years sampled. When only the fishes on top of the shoal in 2004 were evaluated, smallmouth flounder, pinfish, and butterfish showed no preference for either the dredged Area B or the rest of the shoal top and were just as likely to occur in either habitat. Spotted hake on the shoal showed a preference for the shoal top over the dredged Area B, while sea robins preferred the dredged Area B over the rest of the shoal top. In all, no evidence of impact to demersal fishes.

Given that population level changes are difficult to detect for relatively small areas, we focused on possible trophic shifts that may be related to sand dredging buy collecting data on fish feeding preferences, secondary production, and stable isotopes of nitrogen and carbon. There were differences between fish species in their diets with mysids and other planktonic larvae being the most abundant food items. Other important prey were decapods, mainly sand shrimp, amphipods, polychaetes, lancelets, and molluscs. Differences in feeding patterns were examined for 2004 data for spotted hake, sea robins, smallmouth flounder, and pinfish but there were no differences between what was eaten between habitats. The trophic value of the dredged Area B was the same as the other three habitats examined. The major food items consumed in all habitats and by all fishes were epifaunal species, mostly decapods and mysids. The second most abundant food item were surface dwelling or shallow burrowing amphipods.

Stable isotope signatures of both carbon and nitrogen for the fauna on and around Sandbrige Shoal were typical for marine food webs (Peterson 1999). The general pattern of isotopic enrichment form invertebrates to fishes combined with gut content analysis confirmed that the demersal fishes on and around Sandbridge Shoal were feeding and relying primarily on the local epibenthic or surface dwelling invertebrates, but there were no significant differences between habitats for either stable isotope ratios for any of the taxonomic groups. Based on stable isotopes data, there were two trophic levels beyond the primary producers present on or around Sandbridge Shoal. Basically the demersal food web for Sandbridge was short and it appeared that the primary consumers at the second trophic level directly supported both the secondary consumers and fishes at the third trophic level (Table 8). The fishes in turn also preyed on the secondary consumers and other fishes. The top trophic level species appeared to be spotted hake and weakfish.

5. Evaluating the Biological Monitoring Protocols

The biological monitoring protocols developed by Research Planning *et al.* (2001) for the MMS Sand and Gravel Program (Drucker *et al.* 2003) to assess impacts from sand dredging on the outer continental shelf focus on a broad range of benthic effects and methods from infaunal communities to demersal fish feeding. It must be pointed out that the protocols are guidance to scientists already knowledgeable in benthic and fisheries field/laboratory methods, and are not a manual for how to conduct such studies. In this section, proposed methods for assessing benthic communities and their trophic relationships to fish will be evaluated. A summary of the protocol data requirements are presented in Table 9.

The protocols recommend the use of a stratified field design to reduce variation and increase statistical power for a given unit of effort with two requirements. One, that both infauna and fishes be sampled within each stratum, and two, that defined strata should be present in both dredged area and reference area. This basic approach was implemented at Sandbridge with the previous work of Cutter and Diaz (1998), which had surveyed sediments and biota over a broader area mostly north of Sandbridge Shoal, providing the necessary background data for defining strata boundaries. Four strata were established based on location relative to the shoal and the designated borrow area, Area B (Figure 2). The Norfolk District Corps of Engineers provided the boundary coordinates for Area B. The boundaries for the other strata were restricted to be no more than about 2 to 3 times the area of Area B. This was to keep the area balanced between strata. The other strata were the remainder of the top of Sandbridge Shoal (Shoal) to the south of Area B, the area east of the shoal (East), and the area west of the shoal (West) (Figure 2).

All types of data (sediment, infauna, and fishes) were collected within each stratum, however, the recommendation to have both dredged and not dredged areas within each defined stratum proved to be impractical. Basically, the dredged area (stratum Area B) was too small to subdivide and did not contain the range of benthic habitat known to exist in the Sandbridge Shoal area. This may be a common problem for other sand dredging projects. Typically the target dredge

Table 8
Trophic Level of Consumers at Sandbridge Shoal Based on Stable Nitrogen Isotope Ratios.
Primary Producers Are Considered to Be Trophic Level 1
(See Text for Explanation)

Taxonomic Group:	Trophic Level
Primary Consumers:	
Bivalva	1.6
Tunicates	1.7
Amphipoda	1.9
Lancelets	2.0
Secondary Consumers:	
Decapoda	2.7
Gastropoda	2.8
Nemertean	2.9
Squid	3.1
Mixed Primary and Secondary Consumers:	
Polychaeta	2.9
Fishes and Skates:	
Black Sea Bass	3.2
Sea Robin	3.2
Pinfish	3.2
Butterfish	3.3
Smallmouth Flounder	3.3
Flounder	3.3
Weakfish	3.5
Spotted Hake	3.5
Skate	3.0

Table 9
Summary of Protocol Recommendations on Data to Collect and
Level of Processing for Assessing Biological Impacts of Sand Dredging

Collect Data on:	Data Processed to:	Gear:
Infauna Abundance	Individuals/m^2 by Taxon	Grab
Infauna Biomass	g AFDW/m^2 by Taxon, Secondary Production	Grab
Fish and Megafauna Abundance	Individuals/1000m^2 by Species	Trawl
Fish Feeding Habits	Taxon Count and Biomass by Species Taxon Percent of Food Items	Trawl
Fish Stable Isotope	Carbon and Nitrogen by Species	Trawl
Food Item Stable Isotope	Carbon and Nitrogen by Taxon	Grab/Trawl
Sediment Grain-Size	Mean Phi, Percent Sand, Silt, Clay	Grab
Sediment Total Organic Carbon	Percent	Grab

area is small and selected based on its suitability to provide sand of a uniform characteristic. We recommend that consideration be given to making the dredged area a stratum on its own. The four strata we defined were intended to act in a manner similar to the Before-After-Control-Impact (BACI) design where the East, West, and Shoal strata would act as reference areas to be compared to Area B the dredged stratum. If resources permitted, we would have defined additional reference strata to improve the chances of detecting disturbance form dredging.

Within a stratum, the location of grab stations and the initial trawl station was random, which is a critical requirement of most statistical tests including analysis of variance (ANOVA). The randomization of locations for point sampling, such as with grabs, within a stratum is straight forward and not constrained by the gear itself. For trawls, however, it was not possible to randomize all replicate trawls within the boundaries of a stratum for two reasons; first, the area of each stratum was relatively small and, second, deployment of the trawl and trawl track were constrained by wind and current conditions. Thus only the location of the first trawl was random and subsequent trawls within a stratum were related to the position of the first trawl. This restriction on the data did not allow for testing interaction between strata and year as there was no statistical replication within a stratum. The protocols point out that significant interaction between strata and time would be a primary indicator of a dredging effect, assuming, of course, that data were collected pre- and post-dredging. Given the constraints on randomizing trawls within a small area, standard two-way ANOVA could not be applied as at least two replicates per stratum are required to assess interaction (Zar 1999). Trawl data were analyzed with a two-way ANOVA without replication, sometimes referred to as blocked ANOVA without replication, which can test for factor effects but not interaction of factors (Zar 1999). Four trawls were collected within each stratum to assure sufficient fishes to characterize stratum assemblages with all fishes and megafauna collected summed for analysis.

The level of replication for grab samples was determined from infaunal data collected in 1996 and 1997 by Cutter and Diaz (1998). Based on the variability of major taxa we found that seven replicates would be sufficient to achieve a statistical power of 80% with a 95% confidence interval in a one-way ANOVA with strata or year as a factor and for a two-way ANOVA with both strata and year as factors, three replicates would be sufficient for the same level of power and confidence (Bowman and Kastenbaum 1975). The one-way, two-way with replication, and two-way without replication ANOVA analysis strategy worked well on the Sandbridge Shoal data. For the one-way analyses final replication for a factor level ranged from 13 for comparing strata to 20 for comparing years. There were issues with the uneven replication of grab samples between strata that would tend to lower the power of our tests. The biggest differences in replication came in 2005 when only one grab was collected in the East stratum. Particular attention should be given to balancing the design as much as possible. In our case, weather in 2005 cut our field sampling short with just the two East stratum grab left to collect.

For sampling infauna and sediments we used two different grab types, primarily to assess the effectiveness of larger verses smaller grabs at estimating major taxa abundance and biomass. In 2002 and 2003 we used a 0.1 m^2 Smith-MacIntry grab and in 2004 and 2005 a 0.04 m^2 Young modified Van Veen grab. The effort to process a 0.1 m^2 verses a 0.04 m^2 grab is about 3-times higher and also comes with a significantly higher cost. We found the smaller grab to be adequate for characterizing infauna at the major taxa level. In balancing effort, design efficiency, and cost, it would better to take more small-grab samples than fewer large-grab samples. The protocol recommendation to use a 0.1 m^2 grab should be modified to include the use of smaller grabs.

For fishes, emphasis was placed on juveniles as they have higher fidelity to habitat type. A 4.9 m (16-foot) otter trawl with 2.5 cm (1 inch) stretched mesh and a 0.5 cm (3/16 inch) mesh liner was used to collect fishes and megafauna. This is not the type of net recommended in the protocols, which describe large nets more suitable for characterizing adult fishes. It is well established in the fisheries literature that adults are less habitat specific than juveniles (Able and Fahay 1998, Steves *et al.* 1998). Given that the objectives of the protocols are to detect habitat related impacts, emphasis needs to be placed on the juvenile life history stage, which is most habitat specific.

A problem was encountered with the trawl sampling that needs specific attention when designing future studies. In 2002, trawling was conducted from the 65-foot long r/v Bay Eagle and in 2003 and 2004 a smaller vessel that better matched to the net size was used, the 46-foot r/v Langle. We cannot be certain that the trawl fished with the same effiency between all years. For example, fishes that should have been present in all strata were not collected by the trawl in 2002, however, they were observed by the video sled in 2002, for example spotted hake. A sampling issue like this certainly compromises dredging impacts and long-term trend assessment. Fortunately, for our study the key years for assessing impacts were 2003 and 2004, which did have more comparable trawl data. As per the protocols, the start and end points of each trawl were located with GPS, which were used to calculate total length of each trawl for standardizing catch to unit area.

The lack of statistical replication limited the application of ANOVA to the trawl data. With two factors (strata and year) we were able to apply two-way ANOVA without replication, but could not test for interaction. This problem may be difficult to resolve when strata are defined to encompass relatively small areas. For example, our dredged stratum Area B was triangular with an area of approximately 2.2 km2. Given wind and current constraints on trawling direction and the length of a single trawl, which may be up to 1 km, it may not be possible to randomize all trawls within a stratum. To overcome this problem statistical tests with different assumptions and data requirement need to be applied. In our study we used the nonparametric Fisher Exact test and Cochran-Mantel-Haenszel tests to assess differences between strata in the odds of fishes being present (Agresti 1990). In ANOVA what is tested is equality of means. The basic assumption of randomness in Fisher Exact and Cochran-Mantel-Haenszel tests was met by randomly locating the first trawl within a stratum. Replication for these tests is at the individual fish level. The assumption being that a fish's presence in a particular stratum is independent of all other fishes and strata.

Grab samples and trawls were processed according to the protocols and taxonomy done to the major group level for invertebrates and to species level for fishes. For major group taxonomy, it is not necessary to use a relaxing agent, such as magnesium chloride or propylene phenoxytol. Relaxing agents are used when the fine structures of soft-bodied invertebrates are needed for species level identifications. In addition, propylene phenoxytol is no long used by benthic scientists as it is too difficult to obtain and its toxicity to humans has not been fully investigated. Considering the focus of the protocols on assessing impact of sand dredging on benthic trophic transfer to fishes, species level taxonomy is not essential. For Sandbridge Shoal eleven taxa categories were used (Table 4), which provided sufficient resolution of secondary production and trophic support to fishes for assessing impacts.

Stable isotope samples were collected in 2002, 2003, and 2004 from both grabs and trawls, and included all major taxonomic groups and all common fish species. Samples for stable isotopes were processed according to the protocols with the exception that invertebrates were only given 2 to 3 hour to purge their guts and not 24 hours. Care was taken not to include gut contents when processing individuals for stable isotope analysis. Secondary production was estimated using published relationships between biomass, mean individual weight, and productivity. Among the relationships considered, Edgar's (1990) equation was selected because it estimates production over a small time step (per day) from mean individual weight and temperature. Other methods more suitable to use when more than one estimate of biomass per year is collected would be Brey (1990) or Tumbiolo and Downing (1994). Wilber and Clarke (1998) assessed the various secondary production equations relative to dredging impact assessment in Galveston Bay, Texas, and found that Brey's (1990) equations, which do not consider environmental variables, produced lower estimates relative to Tumbiolo and Downing's (1994) and Edgar's (1990) equations that do include the effect of temperature, and depth in the case of Tumbiolo and Downing (1994).

To address the long-term and BACI nature of the protocols, it was our intention to collect Spring/Summer and Summer/Fall data over a two-year period. As storms and requests for sand cannot be predicted, it turned out that another dredging event occurred in the middle of our initial study. Emphasis of the protocols on an adaptive management strategy should be able to cope with these types of unforeseen events. What actually occurred over the four-year period of our study is a good example of adaptive management where our field design and effort were redirected to extract as much environmental information on dredging impacts as possible. The first pre-dredging survey occurred in June 2002, about 6-months prior to dredging 1,530,000 m^3 (2,000,000 yd^3) of sand from Area B between January and May 2003. The first post-dredging survey occurred in August 2003, about 4-months post-dredging and about five months prior to dredging of another 535,000 m^3 (700,000 yd^3) of sand from Area B from January to April 2004. A third survey occurred in June 2004 about 2-months post-dredging from the last dredging in Area B and the fourth survey in June 2005 about 14-months post-dredging in Area B. Protocols suggested sampling at 1, 3, 5, and 7 years post dredging, however, as our study highlights it is in the area of dredging schedule verses environmental sampling that the protocols have to implement an adaptive management strategy. The 2004 dredging at Sandbridge was not scheduled but arose as a result of a storm that eroded the Dam Neck beach creating an emergency request for sand. When a burrow site is subject to dredging whenever a need arises, it may not be possible to assess long-term impacts for a specific dredging event. The strategy than needs to shift to cumulative effects with assessment of a series of short-term impacts and how ecosystem function is altered by the series of dredging events.

Initially, the field design at Sandbridge Shoal was to document Spring and Summer conditions, but the sand dredging event in Area B in January 2004 caused us to shift our design to document shorter and longer term effects by sampling at 6-months and 18-months after sand dredging. The focus on Spring conditions kept seasonal effects to a minimum. This is an important consideration given that on the outer continental shelf, seasonal variation in both benthic and fisheries assemblages is large (Boesch 1979). Given the total level of effort we expended at Sandbridge Shoal, if seasonal variation were assessed we would only have sampled for one calendar year (four seasons) or two years (focus on Spring/Summer and Summer/Fall). While dredging is not constrained to a single season, it may still be optimal to restrict sampling for biological assessment to a single season. The level of effort required to factor seasonal variation into a long-term biological assessment would be large. If impacts are expected to be minimal and recovery rapid, more frequent sampling may be required.

The protocols make recommendations for collecting, processing, and analyzing data on infauna and fishes to assess recovery from a dredging event, and suggest setting an endpoint for recovery prior to post-dredging sampling. This is a good recommendation, which should serve to focus the objectives of the study and sampling effort. A return to within the 95% confidence interval of the mean for parameters selected for assessment was proposed. Using ANOVA as the statistical test, this endpoint is the same as a nonsignificant difference between dredged and reference strata. When ANOVA indicates no significant difference in the means of the factors tested the interpretation is that the mean values are all from the same population and thus all within the 95% confidence interval. This is the endpoint we used for the current Sandbridge Shoal study.

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Appendix A

SPI Data

Date	Station	Stratum	lat	long	Penetration	Surface Relief	Bedforms	Modal Grain-Size	Max Grain-Size	Epifauna	Diopatra Tubes	Other Tubes	Fecal Pellets
Jun-02	1	West of shoal	36.7071833	-75.8778500	5.8	0.5	yes	FSMS	MS		0	0	no
Jun-02	2	On Shoal	36.7276000	-75.8754333	6.0	2.3	yes	FSMS	MS		0	0	no
Jun-02	3	On Shoal	36.7310000	-75.8744333	5.6	0.8	yes	FSMS	MS		0	0	no
Jun-02	4	On Shoal	36.7356500	-75.8779667	5.5	0.7	yes	FSMS	MS	Sand protuberance	0	0	no
Jun-02	9	On Shoal	36.7552333	-75.8766167	6.1	2.3	yes	FSMS	CS		0	0	no
Jun-02	10	Area B	36.7590500	-75.8801500	4.6	0.7	yes	MSCS	CS		0	0	no
Jun-02	11	Area B	36.7616167	-75.8807833	5.9	1.4	yes	MSCS	CS		0	0	no
Jun-02	12	On Shoal	36.7673167	-75.8794833	8.1	2.6	yes	FSMS	MS		0	0	no
Jun-02	13	On Shoal	36.7395667	-75.8776500	5.5	3.0	yes	FSMS	CS		0	0	no
Jun-02	15	On Shoal	36.7474500	-75.8773167	7.8	0.9	yes	FSMS	MS		0	0	no
Jun-02	16	On Shoal	36.7494167	-75.8793833	4.0	0.9	yes	FSMS	GR		0	0	no
Jun-02	17	On Shoal	36.7653167	-75.8807167	4.1	1.6	yes	FSMS	CS		0	4	no
Jun-02	18	Area B	36.7682500	-75.8654000	3.2	1.2	yes	FSMS	CS		0	0	no
Jun-02	19	On Shoal	36.7642667	-75.8664333	5.8	1.9	yes	FSMS	CS		0	0	no
Jun-02	20	Area B	36.7603833	-75.8670000	7.1	2.9	yes	FSMS	MS		0	0	no
Jun-02	21	East of Shoal	36.7575833	-75.8615500	4.6	0.8	yes	FSMS	CS		0	0	no
Jun-02	22	On Shoal	36.7682833	-75.8709833	4.2	0.8	yes	FSMS	CS		0	0	no
Jun-02	23	Area B	36.7652833	-75.8707000	6.4	0.8	yes	FSMS	MS		0	0	no
Jun-02	24	Area B	36.7628167	-75.8698167	5.9	3.1	yes	FSMS	MS		0	0	no
Jun-02	25	Area B	36.7595500	-75.8714333	4.7	2.4	yes	FSMS	MS		0	0	no
Jun-02	26	Area B	36.7572667	-75.8687167	5.5	1.7	yes	FSMS	MS		0	0	no
Jun-02	27	On Shoal	36.7684167	-75.8751167	6.3	1.5	yes	FSMS	MS		0	0	no
Jun-02	28	Area B	36.7651000	-75.8754667	6.8	1.4	yes	FSMS	MS		0	0	no
Jun-02	29	Area B	36.7621833	-75.8733667	0.6	1.2	yes	FSMS	MS		0	0	no
Jun-02	30	Area B	36.7605000	-75.8764167	3.5	1.0	yes	FSMS	CS		0	0	no
Jun-02	31	Area B	36.7571167	-75.8744167	4.2	1.2	yes	FS	FS		0	0	no
Jun-02	32	On Shoal	36.7569167	-75.8806667	4.4	0.9	yes	FSMS	CS		0	0	no
Jun-02	32	On Shoal	36.7570500	-75.8808667	1.5	1.0	yes	FSMS	MS		0	0	no
Jun-02	34	West of shoal	36.7371167	-75.9012500	1.4	1.2	yes	FS	MS		0	0	no
Jun-02	35	West of shoal	36.7425333	-75.8994000	2.6	1.9	yes	FS	FS		0	0	no
Jun-02	36	West of shoal	36.7470333	-75.9005333	1.4	0.8	yes	FS	FS		0	0	no
Jun-02	37	West of shoal	36.7509500	-75.8973000	4.0	1.6	yes	FS	FS	Hermit Crab	0	0	no
Jun-02	38	West of shoal	36.7533167	-75.9007833	3.0	2.3	yes	FS	FS		0	0	no
Jun-02	39	West of shoal	36.7398667	-75.8943833	1.6	0.4	yes	FS	FS	Hermit Crab	0	0	no
Jun-02	40	West of shoal	36.7436833	-75.8903333	6.2	1.4	yes	FSSI	FS	Hermit Crab	0	0	no
Jun-02	41	West of shoal	36.7444833	-75.8942500	4.1	2.2	yes	FS	MS	Hermit Crab	0	0	no
Jun-02	42	West of shoal	36.7491500	-75.8917667	3.0	1.2	yes	FS	MS		0	0	no
Jun-02	43	West of shoal	36.7547167	-75.8937500	2.2	1.8	yes	FS	FS		0	0	no
Jun-02	45	East of Shoal	36.7428667	-75.8699333	4.3	3.2	yes	FSMS	MS		0	0	no
Jun-02	56	On Shoal	36.7470500	-75.8709667	7.4	5.3	yes	FSMS	MS		0	0	no
Jun-02	58	East of Shoal	36.7386000	-75.8688333	3.9	1.3	yes	FSMS	MS		0	0	no
Jun-02	59	East of Shoal	36.7383000	-75.8633500	5.0	2.1	yes	FSMS	CS	Hermit Crab	0	0	no
Jun-02	60	East of Shoal	36.7538333	-75.8622667	2.4	2.0	yes	FSMS	MS	Sand protuberance	0	0	no
Jun-02	61	East of Shoal	36.7637667	-75.8615000	3.3	6.6	yes	FSMS	MS	Sand protuberance	0	4	no
Jun-02	62	East of Shoal	36.7744833	-75.8621667	8.4	0.5	yes	FSMS	CS		0	0	no
Jun-02	63	East of Shoal	36.7813000	-75.8651667	7.2	4.5	yes	MSCS	CS	Sand protuberance	0	0	no
Jun-02	64	East of Shoal	36.7793000	-75.8737167	1.7	1.3	yes	FSMS	MS	Sand protuberance	0	0	no
Jun-02	65	East of Shoal	36.7734000	-75.8779167	1.8	3.6	yes	FSMS	MS	Sand protuberance	0	0	no
Jun-02	66	West of shoal	36.7681667	-75.8829667	2.9	1.2	yes	FSMS	GR		0	0	no
Jun-02	67	Area B	36.7614333	-75.8824667	5.9	3.2	yes	FSMS	CS		0	0	no

Date	Station	Stratum	lat	long	Penetration	Surface Relief	Bedforms	Modal Grain-Size	Max Grain-Size	Epifauna	Diopatra Tubes	Other Tubes	Fecal Pellets
Aug-03	4	On Shoal	36.7358333	-75.8786667	2.5	0.3	yes	FSMS	MS		0	0	no
Aug-03	9	On Shoal	36.7551667	-75.8765000	6.5	1.5	yes	FSMS	MS		0	0	no
Aug-03	9	On Shoal	36.7551667	-75.8765000	6.6	1.7	yes	FSMS	MS		0	0	no
Aug-03	10	Area B	36.7593333	-75.8803333	5.0	1.5	yes	FSMS	MS		0	1	no
Aug-03	10	Area B	36.7593333	-75.8805000	5.0	0.8	yes	MS	MS		0	0	no
Aug-03	11	Area B	36.7615000	-75.8810000	4.4	0.6	yes	CS	GR		0	0	no
Aug-03	11	Area B	36.7615000	-75.8810000	3.7	2.1	yes	FSMS	CS		0	0	no
Aug-03	12	On Shoal	36.7671667	-75.8803333	5.7	0.5	yes	CS	PB		0	0	no
Aug-03	12	On Shoal	36.7671667	-75.8803333	7.2	0.7	yes	CS	GR	Hermit Crab	0	0	no
Aug-03	13	On Shoal	36.7398333	-75.8773333	4.6	1.1	yes	FSMS	MS		0	3	no
Aug-03	13	On Shoal	36.7398333	-75.8776667	2.1	0.6	yes	FSMS	MS		0	0	yes
Aug-03	14	On Shoal	36.7446667	-75.8771667	6.0	0.2	yes	MS	CS		0	0	no
Aug-03	14	On Shoal	36.7446667	-75.8771667	4.3	1.9	yes	MS	CS		0	0	no
Aug-03	15	On Shoal	36.7476667	-75.8778333	3.5	0.4	yes	MS	CS		0	0	no
Aug-03	15	On Shoal	36.7476667	-75.8778333	4.1	3.4	yes	MS	CS		0	0	no
Aug-03	16	On Shoal	36.7493333	-75.8798333	1.2	2.3	yes	MS	MS		0	0	no
Aug-03	16	On Shoal	36.7493333	-75.8798333	3.8	1.2	yes	MS	CS		0	0	no
Aug-03	16	On Shoal	36.7493333	-75.8798333	2.1	0.5	yes	CS	GR		0	0	no
Aug-03	18	Area B	36.7680000	-75.8660000	8.0	0.8	yes	MS	CS	Hermit Crab	0	0	no
Aug-03	19	On Shoal	36.7641667	-75.8815000	9.7	3.0	yes	MS	CS		0	0	no
Aug-03	19	On Shoal	36.7641667	-75.8815000	9.2	3.3	yes	CS	CS		0	0	no
Aug-03	19	On Shoal	36.7646667	-75.8663333	8.1	2.4	yes	FSMS	MS	Hermit Crab	0	0	no
Aug-03	19	On Shoal	36.7646667	-75.8663333	9.0	4.9	yes	MS	MS		0	0	no
Aug-03	20	Area B	36.7605000	-75.8668333	5.1	1.2	yes	CS	GR		0	0	no
Aug-03	20	Area B	36.7605000	-75.8670000	9.5	4.0	yes	CS	CS		0	0	no
Aug-03	21	East of Shoal	36.7576667	-75.8625000	5.8	0.8	yes	MS	MS		0	0	no
Aug-03	21	East of Shoal	36.7576667	-75.8625000	4.0	2.5	yes	MS	MS		0	0	no
Aug-03	22	On Shoal	36.7681667	-75.8721667	11.1	2.4	yes	MS	CS		0	0	no
Aug-03	23	Area B	36.7660000	-75.8706667	7.2	2.5	yes	MS	MS		0	0	no
Aug-03	23	Area B	36.7660000	-75.8708333	7.8	5.1	yes	MS	MS		0	0	no
Aug-03	24	Area B	36.7635000	-75.8700000	6.2	0.8	yes	MS	MS		0	0	no
Aug-03	24	Area B	36.7633333	-75.8700000	6.7	2.0	yes	MS	MS		0	0	no
Aug-03	25	Area B	36.7596667	-75.8713333	8.3	1.0	yes	FSMS	MS		0	0	no
Aug-03	25	Area B	36.7596667	-75.8715000	8.9	0.6	yes	FSMS	MS		0	0	no
Aug-03	26	Area B	36.7568333	-75.8681667	8.9	2.7	yes	FS	FS		0	0	yes
Aug-03	26	Area B	36.7568333	-75.8681667	5.2	1.9	yes	FSMS	MS		0	0	yes
Aug-03	27	On Shoal	36.7686667	-75.8761667	10.1	3.5	yes	CS	GR		0	0	no
Aug-03	27	On Shoal	36.7685000	-75.8761667	7.7	1.8	yes	CS	CS	Hermit Crab	0	0	no
Aug-03	28	Area B	36.7648333	-75.8753333	7.2	3.6	yes	FSMS	MS		0	0	no
Aug-03	28	Area B	36.7648333	-75.8753333	9.5	1.4	yes	FSMS	MS		0	0	no
Aug-03	29	Area B	36.7615000	-75.8738333	11.9	1.0	yes	FSMS	MS		3	3	no
Aug-03	29	Area B	36.7615000	-75.8738333	9.4	1.3	yes	FSMS	MS		1	1	no
Aug-03	30	Area B	36.7598333	-75.8758333	9.0	2.3	yes	FSMS	MS		0	0	no
Aug-03	30	Area B	36.7598333	-75.8758333	15.2	0.9	yes	FSMS	MS		0	0	no
Aug-03	31	Area B	36.7566667	-75.8735000	10.3	1.7	yes	FSMS	MS		0	0	no
Aug-03	31	Area B	36.7566667	-75.8735000	6.5	2.6	yes	FSMS	MS		0	0	no
Aug-03	31	Area B	36.7566667	-75.8728333	6.3	0.6	yes	FSMS	MS		0	1	no
Aug-03	32	On Shoal	36.7565000	-75.8810000	8.0	1.7	yes	FSMS	MS		0	0	no
Aug-03	32	On Shoal	36.7565000	-75.8810000	7.2	1.1	yes	FSMS	MS		0	0	no
Aug-03	43	West of shoal	36.7450000	-75.8851667	4.9	1.4	yes	MS	CS		0	0	no

Date	Station	Stratum	lat	long	Penetration	Surface Relief	Bedforms	Modal Grain-Size	Max Grain-Size	Epifauna	Diopatra Tubes	Other Tubes	Fecal Pellets
Aug-03	43	West of shoal	36.7450000	-75.8851667	2.2	1.5	yes	MS	CS	Hermit Crab	0	0	no
Aug-03	43	West of shoal	36.7550000	-75.8940000	0.8	1.7	yes	FS	FS		1	7	yes
Aug-03	43	West of shoal	36.7550000	-75.8940000	2.5	1.7	yes	FS	FS		0	6	no
Aug-03	45	East of Shoal	36.7428333	-75.8701667	2.3	0.6	yes	FSMS	MS		1	1	no
Aug-03	45	East of Shoal	36.7428333	-75.8701667	2.7	0.7	yes	FSMS	MS		2	1	no
Aug-03	49	On Shoal	36.7435000	-75.8841667	4.2	2.1	yes	MS	GR		0	1	no
Aug-03	49	On Shoal	36.7436667	-75.8841667	2.1	1.0	yes	MS	GR		0	0	no
Aug-03	50	On Shoal	36.7411667	-75.8836667	2.4	0.2	yes	MS	CS		0	6	no
Aug-03	50	On Shoal	36.7410000	-75.8836667	5.9	0.4	yes	MS	CS		0	2	no
Aug-03	51	On Shoal	36.7393333	-75.8823333	2.6	0.2	yes	CS	GR		2	2	no
Aug-03	51	On Shoal	36.7393333	-75.8823333	1.7	0.8	yes	CS	GR		0	0	no
Aug-03	56	On Shoal	36.7475000	-75.8716667	0.6	1.3	yes	FSMS	MS		0	0	no
Aug-03	56	On Shoal	36.7475000	-75.8716667	3.4	1.1	yes	FSMS	MS		0	0	no
Aug-03	56	On Shoal	36.7476667	-75.8721667	0.0	0.0	yes	FSMS	MS	Sand protuberance	0	0	no
Aug-03	58	East of Shoal	36.7390000	-75.8686667	2.5	0.9	yes	FS	FS	Crab, Burrow	7	3	yes
Aug-03	58	East of Shoal	36.7390000	-75.8686667	2.1	0.3	yes	FSMS	MS	Large Hermit crab	1	1	yes
Aug-03	59	East of Shoal	36.7380000	-75.8630000	2.9	0.3	yes	CS	GR		0	0	no
Aug-03	59	East of Shoal	36.7380000	-75.8630000	3.7	0.3	yes	MS	GR		0	0	no
Aug-03	60	East of Shoal	36.7543333	-75.8630000	8.4	2.3	yes	FSMS	MS	Sand dollar	0	0	no
Aug-03	60	East of Shoal	36.7543333	-75.8630000	7.4	3.4	yes	FSMS	MS		0	2	no
Aug-03	61	East of Shoal	36.7635000	-75.8618333	9.5	1.8	yes	MS	MS		0	0	no
Aug-03	61	East of Shoal	36.7635000	-75.8620000	10.1	2.6	yes	MS	MS		0	0	no
Aug-03	66	West of shoal	36.7675000	-75.8825000	8.3	4.1	yes	CS	GR		0	0	no
Aug-03	66	West of shoal	36.7675000	-75.8826667	7.7	2.0	yes	CS	GR		0	0	no
Aug-03	67	Area B	36.7611667	-75.8830000	4.1	0.5	yes	CS	GR		0	0	no
Aug-03	67	Area B	36.7611667	-75.8830000	4.0	1.1	yes	CS	GR		0	0	no
Aug-03	1a	On Shoal	36.7468333	-75.8860000	0.3	0.7	yes	MS	CS	Sand protuberance	0	0	no
Aug-03	1a	On Shoal	36.7466667	-75.8861667	3.6	0.5	yes	MS	GR	Sand protuberance	0	0	no
Aug-03	1b	West of shoal	36.7500000	-75.8866667	0.9	1.8	yes	FSMS	CS	Sand protuberance	0	0	no
Aug-03	1b	West of shoal	36.7500000	-75.8866667	1.3	0.8	yes	MS	MS	Sand protuberance	0	0	no
Aug-03	1c	On Shoal	36.7536667	-75.8865000	1.5	1.4	yes	MS	MS	Sand protuberance	0	1	no
Aug-03	1c	On Shoal	36.7536667	-75.8865000	4.1	1.5	yes	MS	MS		0	0	no
Aug-03	1d	West of shoal	36.7565000	-75.8883333	3.2	0.8	yes	VCS	PB	Hermit Crab	0	0	no
Aug-03	1d	West of shoal	36.7565000	-75.8883333	1.4	0.5	yes	VCS	PB		0	0	no
Jun-04	9	On Shoal	36.75566670	-75.87600000	13.9	1.3	yes	MS	MS		0	1	no
Jun-04	10	Area B	36.75916670	-75.88050000	9.6	1.5	yes	MS	GR		0	0	no
Jun-04	11	Area B	36.76166670	-75.88066670	5.0	1.2	yes	MS	CS		0	0	no
Jun-04	12	On Shoal	36.76800000	-75.87983330	9.2	1.2	yes	MS	MS		0	0	no
Jun-04	14	On Shoal	36.74416670	-75.87666670	9.3	0.6	yes	MS	MS		0	0	no
Jun-04	15	On Shoal	36.74783330	-75.87800000	7.0	0.6	yes	MS	CS	Sand Protuberance, Hermit Crab	0	0	no
Jun-04	16	On Shoal	36.75000000	-75.88000000	9.6	0.6	yes	MS	CS	Sand protuberance	0	0	no
Jun-04	17	On Shoal	36.76500000	-75.88050000	4.9	0.2	yes	MS	MS	Hermit Crab	0	0	no
Jun-04	18	Area B	36.76800000	-75.86591667	6.6	0.7	yes	MS	CS	Sand Protuberance, Hermit Crab	0	0	no
Jun-04	19	On Shoal	36.76430000	-75.88140000	6.7	0.8	yes	MS	MS		0	0	no
Jun-04	20	Area B	36.76066670	-75.86750000	4.7	1.1	yes	MS	GR		0	0	no
Jun-04	21	East of Shoal	36.75800000	-75.86200000	8.3	1.9	yes	MS	MS		0	0	no
Jun-04	22	On Shoal	36.76818333	-75.87203333	9.8	0.9	yes	MS	MS		0	0	no
Jun-04	23	Area B	36.76483330	-75.87016670	8.2	2.2	yes	MS	MS		0	0	yes
Jun-04	24	Area B	36.76283330	-75.87016670	6.0	0.7	yes	MS	MS		0	0	no
Jun-04	25	Area B	36.75950000	-75.87166670	8.3	1.0	yes	MS	MS		0	0	no

Date	Station	Stratum	lat	long	Penetration	Surface Relief	Bedforms	Modal Grain-Size	Max Grain-Size	Epifauna	Diopatra Tubes	Other Tubes	Fecal Pellets
Jun-04	26	Area B	36.75733330	-75.86816670	8.2	0.9	yes	MS	MS		0	0	no
Jun-04	27	On Shoal	36.76866667	-75.87610000	11.3	1.3	yes	CS	CS		0	0	yes
Jun-04	28	Area B	36.76533330	-75.87550000	7.1	2.4	yes	FSMS	MS		0	0	no
Jun-04	29	Area B	36.76250000	-75.87383330	7.9	1.5	yes	FSMS	MS	Sand protuberance	0	0	no
Jun-04	30	Area B	36.76083330	-75.87683330	5.6	1.5	yes	FS	FS		1	1	no
Jun-04	31	Area B	36.75733330	-75.87466670	5.3	1.7	yes	FS	FS		1	1	no
Jun-04	32	On Shoal	36.75700000	-75.88116670	8.6	0.4	yes	MS	MS		1	1	no
Jun-04	32	On Shoal	36.75716670	-75.88133330	8.0	0.2	yes	MS	MS		0	0	no
Jun-04	45	East of Shoal	36.74300000	-75.87066670	5.0	0.6	yes	FS	FS		0	25	yes
Jun-04	58	East of Shoal	36.73883330	-75.86883330	7.3	1.9	yes	FS	FS		1	10	no
Jun-04	60	East of Shoal	36.75416670	-75.86200000	9.9	0.6	yes	MS	MS		0	1	no
Jun-04	61	East of Shoal	36.76383330	-75.86166670	10.6	0.5	yes	CS	CS		0	0	no
Jun-04	63	East of Shoal	36.78116670	-75.86550000	6.3	1.7	yes	CS	CS		0	0	no
Jun-04	64	East of Shoal	36.77933330	-75.87366670	7.1	0.4	yes	MS	CS		0	0	no
Jun-04	65	East of Shoal	36.77333333	-75.87783333	10.8	0.7	yes	MS	MS		0	0	no
Jun-04	66	West of shoal	36.76850000	-75.88316670	4.8	1.5	yes	MS	MS	Sand protuberance	0	0	no
Jun-04	66	West of shoal	36.76850000	-75.88316670	10.1	1.6	yes	MS	MS		0	1	no
Jun-04	67	Area B	36.76200000	-75.88200000	8.1	1.3	yes	CS	GR		0	0	no
Jun-04	23a	Area B	36.76483330	-75.87016670	7.4	1.5	yes	FSMS	MS		0	0	yes
Jun-04	23b	Area B	36.76516670	-75.87016670	9.1	3.9	yes	FSMS	MS		0	0	no
Jun-04	23c	Area B	36.76533330	-75.87033330	4.8	0.4	yes	FSMS	MS		0	0	no
Jun-04	23d	Area B	36.76550000	-75.87050000	4.3	0.5	yes	FSMS	MS	Snail	0	0	no
Jun-04	23e	Area B	36.76550000	-75.87083330	5.9	1.1	yes	MS	MS		0	0	no
Jun-04	23f	Area B	36.76550000	-75.87116670	8.1	1.0	yes	MS	GR		0	0	no
Jun-04	23g	Area B	36.76550000	-75.87133330	6.4	1.0	yes	CS	CS		0	0	no
Jun-04	23h	Area B	36.76533330	-75.87166670	6.7	0.9	yes	CS	CS		0	0	no
Jun-04	23i	Area B	36.76533330	-75.87200000	8.6	1.4	yes	MS	CS		0	0	no
Jun-04	23j	Area B	36.76500000	-75.87233330	6.9	2.1	yes	MS	CS		0	1	no
Jun-04	23k	Area B	36.76500000	-75.87266670	8.5	0.4	yes	MS	CS		0	0	no
Jun-04	23l	Area B	36.76500000	-75.87316670	5.6	0.7	yes	MS	CS	Crab	0	0	no
Jun-04	23m	Area B	36.76516670	-75.87366670	6.3	0.8	yes	CS	CS		0	0	no
Jun-04	23n	Area B	36.76533330	-75.87433330	3.8	0.7	yes	FSMS	MS	Hermit Crab	0	0	no
Jun-04	23o	Area B	36.76540000	-75.87456000	9.0	0.6	yes	CS	CS		0	0	no
Jun-04	23p	Area B	36.76550000	-75.87483330	8.1	0.6	yes	FSMS	MS		0	0	no

Appendix B

Sediment Data

Station	Year	Stratum	latitude	longitude	Wentworth Class.	Folk Scale	GRAVEL%	SAND%	SILT%	CLAY%	Mean Phi	Median Phi	Stnd Dev Phi	Skewness	Kurtosis
297	2002	On Shoal	36.766	-75.879	Medium sand	Moderately sorted	1.9	97.1	0.0	1.1	1.1	1.2	0.7	-0.2	0.7
297	2005	On Shoal	36.766	-75.879	Medium sand	Moderately sorted	17.1	82.9	0.0	0.0	1.0	1.2	0.8	-0.3	0.7
297	2003	On Shoal	36.766	-75.879	Medium sand	Moderately sorted	9.6	87.8	1.6	1.1	1.2	1.3	0.7	-0.3	0.8
307	2002	Area B	36.761	-75.881	Medium sand	Well sorted	0.5	98.5	0.0	1.0	1.4	1.4	0.5	-0.1	0.6
307	2005	Area B	36.762	-75.883	Medium sand	Moderately well sorted	12.0	88.0	0.0	0.0	1.4	1.5	0.6	-0.3	0.6
307	2003	Area B	36.761	-75.881	Medium sand	Moderately well sorted	2.8	94.6	1.5	1.0	1.7	1.7	0.6	-0.2	0.6
307	2004	Area B	36.762	-75.883	Medium sand	Well sorted	0.0	98.9	0.0	1.1	1.8	1.9	0.4	-0.3	0.4
308	2004	Area B	36.763	-75.875	Medium sand	Moderately well sorted	3.0	96.5	0.0	0.5	1.1	1.1	0.6	0.0	0.7
308	2002	Area B	36.761	-75.875	Medium sand	Moderately well sorted	1.0	98.1	0.6	0.3	1.5	1.5	0.7	0.0	0.7
308	2003	Area B	36.761	-75.875	Medium sand	Moderately well sorted	0.0	96.1	3.2	0.7	1.8	1.9	0.5	-0.1	0.5
308	2005	Area B	36.762	-75.875	Fine sand	Moderately well sorted	1.7	98.3	0.0	0.0	2.0	2.0	0.5	-0.2	0.4
316	2004	On Shoal	36.760	-75.884	Medium sand	Moderately well sorted	11.6	87.4	0.8	0.3	1.4	1.4	0.6	-0.2	0.7
316	2003	On Shoal	36.758	-75.883	Medium sand	Moderately well sorted	1.5	94.4	3.9	0.3	1.5	1.5	0.6	-0.2	0.6
316	2002	On Shoal	36.758	-75.883	Medium sand	Moderately well sorted	1.2	97.7	0.0	1.2	1.7	1.8	0.6	0.0	0.6
316	2005	On Shoal	36.760	-75.884	Medium sand	Very well sorted	0.9	99.1	0.0	0.0	1.9	2.0	0.3	-0.2	0.3
318	2002	Area B	36.758	-75.874	Medium sand	Well sorted	0.0	99.1	0.0	0.9	1.7	1.7	0.5	-0.2	0.5
318	2004	Area B	36.759	-75.872	Medium sand	Well sorted	0.0	99.4	0.0	0.6	1.8	1.9	0.4	-0.2	0.4
318	2003	Area B	36.758	-75.874	Medium sand	Well sorted	0.0	95.1	4.2	0.7	1.9	1.9	0.4	0.0	0.4
318	2005	Area B	36.759	-75.872	Medium sand	Moderately well sorted	0.8	99.2	0.0	0.0	1.9	1.9	0.5	-0.2	0.5
329	2004	East of Shoal	36.758	-75.861	Medium sand	Moderately sorted	0.5	98.7	0.0	0.7	1.2	1.4	0.8	-0.3	0.7
329	2002	East of Shoal	36.755	-75.85	Medium sand	Well sorted	0.0	98.5	0.1	1.4	1.8	1.9	0.5	-0.1	0.5
332	2004	West of Shoal	36.753	-75.896	Very fine sand	Very well sorted	0.0	96.1	1.8	2.1	3.3	3.3	0.1	0.2	0.1
332	2005	West of Shoal	36.753	-75.896	Very fine sand	Very well sorted	0.1	98.9	0.5	0.5	3.3	3.3	0.1	0.2	0.1
332	2002	West of Shoal	36.751	-75.896	Very fine sand	Very well sorted	0.0	93.4	3.9	2.8	3.3	3.3	0.2	-0.1	0.2
332	2003	West of Shoal	36.751	-75.896	Very fine sand	Very well sorted	0.0	90.0	7.1	2.9	3.3	3.3	0.3	-0.3	0.3
336	2002	On Shoal	36.751	-75.881	Medium sand	Moderately well sorted	5.0	94.0	0.1	0.8	1.2	1.2	0.6	0.0	0.6
336	2005	On Shoal	36.752	-75.882	Medium sand	Moderately well sorted	0.7	99.3	0.0	0.0	1.5	1.6	0.6	-0.2	0.6
336	2004	On Shoal	36.752	-75.882	Medium sand	Well sorted	0.0	98.7	0.5	0.9	1.6	1.6	0.4	-0.2	0.5
336	2003	On Shoal	36.751	-75.881	Medium sand	Moderately well sorted	0.4	96.8	2.0	0.7	1.6	1.7	0.7	-0.4	0.7
342	2003	West of Shoal	36.765	-75.893	Very fine sand	Very well sorted	0.0	90.7	7.4	1.9	3.4	3.4	0.2	0.1	0.1
342	2002	West of Shoal	36.765	-75.893	Very fine sand	Very well sorted	0.0	93.3	4.0	2.7	3.4	3.4	0.1	0.2	0.1
347	2002	On Shoal	36.746	-75.875	Medium sand	Moderately well sorted	0.8	98.4	0.2	0.7	1.5	1.6	0.5	-0.2	0.6
347	2004	On Shoal	36.747	-75.875	Medium sand	Moderately well sorted	1.0	98.6	0.1	0.4	1.6	1.6	0.6	-0.2	0.6
347	2003	On Shoal	36.746	-75.875	Medium sand	Moderately well sorted	1.4	94.1	4.0	0.4	1.6	1.7	0.5	-0.1	0.5
347	2005	On Shoal	36.747	-75.875	Medium sand	Moderately well sorted	0.2	99.8	0.0	0.0	1.8	1.9	0.5	-0.3	0.5
353	2003	West of Shoal	36.742	-75.89	Coarse sand	Moderately sorted	35.4	60.6	2.6	1.4	0.5	0.6	0.9	0.0	1.1
353	2002	West of Shoal	36.742	-75.89	Medium sand	Poorly sorted	17.3	75.7	4.7	2.3	1.9	2.0	1.4	-0.1	0.5
353	2004	West of Shoal	36.743	-75.894	Very fine sand	Very well sorted	0.0	95.0	3.1	2.0	3.3	3.3	0.2	0.0	0.1
353	2005	West of Shoal	36.743	-75.894	Very fine sand	Very well sorted	0.1	94.6	3.2	2.1	3.4	3.3	0.1	0.3	0.1
356	2002	On Shoal	36.741	-75.879	Medium sand	Moderately well sorted	0.0	98.8	0.2	1.0	1.4	1.5	0.5	-0.3	0.6
356	2003	On Shoal	36.741	-75.879	Medium sand	Well sorted	0.6	98.0	0.8	0.5	1.7	1.7	0.5	-0.2	0.5
356	2004	On Shoal	36.740	-75.880	Medium sand	Well sorted	0.4	98.5	0.4	0.8	1.7	1.8	0.4	-0.2	0.4
356	2005	On Shoal	36.740	-75.880	Fine sand	Very well sorted	0.0	100.0	0.0	0.0	2.1	2.1	0.3	0.0	0.3
360	2002	East of Shoal	36.747	-75.854	Medium sand	Moderately well sorted	0.8	98.1	0.2	0.9	1.3	1.3	0.6	0.0	0.7
360	2004	East of Shoal	36.749	-75.853	Medium sand	Moderately well sorted	0.2	98.9	0.1	0.9	1.7	1.7	0.5	-0.2	0.5
361	2002	West of Shoal	36.738	-75.898	Very fine sand	Very well sorted	0.0	94.2	3.4	2.5	3.3	3.3	0.2	0.1	0.2
361	2003	West of Shoal	36.738	-75.898	Very fine sand	Very well sorted	0.0	89.8	6.1	4.2	3.3	3.3	0.3	-0.2	0.3
361	2005	West of Shoal	36.738	-75.898	Very fine sand	Very well sorted	0.0	97.9	0.6	1.6	3.3	3.3	0.1	0.1	0.1
361	2004	West of Shoal	36.738	-75.898	Very fine sand	Very well sorted	0.0	97.2	0.9	1.9	3.3	3.3	0.1	0.1	0.1
365	2002	On Shoal	36.737	-75.877	Medium sand	Well sorted	0.8	98.0	0.3	0.8	1.7	1.7	0.4	0.2	0.4
365	2004	On Shoal	36.737	-75.878	Medium sand	Moderately well sorted	0.3	98.9	0.2	0.7	1.8	1.9	0.5	-0.2	0.5
365	2003	On Shoal	36.737	-75.877	Fine sand	Moderately well sorted	0.0	96.4	3.0	0.6	2.2	2.2	0.5	0.2	0.5
372	2003	West of Shoal	36.733	-75.892	Very fine sand	Very well sorted	0.0	93.7	4.3	2.1	3.2	3.2	0.3	-0.2	0.3
372	2004	West of Shoal	36.734	-75.892	Very fine sand	Very well sorted	0.0	95.2	2.5	2.3	3.3	3.3	0.2	-0.2	0.2
372	2005	West of Shoal	36.734	-75.892	Very fine sand	Well sorted	0.0	87.9	7.5	4.6	3.3	3.3	0.4	-0.3	0.4
372	2002	West of Shoal	36.733	-75.892	Very fine sand	Very well sorted	0.0	94.1	3.5	2.5	3.3	3.3	0.1	0.1	0.1

Station	Year	Stratum	latitude	longitude	Wentworth Class.	Folk Scale	GRAVEL%	SAND%	SILT%	CLAY%	Mean Phi	Median Phi	Stnd Dev Phi	Skewness	Kurtosis
377	2004	East of Shoal	36.734	-75.871	Fine sand	Moderately well sorted	0.0	97.7	1.0	1.3	2.4	2.5	0.6	-0.3	0.6
377	2003	East of Shoal	36.732	-75.869	Fine sand	Moderately well sorted	0.0	77.4	9.2	13.3	2.6	2.6	0.6	-0.1	0.5
377	2005	East of Shoal	36.734	-75.871	Fine sand	Well sorted	0.0	100.0	0.0	0.0	2.6	2.6	0.4	-0.1	0.3
377	2002	East of Shoal	36.732	-75.869	Fine sand	Well sorted	0.0	96.2	1.5	2.2	2.8	2.7	0.5	0.1	0.3
385	2002	On Shoal	36.731	-75.88	Medium sand	Moderately well sorted	1.2	97.7	0.3	0.7	1.2	1.2	0.7	-0.2	0.7
385	2003	On Shoal	36.731	-75.88	Medium sand	Moderately well sorted	2.7	94.6	2.2	0.4	1.4	1.4	0.6	-0.1	0.6
385	2005	On Shoal	36.731	-75.880	Fine sand	Very well sorted	0.1	99.9	0.0	0.0	2.1	2.1	0.3	0.0	0.3
390	2002	East of Shoal	36.758	-75.861	Coarse sand	Moderately sorted	12.1	86.8	0.2	0.9	0.7	0.8	0.7	0.0	0.8
390	2003	East of Shoal	36.758	-75.861	Medium sand	Moderately well sorted	4.0	94.9	0.4	0.7	1.3	1.3	0.6	0.0	0.6
390	2004	East of Shoal	36.760	-75.862	Medium sand	Moderately well sorted	0.4	97.9	0.4	1.3	1.6	1.7	0.6	-0.2	0.6
396	2002	East of Shoal	36.727	-75.871	Fine sand	Very well sorted	0.0	98.1	1.1	0.9	2.5	2.5	0.3	-0.1	0.3
396	2003	East of Shoal	36.727	-75.871	Fine sand	Well sorted	0.0	97.0	1.2	1.8	2.6	2.6	0.4	0.1	0.4
500	2004	Area B	36.769	-75.869	Medium sand	Moderately sorted	1.6	97.6	0.2	0.7	1.2	1.3	0.8	-0.3	0.8
500	2005	Area B	36.769	-75.869	Medium sand	Moderately well sorted	0.7	99.3	0.0	0.0	1.7	1.7	0.5	0.2	0.6
501	2004	Area B	36.766	-75.871	Medium sand	Moderately sorted	2.5	97.1	0.0	0.5	1.8	1.9	0.8	-0.1	0.7
501	2005	Area B	36.766	-75.870	Medium sand	Well sorted	0.8	99.2	0.0	0.0	1.9	1.9	0.4	-0.2	0.4
502	2004	Area B	36.765	-75.874	Medium sand	Moderately well sorted	1.5	97.8	0.1	0.6	1.6	1.6	0.5	-0.2	0.5
504	2004	On Shoal	36.766	-75.881	Medium sand	Moderately sorted	2.4	97.0	0.1	0.5	1.3	1.4	0.8	-0.3	0.9
509	2005	On Shoal	36.765	-75.881	Medium sand	Well sorted	0.5	99.5	0.0	0.0	1.6	1.6	0.4	-0.1	0.4

Appendix C

Macro Data

Station	Year	Stratum	latitude	longitude	Mean Individual Weight Nemertean mg AFDW	Mean Individual Weight Anemone mg AFDW	Mean Individual Weight Amphipoda mg AFDW	Mean Individual Weight Isopoda mg AFDW	Mean Individual Weight Decapod mg AFDW	Mean Individual Weight Crustacean Other mg AFDW
307	**2002**	Area B	36.761	-75.881	0.20		0.48		0.02	0.07
308	**2002**	Area B	36.763	-75.875			0.31			0.08
318	**2002**	Area B	36.758	-75.874	0.40		0.42	0.25	0.02	0.04
329	**2002**	East of Shoal	36.758	-75.861	3.42		0.32		7.38	
360	**2002**	East of Shoal	36.747	-75.854	0.15		0.39	0.53	0.02	0.02
377	**2002**	East of Shoal	36.734	-75.871	2.50		0.41	0.36	43.24	
390	**2002**	East of Shoal	36.758	-75.861	0.34		0.24	0.37		0.06
396	**2002**	East of Shoal	36.727	-75.871	0.37		0.29		23.25	
297	**2002**	On Shoal	36.766	-75.879	0.02		0.52	0.14		0.06
316	**2002**	On Shoal	36.760	-75.884			0.36			0.06
336	**2002**	On Shoal	36.751	-75.881	0.13		0.15	2.30	14.70	0.06
347	**2002**	On Shoal	36.746	-75.875	0.07		0.45		0.02	0.03
356	**2002**	On Shoal	36.741	-75.879			0.91		0.91	0.06
365	**2002**	On Shoal	36.737	-75.877	0.20		0.57	0.91	14.70	
385	**2002**	On Shoal	36.731	-75.88	0.10		0.30	1.37	0.91	0.05
332	**2002**	West of Shoal	36.753	-75.896			0.31		1.19	0.06
342	**2002**	West of Shoal	36.765	-75.893			0.23		0.19	
353	**2002**	West of Shoal	36.742	-75.89	0.40	6.37	0.20		5.35	
361	**2002**	West of Shoal	36.738	-75.898		2.65	0.45		0.53	
372	**2002**	West of Shoal	36.733	-75.892			0.70	0.36	2.28	0.14
307	**2003**	Area B	36.762	-75.883			0.44		5.80	0.09
308	**2003**	Area B	36.761	-75.875			0.18		0.06	0.06
318	**2003**	Area B	36.759	-75.872			0.14	0.06		0.02
377	**2003**	East of Shoal	36.732	-75.869			5.64	0.36	1.24	
390	**2003**	East of Shoal	36.758	-75.861			0.67	0.36	5.02	0.06
396	**2003**	East of Shoal	36.727	-75.871	1.80		6.39	0.23	0.55	
297	**2003**	On Shoal	36.766	-75.879			0.08	2.30	0.02	0.02
316	**2003**	On Shoal	36.758	-75.883			0.47			0.03
336	**2003**	On Shoal	36.752	-75.882			0.43	0.36	7.42	0.02
347	**2003**	On Shoal	36.747	-75.875	0.10		0.19		0.14	0.02
356	**2003**	On Shoal	36.741	-75.879			1.25		0.14	0.06
365	**2003**	On Shoal	36.737	-75.878			0.32	0.14	0.91	0.08
385	**2003**	On Shoal	36.731	-75.88			0.11	1.56		0.05
332	**2003**	West of Shoal	36.753	-75.896	189.64		4.72	0.02		0.25
342	**2003**	West of Shoal	36.765	-75.893			2.89	0.06	10.10	0.02
353	**2003**	West of Shoal	36.742	-75.89					7.81	
361	**2003**	West of Shoal	36.738	-75.898			0.79	0.14	1.97	
372	**2003**	West of Shoal	36.734	-75.892					1.20	0.36
307	**2004**	Area B	36.761	-75.881	3.78		0.91			
308	**2004**	Area B	36.763	-75.875			0.19			
318	**2004**	Area B	36.758	-75.874			0.31	0.14		0.06
500	**2004**	Area B	36.769	-75.869			0.33			0.02
501	**2004**	Area B	36.766	-75.871			0.48		8.50	
502	**2004**	Area B	36.765	-75.874			0.29			
329	**2004**	East of Shoal	36.755	-75.85				0.14	5.80	
360	**2004**	East of Shoal	36.749	-75.853			0.64		0.36	0.06
377	**2004**	East of Shoal	36.734	-75.871			0.32		0.36	
390	**2004**	East of Shoal	36.760	-75.862			0.67			
316	**2004**	On Shoal	36.758	-75.883	0.15		0.72		14.70	0.02
336	**2004**	On Shoal	36.752	-75.882					14.70	0.06
347	**2004**	On Shoal	36.746	-75.875			0.91			0.06
356	**2004**	On Shoal	36.740	-75.880			0.18	3.08		
365	**2004**	On Shoal	36.737	-75.877			0.50			0.06
504	**2004**	On Shoal	36.766	-75.881			0.51	1.21		0.06

Station	Year	Stratum	latitude	longitude	Mean Individual Weight Nemertean mg AFDW	Mean Individual Weight Anemone mg AFDW	Mean Individual Weight Amphipoda mg AFDW	Mean Individual Weight Isopoda mg AFDW	Mean Individual Weight Decapod mg AFDW	Mean Individual Weight Crustacean Other mg AFDW
332	**2004**	West of Shoal	36.751	-75.896			0.34			
353	**2004**	West of Shoal	36.743	-75.894		15.06	0.30		2.93	
361	**2004**	West of Shoal	36.738	-75.898			2.30		0.53	
372	**2004**	West of Shoal	36.734	-75.892			1.16		2.30	0.36
307	**2005**	Area B	36.762	-75.883	0.14		0.36			0.02
308	**2005**	Area B	36.761	-75.875			0.45	0.10		0.02
318	**2005**	Area B	36.759	-75.872			0.22	0.06		0.06
500	**2005**	Area B	36.769	-75.869	0.01		0.36		14.70	0.19
501	**2005**	Area B	36.766	-75.870	0.05		0.32			0.02
377	**2005**	East of Shoal	36.732	-75.869	0.21		0.15			
297	**2005**	On Shoal	36.766	-75.879	0.95		0.36	0.02		0.03
316	**2005**	On Shoal	36.760	-75.884	0.21		0.26	0.06		0.02
336	**2005**	On Shoal	36.751	-75.881			0.56			0.02
347	**2005**	On Shoal	36.747	-75.875	0.12		0.08			0.02
356	**2005**	On Shoal	36.740	-75.880			0.40			0.02
385	**2005**	On Shoal	36.731	-75.880	5.57		0.39			0.02
509	**2005**	On Shoal	36.765	-75.881	0.07		0.91			
332	**2005**	West of Shoal	36.751	-75.896			1.86			
353	**2005**	West of Shoal	36.743	-75.894			0.19		3.99	0.14
361	**2005**	West of Shoal	36.738	-75.898	0.82		0.36	0.29	2.30	
372	**2005**	West of Shoal	36.733	-75.892			0.35			

Station	Year	Stratum	Mean Individual Weight Bivalva mg AFDW	Mean Individual Weight Gastropoda mg AFDW	Mean Individual Weight Polychaeta mg AFDW	Mean Individual Weight Echinoderms mg AFDW	Mean Individual Weight Phoronid mg AFDW	Mean Individual Weight Tunicate mg AFDW	Mean Individual Weight Lancelet mg AFDW
307	**2002**	Area B	174.62	315.40	0.23				1.73
308	**2002**	Area B	2.87		0.36				2.22
318	**2002**	Area B	0.55	9.25	0.21				1.88
329	**2002**	East of Shoal	7.00	0.72	1.55				2.86
360	**2002**	East of Shoal	0.03	0.15	0.07	0.70			2.66
377	**2002**	East of Shoal	0.82	1.07	0.60				
390	**2002**	East of Shoal	0.82	0.28	0.12	60.60	0.13	0.38	1.82
396	**2002**	East of Shoal	2.32	0.16	0.28				1.40
297	**2002**	On Shoal	0.18		0.11				0.10
316	**2002**	On Shoal	1.40	0.05	0.29				2.08
336	**2002**	On Shoal	0.12		0.15				0.18
347	**2002**	On Shoal	0.05	0.02	0.10				0.04
356	**2002**	On Shoal	1.89	0.15	1.88				0.65
365	**2002**	On Shoal	0.09		0.41	6.70			0.07
385	**2002**	On Shoal	1.81		0.10	4.15	0.00	0.20	0.22
332	**2002**	West of Shoal	3.56	0.62	0.20				
342	**2002**	West of Shoal	1.98	0.83	0.17				
353	**2002**	West of Shoal	4.06		0.37	5.56			0.94
361	**2002**	West of Shoal	4.17	1.08	0.20				
372	**2002**	West of Shoal	8.08		0.34				0.00
307	**2003**	Area B	1.27		0.09				1.64
308	**2003**	Area B	0.25	0.02	0.03	0.70			0.93
318	**2003**	Area B	0.08		0.06				0.63
377	**2003**	East of Shoal	3.09	6.72	0.31				
390	**2003**	East of Shoal	1.77		0.15				8.05
396	**2003**	East of Shoal	0.63	5.34	0.23				2.10
297	**2003**	On Shoal	0.13		0.04				0.37
316	**2003**	On Shoal	0.15		0.10				21.85
336	**2003**	On Shoal	0.29		0.13				2.74
347	**2003**	On Shoal	0.07		0.04	173.10			16.80
356	**2003**	On Shoal	0.17	13.83	0.11				1.95
365	**2003**	On Shoal	0.24	18.10	0.09				2.30
385	**2003**	On Shoal	0.11	0.02	0.09				1.46
332	**2003**	West of Shoal	1.99	1.10	0.23	94.82	0.03		0.90
342	**2003**	West of Shoal	2.14	0.34	0.35		0.10		11.70
353	**2003**	West of Shoal	0.06	0.19	0.13	211.00			9.50
361	**2003**	West of Shoal	0.95	0.96	0.09		0.03		3.13
372	**2003**	West of Shoal	2.62	21.92	0.29		0.05		0.10
307	**2004**	Area B			0.15	171.14		0.00	
308	**2004**	Area B	0.06		0.09				
318	**2004**	Area B	0.06		0.27				
500	**2004**	Area B	0.16		0.07				
501	**2004**	Area B	0.11		0.22				
502	**2004**	Area B			0.04				
329	**2004**	East of Shoal	0.15		0.09				
360	**2004**	East of Shoal	3.74		0.48	743.62		0.42	10.74
377	**2004**	East of Shoal	0.65		0.24	437.37			
390	**2004**	East of Shoal	1.57		0.14				3.19
316	**2004**	On Shoal			0.11				
336	**2004**	On Shoal	18.10		0.08				
347	**2004**	On Shoal			0.09				
356	**2004**	On Shoal	0.09		0.13				8.74
365	**2004**	On Shoal	1.85		0.15				6.01
504	**2004**	On Shoal			0.09				15.86

Station	Year	Stratum	Mean Individual Weight Bivalva mg AFDW	Mean Individual Weight Gastropoda mg AFDW	Mean Individual Weight Polychaeta mg AFDW	Mean Individual Weight Echinoderms mg AFDW	Mean Individual Weight Phoronid mg AFDW	Mean Individual Weight Tunicate mg AFDW	Mean Individual Weight Lancelet mg AFDW
332	**2004**	West of Shoal	2.56		0.09		0.03		
353	**2004**	West of Shoal	0.93	7.00	0.16		0.06		
361	**2004**	West of Shoal	0.80	7.00	0.26				
372	**2004**	West of Shoal	5.35		0.12				
307	**2005**	Area B	0.23		0.04				
308	**2005**	Area B	1.89		0.19	0.04			0.37
318	**2005**	Area B	2.52		0.07				
500	**2005**	Area B	0.03		0.18				0.00
501	**2005**	Area B	2.43	2.67	0.12				
377	**2005**	East of Shoal	0.02	0.40	0.11	0.06			
297	**2005**	On Shoal	0.02	2.67	0.09				0.94
316	**2005**	On Shoal	0.44		0.26	281.90			14.20
336	**2005**	On Shoal	0.02		0.10				0.91
347	**2005**	On Shoal	0.06		0.10				3.62
356	**2005**	On Shoal			0.10				
385	**2005**	On Shoal	0.41	0.06	0.07				
509	**2005**	On Shoal	2.67		0.19				11.24
332	**2005**	West of Shoal	0.48	0.13	0.07				2.06
353	**2005**	West of Shoal	0.56	0.40	0.12		0.16		
361	**2005**	West of Shoal	0.20	0.80	0.09	0.39			
372	**2005**	West of Shoal	1.20	3.23	0.06				

Station	Year	Stratum	Mean Individual Weight Other mg AFDW	Abundance Nemertean Individuals/m2	Abundance Anemone Individuals/m2	Abundance Amphipoda Individuals/m2	Abundance Isopoda Individuals/m2	Abundance Decapod Individuals/m2	Abundance Crustacean Other Individuals/m2	Abundance Bivalva Individuals/m2	Abundance Gastropoda Individuals/m2	Abundance Polychaeta Individuals/m2	Abundance Echinoderms Individuals/m2
307	**2002**	Area B		30	0	160	0	10	30	220	10	2120	0
308	**2002**	Area B		0	0	390	0	0	20	20	0	250	0
318	**2002**	Area B		10	0	140	20	10	80	150	20	180	0
329	**2002**	East of Shoal		50	0	90	0	20	0	20	20	1000	0
360	**2002**	East of Shoal		20	0	690	20	10	10	40	10	3880	10
377	**2002**	East of Shoal		10	0	1190	10	30	0	30	30	3640	0
390	**2002**	East of Shoal		830	0	860	30	0	10	210	50	3060	30
396	**2002**	East of Shoal		30	0	260	0	20	0	60	50	1570	0
297	**2002**	On Shoal		100	0	30	20	0	30	240	0	2870	0
316	**2002**	On Shoal		0	0	250	0	0	30	40	30	310	0
336	**2002**	On Shoal		30	0	80	10	20	10	410	0	2870	0
347	**2002**	On Shoal		180	0	80	0	10	80	110	10	1250	0
356	**2002**	On Shoal		0	0	70	0	30	80	100	10	910	0
365	**2002**	On Shoal		30	0	150	10	10	0	30	0	250	10
385	**2002**	On Shoal		300	0	120	120	40	30	40	0	4820	20
332	**2002**	West of Shoal		0	0	190	0	50	10	360	260	6260	0
342	**2002**	West of Shoal		0	0	430	0	20	0	750	270	4060	0
353	**2002**	West of Shoal	1.01	140	10	1480	0	120	0	300	0	4150	10
361	**2002**	West of Shoal		0	20	850	0	20	0	250	110	8010	0
372	**2002**	West of Shoal		0	0	410	10	30	10	260	0	3910	0
307	**2003**	Area B		0	0	70	0	10	70	170	0	1760	0
308	**2003**	Area B		0	0	290	0	10	40	60	10	1150	10
318	**2003**	Area B		0	0	50	10	0	370	220	0	910	0
377	**2003**	East of Shoal		0	0	10	10	620	0	220	30	2520	0
390	**2003**	East of Shoal		0	0	170	10	60	40	120	0	490	0
396	**2003**	East of Shoal		10	0	40	40	50	0	70	50	4580	0
297	**2003**	On Shoal		0	0	80	10	20	100	130	0	1760	0
316	**2003**	On Shoal		0	0	80	0	0	240	10	0	840	0
336	**2003**	On Shoal		0	0	70	20	20	530	300	0	1770	0
347	**2003**	On Shoal		20	0	150	0	30	870	140	0	690	10
356	**2003**	On Shoal		0	0	20	0	10	10	910	20	400	0
365	**2003**	On Shoal		0	0	70	10	10	50	40	20	170	0
385	**2003**	On Shoal		0	0	100	40	0	70	140	10	390	0
332	**2003**	West of Shoal		50	0	10	10	0	20	730	130	7670	10
342	**2003**	West of Shoal	0.03	0	0	20	20	30	10	330	30	4240	0
353	**2003**	West of Shoal		0	0	0	0	20	0	10	70	5880	10
361	**2003**	West of Shoal		0	0	10	10	60	0	470	90	6230	0
372	**2003**	West of Shoal		0	0	0	0	80	10	370	110	2980	0
307	**2004**	Area B		75	0	25	0	0	0	0	0	925	25
308	**2004**	Area B		0	0	250	0	0	0	50	0	475	0
318	**2004**	Area B		0	0	100	25	0	50	25	0	150	0
500	**2004**	Area B		0	0	75	0	0	25	100	0	975	0
501	**2004**	Area B		0	0	225	0	50	0	50	0	200	0
502	**2004**	Area B		0	0	75	0	0	0	0	0	175	0
329	**2004**	East of Shoal		0	0	0	25	75	0	50	0	2825	0
360	**2004**	East of Shoal		0	0	100	0	25	50	125	0	425	25
377	**2004**	East of Shoal		0	0	350	0	50	0	100	0	400	25
390	**2004**	East of Shoal		0	0	350	0	0	0	325	0	675	0
316	**2004**	On Shoal		75	0	100	0	100	25	0	0	1625	0
336	**2004**	On Shoal		0	0	0	0	25	25	25	0	575	0
347	**2004**	On Shoal		0	0	25	0	0	50	0	0	700	0
356	**2004**	On Shoal		0	0	250	50	0	0	75	0	225	0
365	**2004**	On Shoal		0	0	475	0	0	50	50	0	225	0
504	**2004**	On Shoal		0	0	325	575	0	25	0	0	1050	0

Station	Year	Stratum	Mean Individual Weight Other mg AFDW	Abundance Nemertean Individuals/m2	Abundance Anemone Individuals/m2	Abundance Amphipoda Individuals/m2	Abundance Isopoda Individuals/m2	Abundance Decapod Individuals/m2	Abundance Crustacean Other Individuals/m2	Abundance Bivalva Individuals/m2	Abundance Gastropoda Individuals/m2	Abundance Polychaeta Individuals/m2	Abundance Echinoderms Individuals/m2
332	**2004**	West of Shoal		0	0	175	0	0	0	175	0	3050	0
353	**2004**	West of Shoal		0	25	450	0	50	0	275	100	2350	0
361	**2004**	West of Shoal		0	0	25	0	50	0	125	25	2000	0
372	**2004**	West of Shoal		0	0	250	0	25	25	100	0	2925	0
307	**2005**	Area B		150	0	25	0	0	250	150	0	1400	0
308	**2005**	Area B		0	0	575	50	0	25	100	0	100	25
318	**2005**	Area B		0	0	375	25	0	100	100	0	250	0
500	**2005**	Area B		125	0	75	0	25	50	150	0	450	0
501	**2005**	Area B		25	0	250	0	0	50	100	25	600	0
377	**2005**	East of Shoal		25	0	900	0	0	0	25	25	575	75
297	**2005**	On Shoal		175	0	25	50	0	150	50	25	1100	0
316	**2005**	On Shoal		150	0	675	25	0	400	150	0	325	25
336	**2005**	On Shoal		0	0	300	0	0	25	25	0	325	0
347	**2005**	On Shoal		25	0	50	0	0	100	25	0	50	0
356	**2005**	On Shoal		0	0	675	0	0	50	0	0	700	0
385	**2005**	On Shoal		75	0	50	0	0	200	75	25	100	0
509	**2005**	On Shoal		50	0	50	0	0	0	25	0	200	0
332	**2005**	West of Shoal		0	0	225	0	0	0	1175	150	6600	0
353	**2005**	West of Shoal		0	0	800	0	75	25	550	25	2850	0
361	**2005**	West of Shoal		50	0	275	100	50	0	725	375	5325	25
372	**2005**	West of Shoal		0	0	250	0	0	0	650	75	4700	0

Station	Year	Stratum	Abundance Phoronid Individuals/m2	Abundance Tunicate Individuals/m2	Abundance Lancelet Individuals/m2	Abundance Other Individuals/m2	Abundance Total Individuals/m2	Biomass Nemertean mg AFDW/m2	Biomass Anemone mg AFDW/m3	Biomass Amphipoda mg AFDW/m4	Biomass Isopoda mg AFDW/m5	Biomass Decapod mg AFDW/m6	Biomass Crustacean Other mg AFDW/m7	Biomass Bivalva mg AFDW/m8
307	**2002**	Area B	0	0	180	0	2760	6.00	0.00	77.18	0.00	0.23	2.24	38416.02
308	**2002**	Area B	0	0	180	0	860	0.00	0.00	121.53	0.00	0.00	1.66	57.40
318	**2002**	Area B	0	0	130	0	740	4.00	0.00	58.10	5.03	0.23	3.59	82.90
329	**2002**	East of Shoal	0	0	50	0	1250	171.00	0.00	29.15	0.00	147.58	0.00	140.00
360	**2002**	East of Shoal	0	0	720	0	5410	3.00	0.00	266.61	10.53	0.23	0.23	1.29
377	**2002**	East of Shoal	0	0	0	0	4940	25.00	0.00	485.34	3.60	1297.10	0.00	24.60
390	**2002**	East of Shoal	300	80	280	0	5740	281.00	0.00	207.52	11.11	0.00	0.58	172.40
396	**2002**	East of Shoal	0	0	10	0	2000	11.00	0.00	74.39	0.00	465.00	0.00	139.22
297	**2002**	On Shoal	0	0	230	0	3520	2.00	0.00	15.56	2.86	0.00	1.89	42.34
316	**2002**	On Shoal	0	0	210	0	870	0.00	0.00	91.23	0.00	0.00	1.74	56.12
336	**2002**	On Shoal	0	0	310	0	3740	4.00	0.00	12.14	23.00	294.00	0.58	48.64
347	**2002**	On Shoal	0	0	140	0	1860	13.00	0.00	36.24	0.00	0.23	2.54	5.67
356	**2002**	On Shoal	0	0	80	0	1280	0.00	0.00	63.70	0.00	27.30	4.64	189.16
365	**2002**	On Shoal	0	0	30	0	520	6.00	0.00	85.45	9.10	147.00	0.00	2.72
385	**2002**	On Shoal	10	10	290	0	5800	31.00	0.00	36.18	164.33	36.40	1.39	72.35
332	**2002**	West of Shoal	0	0	0	0	7130	0.00	0.00	59.13	0.00	59.40	0.58	1283.22
342	**2002**	West of Shoal	0	0	0	0	5530	0.00	0.00	100.61	0.00	3.83	0.00	1483.10
353	**2002**	West of Shoal	0	0	10	20	6240	55.34	63.69	294.60	0.00	641.70	0.00	1217.63
361	**2002**	West of Shoal	0	0	0	0	9260	0.00	53.00	382.70	0.00	10.53	0.00	1043.08
372	**2002**	West of Shoal	0	0	10	0	4640	0.00	0.00	288.59	3.60	68.53	1.43	2100.10
307	**2003**	Area B	0	0	1070	0	3150	0.00	0.00	30.77	0.00	58.00	6.26	216.17
308	**2003**	Area B	0	0	40	0	1610	0.00	0.00	52.17	0.00	0.58	2.32	14.77
318	**2003**	Area B	0	0	90	0	1650	0.00	0.00	7.08	0.58	0.00	9.21	17.13
377	**2003**	East of Shoal	0	0	0	0	3410	0.00	0.00	56.36	3.60	766.02	0.00	679.04
390	**2003**	East of Shoal	0	0	20	0	910	0.00	0.00	113.09	3.60	301.04	2.32	212.03
396	**2003**	East of Shoal	0	0	10	0	4850	18.00	0.00	255.77	9.21	27.52	0.00	43.92
297	**2003**	On Shoal	0	0	280	0	2380	0.00	0.00	6.49	23.00	0.46	2.30	16.80
316	**2003**	On Shoal	0	0	20	0	1190	0.00	0.00	37.31	0.00	0.00	8.12	1.52
336	**2003**	On Shoal	0	0	150	0	2860	0.00	0.00	30.25	7.20	148.43	12.54	87.35
347	**2003**	On Shoal	0	0	50	0	1960	2.00	0.00	27.88	0.00	4.29	20.36	10.31
356	**2003**	On Shoal	0	0	1270	0	2640	0.00	0.00	25.00	0.00	1.43	0.58	158.47
365	**2003**	On Shoal	0	0	80	0	450	0.00	0.00	22.29	1.43	9.10	3.75	9.52
385	**2003**	On Shoal	0	0	180	0	930	0.00	0.00	11.13	62.29	0.00	3.51	15.47
332	**2003**	West of Shoal	140	0	20	0	8790	9482.00	0.00	47.18	0.23	0.00	5.03	1450.56
342	**2003**	West of Shoal	10	0	10	30	4730	0.00	0.00	57.70	1.16	303.10	0.23	705.80
353	**2003**	West of Shoal	0	0	20	0	6010	0.00	0.00	2.24	0.00	156.10	0.00	0.60
361	**2003**	West of Shoal	180	0	30	0	7080	0.00	0.00	7.89	1.43	118.32	0.00	447.78
372	**2003**	West of Shoal	460	0	10	0	4020	0.00	0.00	101.55	0.00	95.83	3.60	970.00
307	**2004**	Area B	0	25	0	0	1075	283.50	0.00	22.75	0.00	0.00	1.45	0.00
308	**2004**	Area B	0	0	0	0	775	0.00	0.00	46.43	0.00	0.00	0.00	3.00
318	**2004**	Area B	0	0	0	0	350	0.00	0.00	31.35	3.58	0.00	2.90	1.50
500	**2004**	Area B	0	0	0	0	1175	0.00	0.00	24.78	0.00	0.00	0.58	15.88
501	**2004**	Area B	0	0	0	0	525	0.00	0.00	108.98	0.00	425.00	0.00	5.30
502	**2004**	Area B	0	0	0	0	250	0.00	0.00	21.58	0.00	0.00	0.00	0.00
329	**2004**	East of Shoal	0	0	0	0	2975	0.00	0.00	0.00	3.58	435.00	0.00	7.60
360	**2004**	East of Shoal	0	50	75	0	875	0.00	0.00	63.50	0.00	9.00	2.90	467.70
377	**2004**	East of Shoal	0	0	0	0	925	0.00	0.00	113.53	0.00	18.00	0.00	65.30
390	**2004**	East of Shoal	0	0	25	0	1375	0.00	0.00	234.70	0.00	0.00	0.00	510.50
316	**2004**	On Shoal	0	0	0	0	1925	11.00	0.00	71.83	0.00	1470.00	0.58	0.00
336	**2004**	On Shoal	0	0	0	0	650	0.00	0.00	0.00	0.00	367.50	1.45	452.50
347	**2004**	On Shoal	0	0	0	0	775	0.00	0.00	22.75	0.00	0.00	2.90	0.00
356	**2004**	On Shoal	0	0	100	0	700	0.00	0.00	44.70	154.00	0.00	0.00	6.80
365	**2004**	On Shoal	0	0	75	0	875	0.00	0.00	238.68	0.00	0.00	2.90	92.50
504	**2004**	On Shoal	0	0	25	0	2000	0.00	0.00	167.35	693.95	0.00	1.45	0.00

Station	Year	Stratum	Abundance Phoronid Individuals/m2	Abundance Tunicate Individuals/m2	Abundance Lancelet Individuals/m2	Abundance Other Individuals/m2	Abundance Total Individuals/m2	Biomass Nemertean mg AFDW/m2	Biomass Anemone mg AFDW/m3	Biomass Amphipoda mg AFDW/m4	Biomass Isopoda mg AFDW/m5	Biomass Decapod mg AFDW/m6	Biomass Crustacean Other mg AFDW/m7	Biomass Bivalva mg AFDW/m8
332	**2004**	West of Shoal	50	0	0	0	3450	0.00	0.00	59.13	0.00	0.00	0.00	447.25
353	**2004**	West of Shoal	50	0	0	0	3300	0.00	376.50	135.38	0.00	146.45	0.00	256.40
361	**2004**	West of Shoal	0	0	0	0	2225	0.00	0.00	57.50	0.00	26.33	0.00	100.55
372	**2004**	West of Shoal	0	0	0	0	3325	0.00	0.00	289.15	0.00	57.50	9.00	535.00
307	**2005**	Area B	0	0	0	0	1975	20.50	0.00	9.00	0.00	0.00	5.75	35.08
308	**2005**	Area B	0	0	25	0	900	0.00	0.00	257.63	5.03	0.00	0.58	189.38
318	**2005**	Area B	0	0	0	0	850	0.00	0.00	80.80	1.45	0.00	5.80	252.33
500	**2005**	Area B	0	0	25	0	900	1.00	0.00	27.00	0.00	367.50	9.58	4.38
501	**2005**	Area B	0	0	0	0	1050	1.25	0.00	79.23	0.00	0.00	1.15	242.90
377	**2005**	East of Shoal	0	0	0	0	1625	5.25	0.00	134.30	0.00	0.00	0.00	0.58
297	**2005**	On Shoal	0	0	25	0	1600	166.50	0.00	9.00	1.15	0.00	4.33	1.15
316	**2005**	On Shoal	0	0	25	0	1775	31.00	0.00	178.20	1.45	0.00	9.20	66.00
336	**2005**	On Shoal	0	0	25	0	700	0.00	0.00	166.95	0.00	0.00	0.58	0.58
347	**2005**	On Shoal	0	0	25	0	275	3.00	0.00	4.15	0.00	0.00	2.30	1.50
356	**2005**	On Shoal	0	0	0	0	1425	0.00	0.00	268.48	0.00	0.00	1.15	0.00
385	**2005**	On Shoal	0	0	0	0	525	417.50	0.00	19.45	0.00	0.00	4.60	30.60
509	**2005**	On Shoal	0	0	50	0	375	3.25	0.00	45.50	0.00	0.00	0.00	66.75
332	**2005**	West of Shoal	0	0	25	0	8175	0.00	0.00	419.30	0.00	0.00	0.00	560.50
353	**2005**	West of Shoal	25	0	0	0	4350	0.00	0.00	151.43	0.00	299.00	3.58	306.78
361	**2005**	West of Shoal	0	0	0	0	6925	41.00	0.00	97.73	29.23	115.00	0.00	144.88
372	**2005**	West of Shoal	0	0	0	0	5675	0.00	0.00	87.30	0.00	0.00	0.00	778.13

Station	Year	Stratum	Biomass Gastropoda mg AFDW/m9	Biomass Polychaeta mg AFDW/m10	Biomass Echinoderms mg AFDW/m11	Biomass Phoronid mg AFDW/m12	Biomass Tunicate mg AFDW/m13	Biomass Lancelet mg AFDW/m14	Biomass Other mg AFDW/m15	Biomass Total mg AFDW/m16
307	**2002**	Area B	3154.00	480.86	0.00	0.00	0.00	311.00	0.00	42.45
308	**2002**	Area B	0.00	89.17	0.00	0.00	0.00	400.00	0.00	0.67
318	**2002**	Area B	185.00	37.38	0.00	0.00	0.00	245.00	0.00	0.62
329	**2002**	East of Shoal	14.30	1546.19	0.00	0.00	0.00	143.00	0.00	2.19
360	**2002**	East of Shoal	1.52	283.03	7.00	0.00	0.00	1915.00	0.00	2.49
377	**2002**	East of Shoal	32.22	2177.16	0.00	0.00	0.00	0.00	0.00	4.05
390	**2002**	East of Shoal	13.75	364.12	1818.00	38.00	30.00	509.00	0.00	3.45
396	**2002**	East of Shoal	8.24	438.61	0.00	0.00	0.00	14.00	0.00	1.15
297	**2002**	On Shoal	0.00	310.04	0.00	0.00	0.00	23.00	0.00	0.40
316	**2002**	On Shoal	1.43	91.08	0.00	0.00	0.00	436.00	0.00	0.68
336	**2002**	On Shoal	0.46	416.94	0.00	0.00	0.00	57.00	0.00	0.86
347	**2002**	On Shoal	0.23	130.23	0.00	0.00	0.00	6.00	0.00	0.19
356	**2002**	On Shoal	1.52	1711.76	0.00	0.00	0.00	52.00	0.00	2.05
365	**2002**	On Shoal	0.00	101.61	67.00	0.00	0.00	2.00	0.00	0.42
385	**2002**	On Shoal	0.00	479.35	83.00	0.00	2.00	63.00	0.00	0.97
332	**2002**	West of Shoal	159.95	1248.98	0.00	0.00	0.00	0.00	0.00	2.81
342	**2002**	West of Shoal	224.35	701.30	0.00	0.00	0.00	0.00	0.00	2.51
353	**2002**	West of Shoal	43.96	1554.76	55.63	0.00	0.00	9.42	20.18	3.96
361	**2002**	West of Shoal	119.27	1611.26	0.00	0.00	0.00	0.00	0.00	3.22
372	**2002**	West of Shoal	0.00	1331.00	0.00	0.00	0.00	0.00	0.00	3.79
307	**2003**	Area B	0.00	157.82	0.00	0.00	0.00	1754.00	0.00	2.22
308	**2003**	Area B	0.23	37.30	7.00	0.00	0.00	37.00	0.00	0.15
318	**2003**	Area B	0.00	52.69	0.00	0.00	0.00	57.00	0.00	0.14
377	**2003**	East of Shoal	201.60	769.39	0.00	0.00	0.00	0.00	0.00	2.48
390	**2003**	East of Shoal	0.00	71.44	0.00	0.00	0.00	161.00	0.00	0.86
396	**2003**	East of Shoal	266.82	1066.16	0.00	0.00	0.00	21.00	0.00	1.71
297	**2003**	On Shoal	0.00	70.10	0.00	0.00	0.00	103.00	0.00	0.22
316	**2003**	On Shoal	0.00	82.74	0.00	0.00	0.00	437.00	0.00	0.57
336	**2003**	On Shoal	0.00	233.43	0.00	0.00	0.00	411.00	0.00	0.93
347	**2003**	On Shoal	0.00	30.39	1731.00	0.00	0.00	840.00	0.00	2.67
356	**2003**	On Shoal	276.52	45.28	0.00	0.00	0.00	2479.00	0.00	2.99
365	**2003**	On Shoal	362.00	15.98	0.00	0.00	0.00	184.00	0.00	0.61
385	**2003**	On Shoal	0.23	34.02	0.00	0.00	0.00	262.00	0.00	0.39
332	**2003**	West of Shoal	143.20	1768.72	948.18	4.00	0.00	18.00	0.00	13.87
342	**2003**	West of Shoal	10.30	1480.73	0.00	1.00	0.00	117.00	0.84	2.68
353	**2003**	West of Shoal	13.39	744.69	2110.00	0.00	0.00	190.00	0.00	3.22
361	**2003**	West of Shoal	86.56	535.37	0.00	6.00	0.00	94.00	0.00	1.30
372	**2003**	West of Shoal	2411.30	870.34	0.00	25.00	0.00	1.00	0.00	4.48
307	**2004**	Area B	0.00	134.20	4278.50	0.00	0.00	0.00	0.00	4.72
308	**2004**	Area B	0.00	41.35	0.00	0.00	0.00	0.00	0.00	0.09
318	**2004**	Area B	0.00	40.35	0.00	0.00	0.00	0.00	0.00	0.08
500	**2004**	Area B	0.00	70.20	0.00	0.00	0.00	0.00	0.00	0.11
501	**2004**	Area B	0.00	43.78	0.00	0.00	0.00	0.00	0.00	0.58
502	**2004**	Area B	0.00	7.83	0.00	0.00	0.00	0.00	0.00	0.03
329	**2004**	East of Shoal	0.00	267.28	0.00	0.00	0.00	0.00	0.00	0.71
360	**2004**	East of Shoal	0.00	205.95	18590.50	0.00	20.75	805.75	0.00	20.17
377	**2004**	East of Shoal	0.00	97.30	10934.25	0.00	0.00	0.00	0.00	11.23
390	**2004**	East of Shoal	0.00	94.95	0.00	0.00	0.00	79.75	0.00	0.92
316	**2004**	On Shoal	0.00	178.25	0.00	0.00	0.00	0.00	0.00	1.73
336	**2004**	On Shoal	0.00	46.70	0.00	0.00	0.00	0.00	0.00	0.87
347	**2004**	On Shoal	0.00	65.13	0.00	0.00	0.00	0.00	0.00	0.09
356	**2004**	On Shoal	0.00	29.10	0.00	0.00	0.00	873.50	0.00	1.11
365	**2004**	On Shoal	0.00	34.05	0.00	0.00	0.00	450.50	0.00	0.82
504	**2004**	On Shoal	0.00	94.13	0.00	0.00	0.00	396.50	0.00	1.35

Station	Year	Stratum	Biomass Gastropoda mg AFDW/m9	Biomass Polychaeta mg AFDW/m10	Biomass Echinoderms mg AFDW/m11	Biomass Phoronid mg AFDW/m12	Biomass Tunicate mg AFDW/m13	Biomass Lancelet mg AFDW/m14	Biomass Other mg AFDW/m15	Biomass Total mg AFDW/m16
332	**2004**	West of Shoal	0.00	280.85	0.00	1.50	0.00	0.00	0.00	0.79
353	**2004**	West of Shoal	700.00	384.18	0.00	3.00	0.00	0.00	0.00	2.00
361	**2004**	West of Shoal	175.00	526.35	0.00	0.00	0.00	0.00	0.00	0.89
372	**2004**	West of Shoal	0.00	338.75	0.00	0.00	0.00	0.00	0.00	1.23
307	**2005**	Area B	0.00	56.60	0.00	0.00	0.00	0.00	0.00	0.13
308	**2005**	Area B	0.00	19.23	1.00	0.00	0.00	9.25	0.00	0.48
318	**2005**	Area B	0.00	16.75	0.00	0.00	0.00	0.00	0.00	0.36
500	**2005**	Area B	0.00	81.00	0.00	0.00	0.00	0.00	0.00	0.49
501	**2005**	Area B	66.75	74.63	0.00	0.00	0.00	0.00	0.00	0.47
377	**2005**	East of Shoal	10.00	66.05	4.50	0.00	0.00	0.00	0.00	0.22
297	**2005**	On Shoal	66.75	103.05	0.00	0.00	0.00	23.50	0.00	0.38
316	**2005**	On Shoal	0.00	84.78	7047.50	0.00	0.00	355.00	0.00	7.77
336	**2005**	On Shoal	0.00	33.85	0.00	0.00	0.00	22.75	0.00	0.22
347	**2005**	On Shoal	0.00	4.85	0.00	0.00	0.00	90.50	0.00	0.11
356	**2005**	On Shoal	0.00	67.75	0.00	0.00	0.00	0.00	0.00	0.34
385	**2005**	On Shoal	1.50	6.70	0.00	0.00	0.00	0.00	0.00	0.48
509	**2005**	On Shoal	0.00	37.25	0.00	0.00	0.00	562.00	0.00	0.71
332	**2005**	West of Shoal	19.80	487.05	0.00	0.00	0.00	51.50	0.00	1.54
353	**2005**	West of Shoal	10.00	333.00	0.00	4.00	0.00	0.00	0.00	1.11
361	**2005**	West of Shoal	298.25	477.78	9.75	0.00	0.00	0.00	0.00	1.21
372	**2005**	West of Shoal	242.33	272.15	0.00	0.00	0.00	0.00	0.00	1.38

Appendix D – 1

Macro Size – 2002

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
297	1.0	Amphipoda	Amphipoda	1	0.143
297	1.4	Amphipoda	Haustoriidae	1	0.360
297	2.0	Amphipoda	Haustoriidae	1	0.910
297	0.5	Bivalve	Bivalve	6	0.138
297	0.7	Bivalve	Bivalve	7	0.420
297	1.0	Bivalve	Bivalve	8	1.216
297	1.4	Bivalve	Bivalve	1	0.400
297	2.0	Bivalve	Bivalve	2	2.060
297	1.0	Crustacean Other	Cumacean	1	0.143
297	0.5	Crustacean Other	Tanaids	2	0.046
297	1.0	Isopoda	Isopoda	2	0.286
297	0.5	Lancelets	Lancelets	12	0.200
297	0.7	Lancelets	Lancelets	10	0.100
297	2.8	Lancelets	Lancelets	1	2.000
297	0.7	Nemertean	Nemertean	5	0.100
297	1.0	Nemertean	Nemertean	5	0.100
297	0.5	Polychaetes	Polychaetes	102	2.856
297	0.7	Polychaetes	Polychaetes	98	6.566
297	1.0	Polychaetes	Polychaetes	62	10.292
297	1.4	Polychaetes	Polychaetes	21	7.770
297	2.0	Polychaetes	Polychaetes	4	3.520
307	1.0	Amphipoda	Amphipoda	3	0.429
307	1.4	Amphipoda	Amphipoda	1	0.360
307	0.7	Amphipoda	Haustoriidae	1	0.058
307	1.0	Amphipoda	Haustoriidae	7	1.001
307	1.4	Amphipoda	Haustoriidae	1	0.360
307	2.0	Amphipoda	Haustoriidae	1	0.910
307	2.8	Amphipoda	Haustoriidae	2	4.600
307	0.5	Bivalve	Bivalve	4	0.092
307	0.7	Bivalve	Bivalve	9	0.540
307	1.0	Bivalve	Bivalve	5	0.760
307	2.8	Bivalve	Bivalve	3	8.010
307	9.0	Bivalve	Bivalve	1	3832.200
307	0.5	Crustacean Other	Tanaids	1	0.023
307	0.7	Crustacean Other	Tanaids	1	0.058
307	1.0	Crustacean Other	Tanaids	1	0.143
307	0.5	Decapods	Hermit Crab	1	0.023
307	5.6	Gastropoda	Crepidula	1	18.100
307	9.0	Gastropoda	Moonsnail	1	297.300
307	0.5	Lancelets	Lancelets	2	0.100
307	0.7	Lancelets	Lancelets	5	0.100
307	1.0	Lancelets	Lancelets	2	0.100
307	2.0	Lancelets	Lancelets	3	5.100
307	2.8	Lancelets	Lancelets	6	25.700
307	0.7	Nemertean	Nemertean	1	0.400
307	1.0	Nemertean	Nemertean	2	0.200

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
307	0.5	Polychaetes	Polychaetes	27	0.756
307	0.7	Polychaetes	Polychaetes	66	4.422
307	1.0	Polychaetes	Polychaetes	58	9.628
307	1.4	Polychaetes	Polychaetes	40	14.800
307	2.0	Polychaetes	Polychaetes	21	18.480
308	0.7	Amphipoda	Amphipoda	10	0.580
308	1.0	Amphipoda	Amphipoda	10	1.430
308	1.4	Amphipoda	Amphipoda	1	0.360
308	2.0	Amphipoda	Amphipoda	1	0.910
308	0.7	Amphipoda	Haustoriidae	1	0.058
308	1.0	Amphipoda	Haustoriidae	5	0.715
308	1.4	Amphipoda	Haustoriidae	6	2.160
308	2.0	Amphipoda	Haustoriidae	4	3.640
308	2.8	Amphipoda	Haustoriidae	1	2.300
308	1.4	Bivalve	Bivalve	1	0.400
308	2.8	Bivalve	Bivalve	1	2.670
308	2.8	Bivalve	Razor clam	1	2.670
308	0.5	Crustacean Other	Tanaids	1	0.023
308	1.0	Crustacean Other	Tanaids	1	0.143
308	0.5	Lancelets	Lancelets	5	0.200
308	0.7	Lancelets	Lancelets	3	0.400
308	2.0	Lancelets	Lancelets	2	3.000
308	2.8	Lancelets	Lancelets	8	36.400
308	0.5	Polychaetes	Polychaetes	4	0.112
308	0.7	Polychaetes	Polychaetes	5	0.335
308	1.0	Polychaetes	Polychaetes	5	0.830
308	1.4	Polychaetes	Polychaetes	4	1.480
308	2.0	Polychaetes	Polychaetes	7	6.160
316	0.5	Amphipoda	Amphipoda	1	0.023
316	0.7	Amphipoda	Amphipoda	7	0.406
316	1.0	Amphipoda	Amphipoda	3	0.429
316	1.4	Amphipoda	Amphipoda	5	1.800
316	2.0	Amphipoda	Amphipoda	1	0.910
316	2.8	Amphipoda	Amphipoda	1	2.300
316	0.5	Amphipoda	Haustoriidae	1	0.023
316	1.0	Amphipoda	Haustoriidae	4	0.572
316	1.4	Amphipoda	Haustoriidae	1	0.360
316	2.8	Amphipoda	Haustoriidae	1	2.300
316	0.7	Bivalve	Bivalve	2	0.120
316	1.0	Bivalve	Bivalve	1	0.152
316	2.8	Bivalve	Bivalve	1	2.670
316	2.8	Bivalve	Oyster	1	2.670
316	0.7	Crustacean Other	Tanaids	3	0.174
316	0.5	Gastropoda	Gastropoda	1	0.023
316	0.7	Gastropoda	Gastropoda	2	0.120
316	0.5	Lancelets	Lancelets	2	0.100

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
316	0.7	Lancelets	Lancelets	2	0.100
316	2.0	Lancelets	Lancelets	5	10.200
316	2.8	Lancelets	Lancelets	9	16.800
316	5.6	Lancelets	Lancelets	3	16.400
316	0.5	Polychaetes	Polychaetes	9	0.252
316	0.7	Polychaetes	Polychaetes	10	0.670
316	1.0	Polychaetes	Polychaetes	6	0.996
316	1.4	Polychaetes	Polychaetes	1	0.370
316	2.0	Polychaetes	Polychaetes	3	2.640
316	2.8	Polychaetes	Polychaetes	2	4.180
318	0.7	Amphipoda	Haustoriidae	1	0.058
318	1.0	Amphipoda	Haustoriidae	4	0.572
318	1.4	Amphipoda	Haustoriidae	8	2.880
318	2.8	Amphipoda	Haustoriidae	1	2.300
318	0.5	Bivalve	Bivalve	2	0.046
318	0.7	Bivalve	Bivalve	9	0.540
318	1.0	Bivalve	Bivalve	2	0.304
318	1.4	Bivalve	Bivalve	1	0.400
318	4.0	Bivalve	Bivalve	1	7.000
318	0.5	Crustacean Other	Tanaids	3	0.069
318	0.7	Crustacean Other	Tanaids	5	0.290
318	0.5	Decapods	Hermit Crab	1	0.023
318	1.4	Gastropoda	Moonsnail	1	0.400
318	5.6	Gastropoda	Nassarius	1	18.100
318	1.0	Isopoda	Isopoda	1	0.143
318	1.4	Isopoda	Isopoda	1	0.360
318	0.5	Lancelets	Lancelets	4	0.700
318	0.7	Lancelets	Lancelets	8	0.500
318	4.0	Lancelets	Lancelets	1	23.300
318	1.0	Nemertean	Nemertean	1	0.400
318	0.5	Polychaetes	Polychaetes	5	0.140
318	0.7	Polychaetes	Polychaetes	4	0.268
318	1.0	Polychaetes	Polychaetes	5	0.830
318	1.4	Polychaetes	Polychaetes	2	0.740
318	2.0	Polychaetes	Polychaetes	2	1.760
329	0.7	Amphipoda	Amphipoda	4	0.232
329	1.0	Amphipoda	Amphipoda	1	0.143
329	1.4	Amphipoda	Amphipoda	1	0.360
329	1.4	Amphipoda	Haustoriidae	1	0.360
329	2.0	Amphipoda	Haustoriidae	2	1.820
329	4.0	Bivalve	Bivalve	2	14.000
329	0.7	Decapods	Hermit Crab	1	0.058
329	5.6	Decapods	Hermit Crab	1	14.700
329	1.4	Gastropoda	Moonsnail	1	0.400
329	2.0	Gastropoda	Nassarius	1	1.030
329	1.4	Lancelets	Lancelets	1	0.700

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
329	2.0	Lancelets	Lancelets	4	13.600
329	1.4	Nemertean	Nemertean	4	2.400
329	5.6	Nemertean	Nemertean	1	14.700
329	0.5	Polychaetes	Polychaetes	10	0.280
329	0.7	Polychaetes	Polychaetes	7	0.469
329	1.0	Polychaetes	Polychaetes	20	3.320
329	1.4	Polychaetes	Polychaetes	32	11.840
329	2.0	Polychaetes	Polychaetes	20	17.600
329	2.8	Polychaetes	Polychaetes	9	18.810
329	4.0	Polychaetes	Polychaetes	1	5.000
329	9.0	Polychaetes	Polychaetes	1	97.300
332	0.5	Amphipoda	Amphipoda	2	0.046
332	0.7	Amphipoda	Amphipoda	3	0.174
332	1.0	Amphipoda	Amphipoda	11	1.573
332	2.0	Amphipoda	Amphipoda	2	1.820
332	2.8	Amphipoda	Amphipoda	1	2.300
332	0.7	Bivalve	Bivalve	2	0.120
332	1.0	Bivalve	Bivalve	1	0.152
332	1.4	Bivalve	Bivalve	3	1.200
332	2.8	Bivalve	Bivalve	3	8.010
332	4.0	Bivalve	Bivalve	2	14.000
332	2.0	Bivalve	Razor Clams	5	5.150
332	2.8	Bivalve	Razor Clams	17	45.390
332	5.6	Bivalve	Razor Clams	3	54.300
332	0.7	Crustacean Other	Cumacean	1	0.058
332	2.0	Decapods	Hermit Crab	4	3.640
332	2.8	Decapods	Hermit Crab	1	2.300
332	0.5	Gastropoda	Gastropoda	1	0.023
332	0.7	Gastropoda	Gastropoda	4	0.240
332	1.0	Gastropoda	Gastropoda	1	0.152
332	1.4	Gastropoda	Gastropoda	4	1.600
332	1.0	Gastropoda	moonsnails	1	0.152
332	2.0	Gastropoda	moonsnails	1	1.030
332	0.7	Gastropoda	Nassarius	2	0.120
332	1.0	Gastropoda	Nassarius	4	0.608
332	1.4	Gastropoda	Nassarius	6	2.400
332	2.8	Gastropoda	Nassarius	1	2.670
332	4.0	Gastropoda	Nassarius	1	7.000
332	0.5	Polychaetes	Polychaetes	89	2.492
332	0.7	Polychaetes	Polychaetes	170	11.390
332	1.0	Polychaetes	Polychaetes	271	44.986
332	1.4	Polychaetes	Polychaetes	79	29.230
332	2.0	Polychaetes	Polychaetes	15	13.200
332	5.6	Polychaetes	Polychaetes	2	23.600
336	0.5	Amphipoda	Amphipoda	1	0.023
336	0.7	Amphipoda	Amphipoda	1	0.058

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
336	1.0	Amphipoda	Amphipoda	1	0.143
336	1.4	Amphipoda	Amphipoda	1	0.360
336	0.7	Amphipoda	Haustoriidae	1	0.058
336	1.0	Amphipoda	Haustoriidae	4	0.572
336	0.5	Bivalve	Bivalve	18	0.414
336	0.7	Bivalve	Bivalve	17	1.020
336	1.0	Bivalve	Bivalve	5	0.760
336	2.8	Bivalve	Bivalve	1	2.670
336	0.7	Crustacean Other	Cumacean	1	0.058
336	5.6	Decapods	Hermit Crab	2	29.400
336	0.5	Gastropoda	Crepidula	2	0.046
336	2.8	Isopoda	Isopoda	1	2.300
336	0.5	Lancelets	Lancelets	11	0.200
336	0.7	Lancelets	Lancelets	4	0.500
336	1.0	Lancelets	Lancelets	14	0.400
336	2.0	Lancelets	Lancelets	1	1.400
336	2.8	Lancelets	Lancelets	1	3.200
336	0.7	Nemertean	Nemertean	2	0.200
336	1.0	Nemertean	Nemertean	1	0.200
336	0.5	Polychaetes	Polychaetes	114	3.192
336	0.7	Polychaetes	Polychaetes	70	4.690
336	1.0	Polychaetes	Polychaetes	57	9.462
336	1.4	Polychaetes	Polychaetes	34	12.580
336	2.0	Polychaetes	Polychaetes	11	9.680
336	2.8	Polychaetes	Polychaetes	1	2.090
342	0.5	Amphipoda	Amphipoda	1	0.023
342	0.7	Amphipoda	Amphipoda	12	0.696
342	1.0	Amphipoda	Amphipoda	13	1.859
342	1.4	Amphipoda	Amphipoda	14	5.040
342	2.8	Amphipoda	Amphipoda	1	2.300
342	1.0	Amphipoda	Haustoriidae	1	0.143
342	0.7	Amphipoda	Paracrepella tennius	1	0.044
342	0.7	Bivalve	Bivalve	2	0.120
342	1.4	Bivalve	Bivalve	3	1.200
342	2.8	Bivalve	Bivalve	1	2.670
342	1.4	Bivalve	Razor Clams	6	2.400
342	2.0	Bivalve	Razor Clams	36	37.080
342	2.8	Bivalve	Razor Clams	22	58.740
342	4.0	Bivalve	Razor Clams	4	28.000
342	5.6	Bivalve	Razor Clams	1	18.100
342	0.5	Decapods	Hermit Crab	1	0.023
342	1.4	Decapods	Hermit Crab	1	0.360
342	0.5	Gastropoda	Gastropoda	5	0.115
342	0.7	Gastropoda	Gastropoda	5	0.300
342	1.0	Gastropoda	Gastropoda	3	0.456
342	1.0	Gastropoda	Nassarius	7	1.064

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
342	1.4	Gastropoda	Nassarius	6	2.400
342	5.6	Gastropoda	Nassarius	1	18.100
342	0.5	Polychaetes	Polychaetes	32	0.896
342	0.7	Polychaetes	Polychaetes	110	7.370
342	1.0	Polychaetes	Polychaetes	199	33.034
342	1.4	Polychaetes	Polychaetes	58	21.460
342	2.0	Polychaetes	Polychaetes	6	5.280
342	2.8	Polychaetes	Polychaetes	1	2.090
347	0.7	Amphipoda	Haustoriidae	3	0.174
347	1.4	Amphipoda	Haustoriidae	2	0.720
347	2.0	Amphipoda	Haustoriidae	3	2.730
347	0.5	Bivalve	Bivalve	5	0.115
347	0.7	Bivalve	Bivalve	5	0.300
347	1.0	Bivalve	Bivalve	1	0.152
347	0.5	Crustacean Other	Tanaids	6	0.138
347	0.7	Crustacean Other	Tanaids	2	0.116
347	0.5	Decapods	Hermit Crab	1	0.023
347	0.5	Gastropoda	Gastropoda	1	0.023
347	0.5	Lancelets	Lancelets	9	0.100
347	0.7	Lancelets	Lancelets	1	0.400
347	1.0	Lancelets	Lancelets	4	0.100
347	0.5	Nemertean	Nemertean	7	0.500
347	0.7	Nemertean	Nemertean	6	0.200
347	1.0	Nemertean	Nemertean	4	0.100
347	2.0	Nemertean	Nemertean	1	0.500
347	0.5	Polychaetes	Polychaetes	40	1.120
347	0.7	Polychaetes	Polychaetes	51	3.417
347	1.0	Polychaetes	Polychaetes	31	5.146
347	1.4	Polychaetes	Polychaetes	1	0.370
347	2.0	Polychaetes	Polychaetes	1	0.880
347	2.8	Polychaetes	Polychaetes	1	2.090
353	0.5	Amphipoda	Amphipoda	31	0.713
353	0.7	Amphipoda	Amphipoda	43	2.494
353	1.0	Amphipoda	Amphipoda	31	4.433
353	1.4	Amphipoda	Amphipoda	34	12.240
353	2.0	Amphipoda	Amphipoda	8	7.280
353	2.8	Amphipoda	Amphipoda	1	2.300
353	2.8	Anemone	Anemone	1	6.369
353	0.5	Bivalve	Bivalve	1	0.023
353	2.0	Bivalve	Bivalve	1	1.030
353	5.6	Bivalve	Bivalve	1	18.100
353	1.4	Bivalve	Razor clams	5	2.000
353	2.0	Bivalve	Razor clams	5	5.150
353	2.8	Bivalve	Razor clams	8	21.360
353	4.0	Bivalve	Razor clams	8	56.000
353	5.6	Bivalve	Razor clams	1	18.100

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
353	1.4	Decapods	Hermit Crab	6	2.160
353	2.0	Decapods	Hermit Crab	1	0.910
353	2.8	Decapods	Hermit Crab	1	2.300
353	5.6	Decapods	Hermit Crab	4	58.800
353	2.8	Echinoderm	Sea Cucumber	1	5.563
353	0.5	Gastropoda	Crepidula	12	0.276
353	0.7	Gastropoda	Crepidula	1	0.060
353	1.4	Gastropoda	Crepidula	5	2.000
353	2.0	Gastropoda	Crepidula	2	2.060
353	2.0	Lancelets	Lancelets	1	0.942
353	0.5	Nemertean	Nemertean	2	0.100
353	0.7	Nemertean	Nemertean	1	0.100
353	1.0	Nemertean	Nemertean	4	1.000
353	1.4	Nemertean	Nemertean	4	1.800
353	2.0	Nemertean	Nemertean	1	0.334
353	2.8	Nemertean	Nemertean	1	2.200
353	2.0	Other	Flat Worms	1	1.060
353	2.0	Other	Hemichordate	1	0.958
353	0.5	Polychaetes	Polychaetes	70	1.960
353	0.7	Polychaetes	Polychaetes	120	8.040
353	1.0	Polychaetes	Polychaetes	96	15.936
353	1.4	Polychaetes	Polychaetes	47	17.390
353	2.0	Polychaetes	Polychaetes	69	60.720
353	2.8	Polychaetes	Polychaetes	7	14.630
353	4.0	Polychaetes	Polychaetes	5	25.000
353	5.6	Polychaetes	Polychaetes	1	11.800
356	2.0	Amphipoda	Haustoriidae	7	6.370
356	0.7	Bivalve	Bivalve	6	0.360
356	1.0	Bivalve	Bivalve	3	0.456
356	5.6	Bivalve	Bivalve	1	18.100
356	0.7	Crustacean Other	Cumacean	1	0.058
356	0.7	Crustacean Other	Tanaids	7	0.406
356	2.0	Decapods	Hermit Crab	3	2.730
356	1.0	Gastropoda	Moonsnail	1	0.152
356	0.7	Lancelets	Lancelets	4	0.200
356	1.0	Lancelets	Lancelets	3	0.100
356	2.8	Lancelets	Lancelets	1	4.900
356	0.5	Polychaetes	Polychaetes	7	0.196
356	0.7	Polychaetes	Polychaetes	38	2.546
356	1.0	Polychaetes	Polychaetes	39	6.474
356	1.4	Polychaetes	Polychaetes	3	1.110
356	2.0	Polychaetes	Polychaetes	2	1.760
356	2.8	Polychaetes	Polychaetes	1	2.090
356	9.0	Polychaetes	Polychaetes	1	157.000
360	0.5	Amphipoda	Amphipoda	3	0.069
360	0.7	Amphipoda	Amphipoda	4	0.232

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
360	1.0	Amphipoda	Amphipoda	8	1.144
360	1.4	Amphipoda	Amphipoda	1	0.360
360	2.0	Amphipoda	Amphipoda	3	2.730
360	2.8	Amphipoda	Amphipoda	1	2.300
360	0.5	Amphipoda	Haustoriidae	14	0.322
360	0.7	Amphipoda	Haustoriidae	6	0.348
360	1.0	Amphipoda	Haustoriidae	12	1.716
360	1.4	Amphipoda	Haustoriidae	4	1.440
360	2.0	Amphipoda	Haustoriidae	10	9.100
360	2.8	Amphipoda	Haustoriidae	3	6.900
360	0.5	Bivalve	Bivalve	3	0.069
360	0.7	Bivalve	Bivalve	1	0.060
360	0.5	Crustacean Other	Tanaids	1	0.023
360	0.5	Decapods	Hermit Crab	1	0.023
360	2.8	Echinoderm	Sand Dollar	1	0.700
360	1.0	Gastropoda	moonsnails	1	0.152
360	1.0	Isopoda	Isopoda	1	0.143
360	2.0	Isopoda	Isopoda	1	0.910
360	0.5	Lancelets	Lancelets	5	0.100
360	0.7	Lancelets	Lancelets	3	0.100
360	1.0	Lancelets	Lancelets	7	4.400
360	1.4	Lancelets	Lancelets	45	130.000
360	2.0	Lancelets	Lancelets	11	44.300
360	4.0	Lancelets	Lancelets	1	12.600
360	0.5	Nemertean	Nemertean	1	0.200
360	1.4	Nemertean	Nemertean	1	0.100
360	0.5	Polychaetes	Polychaetes	113	3.164
360	0.7	Polychaetes	Polychaetes	235	15.745
360	1.0	Polychaetes	Polychaetes	29	4.814
360	1.4	Polychaetes	Polychaetes	10	3.700
360	2.0	Polychaetes	Polychaetes	1	0.880
361	0.5	Amphipoda	Amphipoda	1	0.023
361	0.5	Amphipoda	Amphipoda	8	0.184
361	0.7	Amphipoda	Amphipoda	11	0.638
361	1.0	Amphipoda	Amphipoda	14	2.002
361	1.4	Amphipoda	Amphipoda	30	10.800
361	2.0	Amphipoda	Amphipoda	14	12.740
361	2.8	Amphipoda	Amphipoda	5	11.500
361	0.5	Amphipoda	Haustoriidae	1	0.023
361	1.4	Amphipoda	Haustoriidae	1	0.360
361	1.4	Anemone	Anemone	1	1.000
361	4.0	Anemone	Anemone	1	4.300
361	1.0	Bivalve	Bivalve	4	0.608
361	2.8	Bivalve	Razor Clams	10	26.700
361	4.0	Bivalve	Razor Clams	11	77.000
361	2.0	Decapods	Hermit Crab	1	0.910

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
361	1.0	Decapods	Shrimp	1	0.143
361	0.5	Gastropoda	Gastropoda	1	0.023
361	0.7	Gastropoda	Gastropoda	2	0.120
361	1.0	Gastropoda	Gastropoda	1	0.152
361	1.0	Gastropoda	Nassarius	1	0.152
361	1.4	Gastropoda	Nassarius	2	0.800
361	2.8	Gastropoda	Nassarius	4	10.680
361	0.5	Polychaetes	Polychaetes	95	2.660
361	0.7	Polychaetes	Polychaetes	250	16.750
361	1.0	Polychaetes	Polychaetes	311	51.626
361	1.4	Polychaetes	Polychaetes	121	44.770
361	2.0	Polychaetes	Polychaetes	4	3.520
361	2.8	Polychaetes	Polychaetes	20	41.800
365	0.7	Amphipoda	Amphipoda	1	0.058
365	0.7	Amphipoda	Haustoriidae	1	0.058
365	1.0	Amphipoda	Haustoriidae	3	0.429
365	1.4	Amphipoda	Haustoriidae	2	0.720
365	2.0	Amphipoda	Haustoriidae	8	7.280
365	0.7	Bivalve	Bivalve	2	0.120
365	1.0	Bivalve	Bivalve	1	0.152
365	5.6	Decapods	Hermit Crab	1	14.700
365	4.0	Echinoderm	Brittle Star	1	6.700
365	2.0	Isopoda	Isopoda	1	0.910
365	0.7	Lancelets	Lancelets	3	0.200
365	1.0	Nemertean	Nemertean	3	0.600
365	0.5	Polychaetes	Polychaetes	2	0.056
365	0.7	Polychaetes	Polychaetes	13	0.871
365	1.0	Polychaetes	Polychaetes	4	0.664
365	1.4	Polychaetes	Polychaetes	4	1.480
365	2.8	Polychaetes	Polychaetes	1	2.090
365	4.0	Polychaetes	Polychaetes	1	5.000
372	0.5	Amphipoda	Amphipoda	5	0.115
372	0.7	Amphipoda	Amphipoda	8	0.464
372	1.0	Amphipoda	Amphipoda	11	1.573
372	1.4	Amphipoda	Amphipoda	7	2.520
372	2.0	Amphipoda	Amphipoda	2	1.820
372	2.8	Amphipoda	Amphipoda	2	4.600
372	4.0	Amphipoda	Amphipoda	3	17.400
372	0.5	Amphipoda	Haustoriidae	1	0.023
372	0.7	Amphipoda	Haustoriidae	1	0.058
372	1.0	Amphipoda	Haustoriidae	2	0.286
372	1.4	Bivalve	Razor clams	1	0.400
372	2.0	Bivalve	Razor clams	4	4.120
372	2.8	Bivalve	Razor clams	7	18.690
372	4.0	Bivalve	Razor clams	6	42.000
372	5.6	Bivalve	Razor clams	8	144.800

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
372	1.0	Crustacean Other	Tanaids	1	0.143
372	4.0	Decapods	Crab	1	5.800
372	1.0	Decapods	Hermit Crab	1	0.143
372	2.0	Decapods	Hermit Crab	1	0.910
372	1.4	Isopoda	Isopoda	1	0.360
372	1.4	Lancelets	Lancelets	1	1.000
372	0.5	Polychaetes	Polychaetes	50	1.400
372	0.7	Polychaetes	Polychaetes	82	5.494
372	1.0	Polychaetes	Polychaetes	181	30.046
372	1.4	Polychaetes	Polychaetes	64	23.680
372	2.0	Polychaetes	Polychaetes	6	5.280
372	4.0	Polychaetes	Polychaetes	4	20.000
372	5.6	Polychaetes	Polychaetes	4	47.200
377	0.5	Amphipoda	Amphipoda	2	0.046
377	0.7	Amphipoda	Amphipoda	17	0.986
377	1.0	Amphipoda	Amphipoda	3	0.429
377	1.0	Amphipoda	Amphipoda	41	5.863
377	1.4	Amphipoda	Amphipoda	4	1.440
377	1.4	Amphipoda	Amphipoda	39	14.040
377	2.0	Amphipoda	Amphipoda	2	1.820
377	2.8	Amphipoda	Amphipoda	10	23.000
377	2.0	Amphipoda	Haustoriidae	1	0.910
377	2.0	Bivalve	Bivalve	1	1.030
377	1.4	Bivalve	Razor Clams	1	0.400
377	2.0	Bivalve	Razor Clams	1	1.030
377	2.0	Decapods	Crab	1	0.910
377	9.0	Decapods	Hermit Crab	1	61.800
377	9.0	Decapods	Stone Crab	1	67.000
377	1.4	Gastropoda	Gastropoda	1	0.400
377	1.0	Gastropoda	Nassarius	1	0.152
377	2.8	Gastropoda	Nassarius	1	2.670
377	1.4	Isopoda	Isopoda	1	0.360
377	1.4	Nemertean	Nemertean	1	2.500
377	0.7	Polychaetes	Polychaetes	12	0.804
377	1.0	Polychaetes	Polychaetes	82	13.612
377	1.4	Polychaetes	Polychaetes	72	26.640
377	2.0	Polychaetes	Polychaetes	196	172.480
377	2.8	Polychaetes	Polychaetes	2	4.180
385	0.7	Amphipoda	Amphipoda	1	0.058
385	1.0	Amphipoda	Amphipoda	6	0.858
385	0.7	Amphipoda	Haustoriidae	2	0.116
385	1.0	Amphipoda	Haustoriidae	2	0.286
385	2.8	Amphipoda	Haustoriidae	1	2.300
385	0.5	Bivalve	Bivalve	1	0.023
385	0.7	Bivalve	Bivalve	1	0.060
385	1.0	Bivalve	Bivalve	1	0.152

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
385	4.0	Bivalve	Bivalve	1	7.000
385	0.5	Crustacean Other	Cumacean	1	0.023
385	0.7	Crustacean Other	Tanaids	2	0.116
385	2.0	Decapods	Hermit Crab	4	3.640
385	2.8	Echinoderm	Sea Cucumber	2	8.300
385	1.0	Isopoda	Isopoda	1	0.143
385	2.0	Isopoda	Isopoda	9	8.190
385	2.8	Isopoda	Isopoda	1	2.300
385	4.0	Isopoda	Isopoda	1	5.800
385	0.5	Lancelets	Lancelets	6	0.100
385	0.7	Lancelets	Lancelets	20	0.400
385	2.0	Lancelets	Lancelets	3	5.800
385	0.5	Nemertean	Nemertean	5	0.800
385	0.7	Nemertean	Nemertean	7	0.300
385	1.0	Nemertean	Nemertean	17	1.500
385	1.4	Nemertean	Nemertean	1	0.500
385	1.4	Other	Tunicate	1	0.200
385	1.0	Phoronid	Phoronid	1	0.000
385	0.5	Polychaetes	Polychaetes	122	3.416
385	0.7	Polychaetes	Polychaetes	207	13.869
385	1.0	Polychaetes	Polychaetes	145	24.070
385	1.4	Polychaetes	Polychaetes	5	1.850
385	2.0	Polychaetes	Polychaetes	3	2.640
385	2.8	Polychaetes	Polychaetes	1	2.090
390	0.5	Amphipoda	Amphipoda	9	0.207
390	0.7	Amphipoda	Amphipoda	13	0.754
390	1.0	Amphipoda	Amphipoda	9	1.287
390	1.4	Amphipoda	Amphipoda	7	2.520
390	2.0	Amphipoda	Amphipoda	3	2.730
390	2.8	Amphipoda	Amphipoda	3	6.900
390	0.5	Amphipoda	Haustoriidae	6	0.138
390	0.7	Amphipoda	Haustoriidae	13	0.754
390	1.0	Amphipoda	Haustoriidae	4	0.572
390	1.4	Amphipoda	Haustoriidae	6	2.160
390	2.0	Amphipoda	Haustoriidae	3	2.730
390	0.5	Bivalve	Bivalve	12	0.276
390	0.7	Bivalve	Bivalve	6	0.360
390	1.0	Bivalve	Bivalve	2	0.304
390	9.0	Bivalve	Bivalve	1	16.300
390	0.7	Crustacean Other	Tanaids	1	0.058
390	9.0	Echinoderm	Sand Dollar	1	179.000
390	2.0	Echinoderm	Sea Cucumber	1	2.000
390	2.8	Echinoderm	Sea Star	1	0.800
390	0.5	Gastropoda	moonsnails	1	0.023
390	1.0	Gastropoda	moonsnails	1	0.152
390	1.4	Gastropoda	moonsnails	3	1.200

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
390	0.7	Isopoda	Isopoda	1	0.058
390	1.0	Isopoda	Isopoda	1	0.143
390	2.0	Isopoda	Isopoda	1	0.910
390	0.5	Lancelets	Lancelets	2	0.300
390	0.7	Lancelets	Lancelets	7	0.100
390	2.0	Lancelets	Lancelets	18	33.000
390	2.8	Lancelets	Lancelets	1	17.500
390	0.5	Nemertean	Nemertean	17	0.600
390	0.7	Nemertean	Nemertean	23	1.500
390	1.0	Nemertean	Nemertean	20	1.700
390	1.4	Nemertean	Nemertean	17	2.300
390	2.0	Nemertean	Nemertean	6	22.000
390	0.5	Other	Tunicate	1	0.100
390	0.7	Other	Tunicate	1	0.200
390	1.0	Other	Tunicate	1	0.100
390	1.4	Other	Tunicate	3	0.700
390	2.0	Other	Tunicate	1	0.200
390	2.8	Other	Tunicate	1	1.700
390	0.7	Phoronid	Phoronid	2	0.200
390	1.0	Phoronid	Phoronid	10	0.600
390	1.4	Phoronid	Phoronid	18	3.000
390	0.5	Polychaetes	Polychaetes	89	2.492
390	0.7	Polychaetes	Polychaetes	154	10.318
390	1.0	Polychaetes	Polychaetes	22	3.652
390	1.4	Polychaetes	Polychaetes	34	12.580
390	2.0	Polychaetes	Polychaetes	6	5.280
390	2.8	Polychaetes	Polychaetes	1	2.090
396	0.7	Amphipoda	Amphipoda	5	0.290
396	1.0	Amphipoda	Amphipoda	3	0.429
396	1.4	Amphipoda	Amphipoda	4	1.440
396	2.8	Amphipoda	Amphipoda	1	2.300
396	0.5	Amphipoda	Haustoriidae	1	0.023
396	0.7	Amphipoda	Haustoriidae	6	0.348
396	1.0	Amphipoda	Haustoriidae	3	0.429
396	1.4	Amphipoda	Haustoriidae	1	0.360
396	2.0	Amphipoda	Haustoriidae	2	1.820
396	1.0	Bivalve	Bivalve	1	0.152
396	4.0	Bivalve	Bivalve	1	7.000
396	1.4	Bivalve	Razor clams	1	0.400
396	2.0	Bivalve	Razor clams	1	1.030
396	2.8	Bivalve	Razor clams	2	5.340
396	5.6	Decapods	Hermit Crab	1	14.700
396	9.0	Decapods	Hermit Crab	1	31.800
396	0.7	Gastropoda	Gastropoda	1	0.060
396	1.0	Gastropoda	Gastropoda	2	0.304
396	1.4	Gastropoda	Gastropoda	1	0.400

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
396	0.7	Gastropoda	Nassarius	1	0.060
396	1.4	Lancelets	Lancelets	1	1.400
396	0.7	Nemertean	Nemertean	2	0.300
396	2.0	Nemertean	Nemertean	1	0.800
396	0.5	Polychaetes	Polychaetes	10	0.280
396	0.7	Polychaetes	Polychaetes	35	2.345
396	1.0	Polychaetes	Polychaetes	36	5.976
396	1.4	Polychaetes	Polychaetes	62	22.940
396	2.0	Polychaetes	Polychaetes	14	12.320

Appendix D – 2

Macro Size – 2003

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
297	0.5	Amphipoda	Amphipoda	1	0.023
307	0.5	Amphipoda	Amphipoda	3	0.069
308	0.5	Amphipoda	Amphipoda	2	0.046
332	0.5	Amphipoda	Amphipoda	13	0.299
336	0.5	Amphipoda	Amphipoda	7	0.161
347	0.5	Amphipoda	Amphipoda	2	0.046
353	0.5	Amphipoda	Amphipoda	1	0.023
356	0.5	Amphipoda	Amphipoda	1	0.023
372	0.5	Amphipoda	Amphipoda	1	0.023
390	0.5	Amphipoda	Amphipoda	4	0.092
396	0.5	Amphipoda	Amphipoda	3	0.069
297	0.5	Bivalva	Bivalva	4	0.092
307	0.5	Bivalva	Bivalva	11	0.253
308	0.5	Bivalva	Bivalva	1	0.023
318	0.5	Bivalva	Bivalva	11	0.253
336	0.5	Bivalva	Bivalva	21	0.483
347	0.5	Bivalva	Bivalva	9	0.207
356	0.5	Bivalva	Bivalva	27	0.621
385	0.5	Bivalva	Bivalva	5	0.115
390	0.5	Bivalva	Bivalva	7	0.161
353	0.5	Gastropoda	Crepidula	1	0.023
297	0.5	Crustacean Other	Cumacean	1	0.023
342	0.5	Crustacean Other	Cumacean	1	0.023
347	0.5	Crustacean Other	Cumacean	1	0.023
332	0.5	Isopoda	Edotea	1	0.023
342	0.5	Flatworm	Flatworm	3	0.084
308	0.5	Gastropoda	Gastropoda	1	0.023
385	0.5	Gastropoda	Gastropoda	1	0.023
297	0.5	Amphipoda	Haustoriidae	1	0.023
307	0.5	Amphipoda	Haustoriidae	1	0.023
308	0.5	Amphipoda	Haustoriidae	4	0.092
336	0.5	Amphipoda	Haustoriidae	2	0.046
385	0.5	Amphipoda	Haustoriidae	1	0.023
297	0.5	Decapod	Hermit Crab	2	0.046
297	0.5	Lancelet	Lancelet	24	0.300
307	0.5	Lancelet	Lancelet	4	0.100
318	0.5	Lancelet	Lancelet	7	0.100
336	0.5	Lancelet	Lancelet	5	0.100
347	0.5	Lancelet	Lancelet	2	0.000
347	0.5	Lancelet	Lancelet	1	0.100
356	0.5	Lancelet	Lancelet	10	0.100
347	0.5	Nemertean	Nemertean	1	0.100
297	0.5	Polychaete	Polychaete	146	4.088
307	0.5	Polychaete	Polychaete	101	2.828
308	0.5	Polychaete	Polychaete	107	2.996
316	0.5	Polychaete	Polychaete	38	1.064

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
318	0.5	Polychaete	Polychaete	70	1.960
332	0.5	Polychaete	Polychaete	70	1.960
336	0.5	Polychaete	Polychaete	27	0.756
342	0.5	Polychaete	Polychaete	102	2.856
347	0.5	Polychaete	Polychaete	64	1.792
353	0.5	Polychaete	Polychaete	101	2.828
356	0.5	Polychaete	Polychaete	11	0.308
361	0.5	Polychaete	Polychaete	320	8.960
365	0.5	Polychaete	Polychaete	6	0.168
377	0.5	Polychaete	Polychaete	8	0.224
385	0.5	Polychaete	Polychaete	18	0.504
396	0.5	Polychaete	Polychaete	15	0.420
396	0.5	Decapod	Shrimp	1	0.023
297	0.5	Crustacean Other	Tanaid	9	0.207
307	0.5	Crustacean Other	Tanaid	1	0.023
316	0.5	Crustacean Other	Tanaid	19	0.437
318	0.5	Crustacean Other	Tanaid	35	0.805
336	0.5	Crustacean Other	Tanaid	52	1.196
347	0.5	Crustacean Other	Tanaid	85	1.955
385	0.5	Crustacean Other	Tanaid	4	0.092
297	0.7	Amphipoda	Amphipoda	1	0.058
307	0.7	Amphipoda	Amphipoda	26	1.508
308	0.7	Amphipoda	Amphipoda	1	0.058
308	0.7	Amphipoda	Amphipoda	3	0.174
318	0.7	Amphipoda	Amphipoda	1	0.058
332	0.7	Amphipoda	Amphipoda	6	0.348
342	0.7	Amphipoda	Amphipoda	4	0.232
347	0.7	Amphipoda	Amphipoda	1	0.058
353	0.7	Amphipoda	Amphipoda	1	0.058
356	0.7	Amphipoda	Amphipoda	2	0.116
372	0.7	Amphipoda	Amphipoda	14	0.812
377	0.7	Amphipoda	Amphipoda	3	0.174
390	0.7	Amphipoda	Amphipoda	23	1.334
396	0.7	Amphipoda	Amphipoda	16	0.928
297	0.7	Bivalva	Bivalva	3	0.180
307	0.7	Bivalva	Bivalva	1	0.060
308	0.7	Bivalva	Bivalva	2	0.120
318	0.7	Bivalva	Bivalva	5	0.300
332	0.7	Bivalva	Bivalva	10	0.600
336	0.7	Bivalva	Bivalva	5	0.300
342	0.7	Bivalva	Bivalva	1	0.060
347	0.7	Bivalva	Bivalva	2	0.120
353	0.7	Bivalva	Bivalva	1	0.060
356	0.7	Bivalva	Bivalva	18	1.080
361	0.7	Bivalva	Bivalva	11	0.660
372	0.7	Bivalva	Bivalva	2	0.120

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
377	0.7	Bivalva	Bivalva	3	0.180
385	0.7	Bivalva	Bivalva	2	0.120
390	0.7	Bivalva	Bivalva	2	0.120
396	0.7	Bivalva	Bivalva	2	0.120
353	0.7	Gastropoda	Crepidula	1	0.060
307	0.7	Crustacean Other	Cumacean	1	0.058
308	0.7	Crustacean Other	Cumacean	4	0.232
318	0.7	Crustacean Other	Cumacean	2	0.116
336	0.7	Crustacean Other	Cumacean	1	0.058
347	0.7	Crustacean Other	Cumacean	1	0.058
356	0.7	Crustacean Other	Cumacean	1	0.058
385	0.7	Crustacean Other	Cumacean	2	0.116
390	0.7	Crustacean Other	Cumacean	1	0.058
342	0.7	Isopoda	Edotea	2	0.116
396	0.7	Isopoda	Edotea	1	0.058
297	0.7	Amphipoda	Haustoriidae	2	0.116
307	0.7	Amphipoda	Haustoriidae	2	0.116
308	0.7	Amphipoda	Haustoriidae	9	0.522
316	0.7	Amphipoda	Haustoriidae	2	0.116
318	0.7	Amphipoda	Haustoriidae	5	0.290
336	0.7	Amphipoda	Haustoriidae	4	0.232
347	0.7	Amphipoda	Haustoriidae	3	0.174
356	0.7	Amphipoda	Haustoriidae	1	0.058
385	0.7	Amphipoda	Haustoriidae	4	0.232
390	0.7	Amphipoda	Haustoriidae	15	0.870
308	0.7	Decapod	Hermit Crab	1	0.058
361	0.7	Decapod	Hermit Crab	4	0.232
390	0.7	Decapod	Hermit Crab	1	0.058
318	0.7	Isopoda	Isopoda	1	0.058
307	0.7	Lancelet	Lancelet	7	0.200
308	0.7	Lancelet	Lancelet	1	0.100
356	0.7	Lancelet	Lancelet	14	0.100
385	0.7	Lancelet	Lancelet	16	0.300
361	0.7	Phoronid	Phoronid	18	0.600
372	0.7	Phoronid	Phoronid	44	0.400
297	0.7	Polychaete	Polychaete	28	1.876
307	0.7	Polychaete	Polychaete	32	2.144
308	0.7	Polychaete	Polychaete	6	0.402
316	0.7	Polychaete	Polychaete	28	1.876
318	0.7	Polychaete	Polychaete	9	0.603
332	0.7	Polychaete	Polychaete	184	12.328
336	0.7	Polychaete	Polychaete	45	3.015
342	0.7	Polychaete	Polychaete	99	6.633
347	0.7	Polychaete	Polychaete	3	0.201
353	0.7	Polychaete	Polychaete	333	22.311
356	0.7	Polychaete	Polychaete	6	0.402

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
361	0.7	Polychaete	Polychaete	133	8.911
365	0.7	Polychaete	Polychaete	4	0.268
372	0.7	Polychaete	Polychaete	44	2.948
377	0.7	Polychaete	Polychaete	67	4.489
385	0.7	Polychaete	Polychaete	8	0.536
390	0.7	Polychaete	Polychaete	10	0.670
396	0.7	Polychaete	Polychaete	74	4.958
307	0.7	Crustacean Other	Tanaid	2	0.116
316	0.7	Crustacean Other	Tanaid	4	0.232
365	0.7	Crustacean Other	Tanaid	4	0.232
390	0.7	Crustacean Other	Tanaid	3	0.174
297	1.0	Amphipoda	Amphipoda	1	0.143
307	1.0	Amphipoda	Amphipoda	4	0.572
308	1.0	Amphipoda	Amphipoda	1	0.143
316	1.0	Amphipoda	Amphipoda	2	0.286
332	1.0	Amphipoda	Amphipoda	7	1.001
336	1.0	Amphipoda	Amphipoda	1	0.143
342	1.0	Amphipoda	Amphipoda	6	0.858
347	1.0	Amphipoda	Amphipoda	1	0.143
353	1.0	Amphipoda	Amphipoda	1	0.143
361	1.0	Amphipoda	Amphipoda	3	0.429
365	1.0	Amphipoda	Amphipoda	1	0.143
372	1.0	Amphipoda	Amphipoda	10	1.430
377	1.0	Amphipoda	Amphipoda	4	0.572
385	1.0	Amphipoda	Amphipoda	1	0.143
396	1.0	Amphipoda	Amphipoda	20	2.860
297	1.0	Bivalva	Bivalva	4	0.608
307	1.0	Bivalva	Bivalva	2	0.304
308	1.0	Bivalva	Bivalva	2	0.304
316	1.0	Bivalva	Bivalva	1	0.152
318	1.0	Bivalva	Bivalva	5	0.760
332	1.0	Bivalva	Bivalva	8	1.216
336	1.0	Bivalva	Bivalva	1	0.152
342	1.0	Bivalva	Bivalva	10	1.520
347	1.0	Bivalva	Bivalva	2	0.304
356	1.0	Bivalva	Bivalva	38	5.776
361	1.0	Bivalva	Bivalva	19	2.888
365	1.0	Bivalva	Bivalva	1	0.152
372	1.0	Bivalva	Bivalva	5	0.760
377	1.0	Bivalva	Bivalva	2	0.304
385	1.0	Bivalva	Bivalva	6	0.912
390	1.0	Bivalva	Bivalva	1	0.152
353	1.0	Gastropoda	Crepidula	3	0.456
307	1.0	Crustacean Other	Cumacean	3	0.429
316	1.0	Crustacean Other	Cumacean	1	0.143
332	1.0	Crustacean Other	Cumacean	1	0.143

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
365	1.0	Crustacean Other	Cumacean	1	0.143
385	1.0	Crustacean Other	Cumacean	1	0.143
361	1.0	Isopoda	Edotea	1	0.143
365	1.0	Isopoda	Edotea	1	0.143
396	1.0	Isopoda	Edotea	1	0.143
356	1.0	Gastropoda	Gastropoda	1	0.152
361	1.0	Gastropoda	Gastropoda	3	0.456
396	1.0	Gastropoda	Gastropoda	1	0.152
297	1.0	Amphipoda	Haustoriidae	2	0.286
307	1.0	Amphipoda	Haustoriidae	3	0.429
308	1.0	Amphipoda	Haustoriidae	14	2.002
316	1.0	Amphipoda	Haustoriidae	3	0.429
336	1.0	Amphipoda	Haustoriidae	1	0.143
347	1.0	Amphipoda	Haustoriidae	9	1.287
356	1.0	Amphipoda	Haustoriidae	1	0.143
365	1.0	Amphipoda	Haustoriidae	2	0.286
385	1.0	Amphipoda	Haustoriidae	5	0.715
390	1.0	Amphipoda	Haustoriidae	1	0.143
336	1.0	Decapod	Hermit Crab	1	0.143
347	1.0	Decapod	Hermit Crab	3	0.429
356	1.0	Decapod	Hermit Crab	1	0.143
372	1.0	Decapod	Hermit Crab	1	0.143
377	1.0	Decapod	Hermit Crab	4	0.572
390	1.0	Decapod	Hermit Crab	2	0.286
396	1.0	Decapod	Hermit Crab	2	0.286
385	1.0	Isopoda	Isopoda	3	0.429
297	1.0	Lancelet	Lancelet	2	2.400
307	1.0	Lancelet	Lancelet	21	17.100
308	1.0	Lancelet	Lancelet	1	0.100
318	1.0	Lancelet	Lancelet	1	0.900
332	1.0	Lancelet	Lancelet	2	1.800
356	1.0	Lancelet	Lancelet	95	189.000
390	1.0	Lancelet	Lancelet	1	0.700
332	1.0	Nemertean	Nemertean	1	0.600
347	1.0	Nemertean	Nemertean	1	0.100
396	1.0	Nemertean	Nemertean	1	1.800
332	1.0	Phoronid	Phoronid	14	0.400
342	1.0	Phoronid	Phoronid	1	0.100
372	1.0	Phoronid	Phoronid	1	0.200
297	1.0	Polychaete	Polychaete	1	0.166
307	1.0	Polychaete	Polychaete	25	4.150
308	1.0	Polychaete	Polychaete	2	0.332
316	1.0	Polychaete	Polychaete	14	2.324
318	1.0	Polychaete	Polychaete	11	1.826
332	1.0	Polychaete	Polychaete	254	42.164
336	1.0	Polychaete	Polychaete	102	16.932

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
342	1.0	Polychaete	Polychaete	89	14.774
347	1.0	Polychaete	Polychaete	1	0.166
353	1.0	Polychaete	Polychaete	40	6.640
356	1.0	Polychaete	Polychaete	23	3.818
361	1.0	Polychaete	Polychaete	151	25.066
365	1.0	Polychaete	Polychaete	7	1.162
372	1.0	Polychaete	Polychaete	136	22.576
377	1.0	Polychaete	Polychaete	91	15.106
385	1.0	Polychaete	Polychaete	12	1.992
390	1.0	Polychaete	Polychaete	39	6.474
396	1.0	Polychaete	Polychaete	193	32.038
396	1.0	Bivalva	Razor Clam	1	0.152
396	1.0	Decapod	Shrimp	1	0.143
308	1.4	Amphipoda	Amphipoda	1	0.360
316	1.4	Amphipoda	Amphipoda	2	0.720
318	1.4	Amphipoda	Amphipoda	1	0.360
332	1.4	Amphipoda	Amphipoda	6	2.160
342	1.4	Amphipoda	Amphipoda	13	4.680
356	1.4	Amphipoda	Amphipoda	6	2.160
361	1.4	Amphipoda	Amphipoda	1	0.360
365	1.4	Amphipoda	Amphipoda	1	0.360
372	1.4	Amphipoda	Amphipoda	13	4.680
377	1.4	Amphipoda	Amphipoda	6	2.160
390	1.4	Amphipoda	Amphipoda	12	4.320
396	1.4	Amphipoda	Amphipoda	12	4.320
297	1.4	Bivalva	Bivalva	2	0.800
318	1.4	Bivalva	Bivalva	1	0.400
332	1.4	Bivalva	Bivalva	28	11.200
336	1.4	Bivalva	Bivalva	2	0.800
342	1.4	Bivalva	Bivalva	12	4.800
347	1.4	Bivalva	Bivalva	1	0.400
356	1.4	Bivalva	Bivalva	5	2.000
361	1.4	Bivalva	Bivalva	11	4.400
365	1.4	Bivalva	Bivalva	2	0.800
372	1.4	Bivalva	Bivalva	14	5.600
377	1.4	Bivalva	Bivalva	7	2.800
385	1.4	Bivalva	Bivalva	1	0.400
353	1.4	Gastropoda	Crepidula	2	0.800
332	1.4	Crustacean Other	Cumacean	1	0.360
372	1.4	Crustacean Other	Cumacean	1	0.360
377	1.4	Isopoda	Edotea	1	0.360
396	1.4	Isopoda	Edotea	2	0.720
372	1.4	Gastropoda	Gastropoda	3	1.200
307	1.4	Amphipoda	Haustoriidae	1	0.360
316	1.4	Amphipoda	Haustoriidae	1	0.360
347	1.4	Amphipoda	Haustoriidae	3	1.080

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
365	1.4	Amphipoda	Haustoriidae	4	1.440
372	1.4	Decapod	Hermit Crab	1	0.360
377	1.4	Decapod	Hermit Crab	21	7.560
336	1.4	Isopoda	Isopoda	2	0.720
390	1.4	Isopoda	Isopoda	1	0.360
297	1.4	Lancelet	Lancelet	1	3.100
307	1.4	Lancelet	Lancelet	75	158.000
308	1.4	Lancelet	Lancelet	2	3.500
353	1.4	Lancelet	Lancelet	1	4.000
356	1.4	Lancelet	Lancelet	8	58.700
361	1.4	Lancelet	Lancelet	3	9.400
365	1.4	Lancelet	Lancelet	6	9.300
372	1.4	Lancelet	Lancelet	1	0.100
396	1.4	Lancelet	Lancelet	1	2.100
332	1.4	Gastropoda	Nassarius	8	3.200
361	1.4	Gastropoda	Nassarius	2	0.800
372	1.4	Gastropoda	Nassarius	1	0.400
396	1.4	Gastropoda	Nassarius	1	0.400
332	1.4	Nemertean	Nemertean	2	2.100
372	1.4	Phoronid	Phoronid	1	1.900
307	1.4	Polychaete	Polychaete	18	6.660
316	1.4	Polychaete	Polychaete	1	0.370
332	1.4	Polychaete	Polychaete	244	90.280
342	1.4	Polychaete	Polychaete	62	22.940
353	1.4	Polychaete	Polychaete	113	41.810
361	1.4	Polychaete	Polychaete	12	4.440
372	1.4	Polychaete	Polychaete	83	30.710
377	1.4	Polychaete	Polychaete	53	19.610
385	1.4	Polychaete	Polychaete	1	0.370
396	1.4	Polychaete	Polychaete	168	62.160
372	1.4	Decapod	Shrimp	1	0.360
390	1.4	Decapod	Shrimp	1	0.360
332	2.0	Amphipoda	Amphipoda	1	0.910
372	2.0	Amphipoda	Amphipoda	1	0.910
377	2.0	Amphipoda	Amphipoda	3	2.730
390	2.0	Amphipoda	Amphipoda	4	3.640
308	2.0	Bivalva	Bivalva	1	1.030
332	2.0	Bivalva	Bivalva	8	8.240
342	2.0	Bivalva	Bivalva	3	3.090
356	2.0	Bivalva	Bivalva	1	1.030
361	2.0	Bivalva	Bivalva	2	2.060
372	2.0	Bivalva	Bivalva	7	7.210
377	2.0	Bivalva	Bivalva	1	1.030
342	2.0	Decapod	Decapod	1	0.910
372	2.0	Decapod	Decapod	1	0.910
332	2.0	Gastropoda	Gastropoda	3	3.090

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
342	2.0	Gastropoda	Gastropoda	1	1.030
361	2.0	Gastropoda	Gastropoda	1	1.030
372	2.0	Gastropoda	Gastropoda	2	2.060
377	2.0	Gastropoda	Gastropoda	2	2.060
396	2.0	Gastropoda	Gastropoda	1	1.030
308	2.0	Amphipoda	Haustoriidae	2	1.820
316	2.0	Amphipoda	Haustoriidae	2	1.820
390	2.0	Amphipoda	Haustoriidae	1	0.910
353	2.0	Decapod	Hermit Crab	1	0.910
372	2.0	Decapod	Hermit Crab	1	0.910
377	2.0	Decapod	Hermit Crab	16	14.560
297	2.0	Lancelet	Lancelet	1	4.500
318	2.0	Lancelet	Lancelet	1	4.700
336	2.0	Lancelet	Lancelet	10	41.000
347	2.0	Lancelet	Lancelet	1	6.900
353	2.0	Lancelet	Lancelet	1	15.000
365	2.0	Lancelet	Lancelet	2	9.100
385	2.0	Lancelet	Lancelet	1	6.400
390	2.0	Lancelet	Lancelet	1	15.400
332	2.0	Gastropoda	Nassarius	1	1.030
361	2.0	Gastropoda	Nassarius	1	1.030
332	2.0	Nemertean	Nemertean	1	33.900
297	2.0	Polychaete	Polychaete	1	0.880
316	2.0	Polychaete	Polychaete	3	2.640
318	2.0	Polychaete	Polychaete	1	0.880
332	2.0	Polychaete	Polychaete	1	0.880
336	2.0	Polychaete	Polychaete	3	2.640
342	2.0	Polychaete	Polychaete	41	36.080
347	2.0	Polychaete	Polychaete	1	0.880
353	2.0	Polychaete	Polychaete	1	0.880
361	2.0	Polychaete	Polychaete	7	6.160
372	2.0	Polychaete	Polychaete	35	30.800
377	2.0	Polychaete	Polychaete	26	22.880
396	2.0	Polychaete	Polychaete	8	7.040
332	2.0	Bivalva	Razor Clam	1	1.030
396	2.0	Bivalva	Razor Clam	4	4.120
365	2.0	Decapod	Shrimp	1	0.910
377	2.0	Decapod	Shrimp	1	0.910
336	2.8	Amphipoda	Amphipoda	1	2.300
372	2.8	Amphipoda	Amphipoda	1	2.300
332	2.8	Bivalva	Bivalva	10	26.700
342	2.8	Bivalva	Bivalva	3	8.010
356	2.8	Bivalva	Bivalva	2	5.340
372	2.8	Bivalva	Bivalva	3	8.010
377	2.8	Bivalva	Bivalva	7	18.690
390	2.8	Bivalva	Bivalva	1	2.670

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
372	2.8	Decapod	Decapod	2	4.600
377	2.8	Decapod	Decapod	1	2.300
372	2.8	Gastropoda	Gastropoda	1	2.670
372	2.8	Decapod	Hermit Crab	1	2.300
377	2.8	Decapod	Hermit Crab	17	39.100
396	2.8	Decapod	Hermit Crab	1	2.300
297	2.8	Isopoda	Isopoda	1	2.300
316	2.8	Lancelet	Lancelet	2	43.700
342	2.8	Lancelet	Lancelet	1	11.700
347	2.8	Lancelet	Lancelet	1	77.000
385	2.8	Lancelet	Lancelet	1	19.500
361	2.8	Gastropoda	Nassarius	2	5.340
332	2.8	Polychaete	Polychaete	14	29.260
342	2.8	Polychaete	Polychaete	31	64.790
377	2.8	Polychaete	Polychaete	7	14.630
332	2.8	Bivalva	Razor Clam	1	2.670
361	2.8	Bivalva	Razor Clam	1	2.670
308	2.8	Echinoderm	sand dollar	1	0.700
396	4.0	Amphipoda	Amphipoda	3	17.400
307	4.0	Bivalva	Bivalva	1	7.000
332	4.0	Bivalva	Bivalva	1	7.000
336	4.0	Bivalva	Bivalva	1	7.000
372	4.0	Bivalva	Bivalva	1	7.000
307	4.0	Decapod	Hermit Crab	1	5.800
361	4.0	Decapod	Hermit Crab	2	11.600
377	4.0	Decapod	Hermit Crab	2	11.600
385	4.0	Isopoda	Isopoda	1	5.800
332	4.0	Gastropoda	Nassarius	1	7.000
342	4.0	Gastropoda	Nassarius	2	14.000
396	4.0	Gastropoda	Nassarius	1	7.000
307	4.0	Bivalva	Razor Clam	2	14.000
332	4.0	Bivalva	Razor Clam	2	14.000
342	4.0	Bivalva	Razor Clam	5	35.000
361	4.0	Bivalva	Razor Clam	2	14.000
372	4.0	Bivalva	Razor Clam	2	14.000
332	5.6	Bivalva	Bivalva	2	36.200
342	5.6	Bivalva	Bivalva	1	18.100
361	5.6	Bivalva	Bivalva	1	18.100
372	5.6	Bivalva	Bivalva	1	18.100
390	5.6	Bivalva	Bivalva	1	18.100
353	5.6	Isopoda	Emerita	1	14.700
396	5.6	Gastropoda	Gastropoda	1	18.100
336	5.6	Decapod	Hermit Crab	1	14.700
342	5.6	Decapod	Hermit Crab	1	14.700
390	5.6	Decapod	Hermit Crab	2	29.400
365	5.6	Gastropoda	Nassarius	2	36.200

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
372	5.6	Gastropoda	Nassarius	3	54.300
377	5.6	Gastropoda	Nassarius	1	18.100
332	5.6	Nemertean	Nemertean	1	911.600
332	5.6	Bivalva	Razor Clam	2	36.200
365	5.6	Bivalva	Razor Clam	1	18.100
372	5.6	Bivalva	Razor Clam	2	36.200
332	5.6	Echinoderm	sea cucumber	1	94.818
342	5.6	Decapod	Shrimp	1	14.700
377	9	Bivalva	Bivalva	2	44.900
372	9	Gastropoda	moonsnail	1	180.500
356	9	Gastropoda	Nassarius	1	27.500
347	9	Echinoderm	sand dollar	1	173.100
353	9	Echinoderm	sea cucumber	1	211.000

Appendix D – 3

Macro Size – 2004

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
353	0.5	Amphipoda	Amphipoda	1	0.023
365	0.5	Amphipoda	Amphipoda	1	0.023
377	0.5	Amphipoda	Amphipoda	1	0.023
500	0.5	Bivalva	Bivalva	1	0.023
500	0.5	Crustacean Other	Cumacean	1	0.023
500	0.5	Amphipoda	Haustoriidae	1	0.023
332	0.5	Phoronid	Phoronid	2	0.060
372	0.5	Phoronid	Phoronid	1	0.000
307	0.5	Polychaete	Polychaete	4	0.112
316	0.5	Polychaete	Polychaete	5	0.140
329	0.5	Polychaete	Polychaete	19	0.532
332	0.5	Polychaete	Polychaete	69	1.932
336	0.5	Polychaete	Polychaete	7	0.196
347	0.5	Polychaete	Polychaete	23	0.644
353	0.5	Polychaete	Polychaete	1	0.028
356	0.5	Polychaete	Polychaete	1	0.028
360	0.5	Polychaete	Polychaete	4	1.120
361	0.5	Polychaete	Polychaete	22	0.616
365	0.5	Polychaete	Polychaete	1	0.028
372	0.5	Polychaete	Polychaete	50	1.400
390	0.5	Polychaete	Polychaete	11	0.308
500	0.5	Polychaete	Polychaete	18	0.504
502	0.5	Polychaete	Polychaete	4	0.112
504	0.5	Polychaete	Polychaete	22	0.616
508	0.5	Polychaete	Polychaete	8	0.224
316	0.5	Crustacean Other	Tanaid	1	0.023
332	0.7	Amphipoda	Amphipoda	2	0.116
353	0.7	Amphipoda	Amphipoda	5	0.290
356	0.7	Amphipoda	Amphipoda	1	0.058
365	0.7	Amphipoda	Amphipoda	1	0.058
372	0.7	Amphipoda	Amphipoda	1	0.058
377	0.7	Amphipoda	Amphipoda	1	0.058
500	0.7	Amphipoda	Amphipoda	1	0.058
501	0.7	Amphipoda	Amphipoda	2	0.116
318	0.7	Bivalva	Bivalva	1	0.060
356	0.7	Bivalva	Bivalva	1	0.060
500	0.7	Bivalva	Bivalva	1	0.060
501	0.7	Bivalva	Bivalva	1	0.060
508	0.7	Bivalva	Bivalva	2	0.120
318	0.7	Amphipoda	Haustoriidae	1	0.058
356	0.7	Amphipoda	Haustoriidae	5	0.290
365	0.7	Amphipoda	Haustoriidae	1	0.058
372	0.7	Amphipoda	Haustoriidae	1	0.058
377	0.7	Amphipoda	Haustoriidae	5	0.290
390	0.7	Amphipoda	Haustoriidae	2	0.116
504	0.7	Amphipoda	Haustoriidae	1	0.058

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
504	0.7	Amphipoda	Haustoriidae	7	0.406
508	0.7	Amphipoda	Haustoriidae	4	0.232
353	0.7	Decapod	Hermit Crab	1	0.058
504	0.7	Isopoda	Isopoda	1	0.058
353	0.7	Phoronid	Phoronid	2	0.120
307	0.7	Polychaete	Polychaete	28	1.876
316	0.7	Polychaete	Polychaete	30	2.010
318	0.7	Polychaete	Polychaete	2	0.134
329	0.7	Polychaete	Polychaete	55	3.685
332	0.7	Polychaete	Polychaete	32	2.144
336	0.7	Polychaete	Polychaete	12	0.804
347	0.7	Polychaete	Polychaete	3	0.201
353	0.7	Polychaete	Polychaete	69	4.623
356	0.7	Polychaete	Polychaete	4	0.268
360	0.7	Polychaete	Polychaete	8	0.536
361	0.7	Polychaete	Polychaete	34	2.278
365	0.7	Polychaete	Polychaete	2	0.134
372	0.7	Polychaete	Polychaete	46	3.082
377	0.7	Polychaete	Polychaete	4	0.268
390	0.7	Polychaete	Polychaete	6	0.402
500	0.7	Polychaete	Polychaete	14	0.938
501	0.7	Polychaete	Polychaete	5	0.335
502	0.7	Polychaete	Polychaete	3	0.201
504	0.7	Polychaete	Polychaete	11	0.737
508	0.7	Polychaete	Polychaete	4	0.268
356	0.7	Bivalva	Razor Clam	1	0.060
307	0.7	Crustacean Other	Tanaid	1	0.058
318	0.7	Crustacean Other	Tanaid	2	0.116
336	0.7	Crustacean Other	Tanaid	1	0.058
347	0.7	Crustacean Other	Tanaid	2	0.116
360	0.7	Crustacean Other	Tanaid	2	0.116
365	0.7	Crustacean Other	Tanaid	2	0.116
504	0.7	Crustacean Other	Tanaid	1	0.058
332	1.0	Amphipoda	Amphipoda	3	0.429
353	1.0	Amphipoda	Amphipoda	2	0.286
353	1.0	Amphipoda	Amphipoda	2	0.286
329	1.0	Bivalva	Bivalva	1	0.152
353	1.0	Bivalva	Bivalva	3	0.456
356	1.0	Bivalva	Bivalva	1	0.152
361	1.0	Bivalva	Bivalva	1	0.152
500	1.0	Bivalva	Bivalva	1	0.152
316	1.0	Amphipoda	Haustoriidae	1	0.143
318	1.0	Amphipoda	Haustoriidae	2	0.286
365	1.0	Amphipoda	Haustoriidae	6	0.858
390	1.0	Amphipoda	Haustoriidae	4	0.572
501	1.0	Amphipoda	Haustoriidae	1	0.143

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
502	1.0	Amphipoda	Haustoriidae	1	0.143
508	1.0	Amphipoda	Haustoriidae	5	0.715
361	1.0	Decapod	Hermit Crab	1	0.143
318	1.0	Isopoda	Isopoda	1	0.143
329	1.0	Isopoda	Isopoda	1	0.143
360	1.0	Lancelet	Lancelet	1	0.809
316	1.0	Nemertean	Nemertean	3	0.440
316	1.0	Polychaete	Polychaete	30	4.980
318	1.0	Polychaete	Polychaete	4	1.480
329	1.0	Polychaete	Polychaete	39	6.474
332	1.0	Polychaete	Polychaete	13	2.158
336	1.0	Polychaete	Polychaete	3	0.498
353	1.0	Polychaete	Polychaete	6	0.996
356	1.0	Polychaete	Polychaete	3	0.498
360	1.0	Polychaete	Polychaete	2	0.332
361	1.0	Polychaete	Polychaete	15	2.490
365	1.0	Polychaete	Polychaete	5	0.830
372	1.0	Polychaete	Polychaete	13	2.158
377	1.0	Polychaete	Polychaete	4	0.664
390	1.0	Polychaete	Polychaete	8	1.328
500	1.0	Polychaete	Polychaete	6	0.996
501	1.0	Polychaete	Polychaete	1	0.166
504	1.0	Polychaete	Polychaete	7	1.162
508	1.0	Polychaete	Polychaete	7	1.162
329	1.0	Bivalva	Razor Clam	1	0.152
360	1.0	Bivalva	Razor Clam	4	0.608
377	1.0	Bivalva	Razor Clam	1	0.152
390	1.0	Bivalva	Razor Clam	10	1.520
501	1.0	Bivalva	Razor Clam	1	0.152
353	1.4	Amphipoda	Amphipoda	5	1.800
332	1.4	Bivalva	Bivalva	2	0.800
353	1.4	Bivalva	Bivalva	7	2.800
361	1.4	Bivalva	Bivalva	3	1.200
372	1.4	Bivalva	Bivalva	1	0.400
500	1.4	Bivalva	Bivalva	1	0.400
360	1.4	Decapod	Crab	1	0.360
377	1.4	Decapod	Crab	2	0.720
372	1.4	Crustacean Other	Cumacean	1	0.360
356	1.4	Amphipoda	Haustoriidae	4	1.440
360	1.4	Amphipoda	Haustoriidae	2	0.720
365	1.4	Amphipoda	Haustoriidae	1	0.360
377	1.4	Amphipoda	Haustoriidae	4	1.440
390	1.4	Amphipoda	Haustoriidae	5	1.800
501	1.4	Amphipoda	Haustoriidae	1	0.360
502	1.4	Amphipoda	Haustoriidae	2	0.720
504	1.4	Amphipoda	Haustoriidae	2	0.720

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
356	1.4	Isopoda	Isopoda	1	0.360
504	1.4	Isopoda	Isopoda	20	7.200
365	1.4	Lancelet	Lancelet	1	2.880
390	1.4	Lancelet	Lancelet	1	3.190
307	1.4	Nemertean	Nemertean	2	11.300
307	1.4	Polychaete	Polychaete	2	0.740
332	1.4	Polychaete	Polychaete	4	1.480
336	1.4	Polychaete	Polychaete	1	0.370
353	1.4	Polychaete	Polychaete	12	4.440
356	1.4	Polychaete	Polychaete	1	0.370
360	1.4	Polychaete	Polychaete	1	0.370
365	1.4	Polychaete	Polychaete	1	0.370
372	1.4	Polychaete	Polychaete	5	1.850
377	1.4	Polychaete	Polychaete	8	2.960
390	1.4	Polychaete	Polychaete	2	1.760
500	1.4	Polychaete	Polychaete	1	0.370
501	1.4	Polychaete	Polychaete	1	0.370
504	1.4	Polychaete	Polychaete	1	0.370
377	1.4	Bivalva	Razor Clam	1	0.400
390	1.4	Bivalva	Razor Clam	2	0.800
332	2.0	Amphipoda	Amphipoda	2	1.820
353	2.0	Amphipoda	Amphipoda	3	2.730
372	2.0	Amphipoda	Amphipoda	5	4.550
377	2.0	Amphipoda	Amphipoda	2	1.820
332	2.0	Bivalva	Bivalva	3	3.090
365	2.0	Bivalva	Bivalva	1	1.030
377	2.0	Bivalva	Bivalva	2	2.060
361	2.0	Decapod	Crab	1	0.910
307	2.0	Amphipoda	Haustoriidae	1	0.910
316	2.0	Amphipoda	Haustoriidae	3	2.730
318	2.0	Amphipoda	Haustoriidae	1	0.910
347	2.0	Amphipoda	Haustoriidae	1	0.910
360	2.0	Amphipoda	Haustoriidae	2	1.820
365	2.0	Amphipoda	Haustoriidae	9	8.190
377	2.0	Amphipoda	Haustoriidae	1	0.910
500	2.0	Amphipoda	Haustoriidae	1	0.910
501	2.0	Amphipoda	Haustoriidae	4	1.440
504	2.0	Amphipoda	Haustoriidae	1	0.910
508	2.0	Amphipoda	Haustoriidae	1	0.910
356	2.0	Lancelet	Lancelet	3	16.930
365	2.0	Lancelet	Lancelet	2	15.140
307	2.0	Nemertean	Nemertean	1	0.007
307	2.0	Polychaete	Polychaete	3	2.640
332	2.0	Polychaete	Polychaete	4	3.520
347	2.0	Polychaete	Polychaete	2	1.760
353	2.0	Polychaete	Polychaete	6	5.280

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
360	2.0	Polychaete	Polychaete	1	0.880
361	2.0	Polychaete	Polychaete	5	4.400
372	2.0	Polychaete	Polychaete	1	0.880
501	2.0	Polychaete	Polychaete	1	0.880
504	2.0	Polychaete	Polychaete	1	0.880
360	2.0	Tunicate	Tunicate	2	0.830
361	2.8	Amphipoda	Amphipoda	1	2.300
372	2.8	Amphipoda	Amphipoda	3	6.900
361	2.8	Bivalva	Bivalva	1	2.670
365	2.8	Bivalva	Bivalva	1	2.670
390	2.8	Amphipoda	Haustoriidae	3	6.900
501	2.8	Amphipoda	Haustoriidae	1	2.300
504	2.8	Amphipoda	Haustoriidae	2	4.600
501	2.8	Decapod	Hermit Crab	1	2.300
356	2.8	Lancelet	Lancelet	1	18.010
360	2.8	Lancelet	Lancelet	2	31.420
504	2.8	Lancelet	Lancelet	1	15.860
372	2.8	Decapod	Mole crab	1	2.300
361	2.8	Polychaete	Polychaete	3	6.270
372	2.8	Polychaete	Polychaete	2	4.180
332	4.0	Bivalva	Bivalva	2	14.000
353	4.0	Bivalva	Bivalva	1	7.000
372	4.0	Bivalva	Bivalva	3	21.000
353	4.0	Decapod	Crab	1	5.800
353	4.0	Gastropoda	Gastropoda	4	28.000
361	4.0	Gastropoda	Gastropoda	1	7.000
329	4.0	Decapod	Hermit Crab	3	17.400
356	4.0	Isopoda	Isopoda	1	5.800
504	4.0	Isopoda	Isopoda	1	5.800
360	4.0	Polychaete	Polychaete	1	5.000
361	4.0	Polychaete	Polychaete	1	5.000
353	4.0	Sea Anemone	Sea Anemone	1	15.060
336	5.6	Bivalva	Bivalva	1	18.100
360	5.6	Bivalva	Bivalva	1	18.100
390	5.6	Bivalva	Bivalva	1	18.100
316	5.6	Decapod	Hermit Crab	4	58.800
336	5.6	Decapod	Hermit Crab	1	14.700
501	5.6	Decapod	Hermit Crab	1	14.700
504	5.6	Isopoda	Isopoda	1	14.700
307	9	Echinoderm	Sand Dollar	1	171.140
360	9	Echinoderm	Sand Dollar	1	743.600
377	9	Echinoderm	Sand Dollar	1	437.370

Appendix D – 4

Macro Size – 2005

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
308	0.5	Amphipoda	Amphipoda	2	0.046
316	0.5	Amphipoda	Amphipoda	12	0.276
332	0.5	Amphipoda	Amphipoda	3	0.069
347	0.5	Amphipoda	Amphipoda	1	0.023
353	0.5	Amphipoda	Amphipoda	5	0.115
361	0.5	Amphipoda	Amphipoda	6	0.138
501	0.5	Amphipoda	Amphipoda	4	0.092
297	0.5	Bivalva	Bivalva	2	0.046
307	0.5	Bivalva	Bivalva	3	0.069
308	0.5	Bivalva	Bivalva	1	0.023
318	0.5	Bivalva	Bivalva	1	0.023
332	0.5	Bivalva	Bivalva	24	0.552
336	0.5	Bivalva	Bivalva	1	0.023
353	0.5	Bivalva	Bivalva	5	0.115
361	0.5	Bivalva	Bivalva	13	0.299
372	0.5	Bivalva	Bivalva	9	0.207
377	0.5	Bivalva	Bivalva	1	0.023
500	0.5	Bivalva	Bivalva	5	0.115
501	0.5	Bivalva	Bivalva	2	0.046
308	0.5	Crustacean Other	Cumacean	1	0.023
361	0.5	Gastropoda	Gastropoda	2	0.046
372	0.5	Gastropoda	Gastropoda	1	0.023
356	0.5	Amphipoda	Haustoriidae	1	0.023
377	0.5	Amphipoda	Haustoriidae	9	0.207
501	0.5	Amphipoda	Haustoriidae	1	0.023
297	0.5	Isopoda	Isopoda	2	0.046
297	0.5	Polychaetes	Maldanidae	2	0.056
353	0.5	Polychaetes	Maldanidae	1	0.028
297	0.5	Nemertean	Nemertean	6	0.800
307	0.5	Nemertean	Nemertean	5	0.099
316	0.5	Nemertean	Nemertean	1	0.179
347	0.5	Nemertean	Nemertean	1	0.120
500	0.5	Nemertean	Nemertean	4	0.020
509	0.5	Nemertean	Nemertean	2	0.130
297	0.5	Polychaetes	Polychaete	35	0.980
307	0.5	Polychaetes	Polychaete	51	1.428
316	0.5	Polychaetes	Polychaete	3	0.084
332	0.5	Polychaetes	Polychaete	151	4.228
336	0.5	Polychaetes	Polychaete	3	0.084
347	0.5	Polychaetes	Polychaete	1	0.028
353	0.5	Polychaetes	Polychaete	31	0.868
356	0.5	Polychaetes	Polychaete	2	0.056
361	0.5	Polychaetes	Polychaete	104	2.912
372	0.5	Polychaetes	Polychaete	93	2.604
500	0.5	Polychaetes	Polychaete	10	0.280
501	0.5	Polychaetes	Polychaete	6	0.168
509	0.5	Polychaetes	Polychaete	4	0.112

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
297	0.5	Crustacean Other	Tanaid	4	0.092
297	0.5	Crustacean Other	Tanaid	1	0.023
307	0.5	Crustacean Other	Tanaid	10	0.230
316	0.5	Crustacean Other	Tanaid	16	0.368
336	0.5	Crustacean Other	Tanaid	1	0.023
347	0.5	Crustacean Other	Tanaid	4	0.092
356	0.5	Crustacean Other	Tanaid	2	0.046
385	0.5	Crustacean Other	Tanaid	8	0.184
500	0.5	Crustacean Other	Tanaid	1	0.023
501	0.5	Crustacean Other	Tanaid	2	0.046
316	0.7	Amphipoda	Amphipoda	2	0.116
318	0.7	Amphipoda	Amphipoda	8	0.464
353	0.7	Amphipoda	Amphipoda	6	0.348
361	0.7	Amphipoda	Amphipoda	1	0.058
372	0.7	Amphipoda	Amphipoda	2	0.116
501	0.7	Amphipoda	Amphipoda	1	0.058
316	0.7	Bivalva	Bivalva	3	0.180
332	0.7	Bivalva	Bivalva	12	0.720
347	0.7	Bivalva	Bivalva	1	0.060
353	0.7	Bivalva	Bivalva	10	0.600
361	0.7	Bivalva	Bivalva	9	0.540
372	0.7	Bivalva	Bivalva	8	0.480
500	0.7	Bivalva	Bivalva	1	0.060
297	0.7	Crustacean Other	Cumacean	1	0.058
332	0.7	Gastropoda	Gastropoda	4	0.240
361	0.7	Gastropoda	Gastropoda	2	0.120
385	0.7	Gastropoda	Gastropoda	1	0.060
308	0.7	Amphipoda	Haustoriidae	3	0.174
318	0.7	Amphipoda	Haustoriidae	1	0.058
336	0.7	Amphipoda	Haustoriidae	1	0.058
356	0.7	Amphipoda	Haustoriidae	5	0.290
372	0.7	Amphipoda	Haustoriidae	2	0.116
377	0.7	Amphipoda	Haustoriidae	9	0.522
385	0.7	Amphipoda	Haustoriidae	1	0.058
308	0.7	Isopoda	Isopoda	1	0.058
316	0.7	Isopoda	Isopoda	1	0.058
318	0.7	Isopoda	Isopoda	1	0.058
361	0.7	Isopoda	Isopoda	2	0.116
500	0.7	Lancelet	Lancelet	1	0.000
509	0.7	Lancelet	Lancelet	1	0.229
332	0.7	Polychaetes	Maldanidae	5	0.335
353	0.7	Polychaetes	Maldanidae	2	0.134
356	0.7	Polychaetes	Maldanidae	1	0.067
372	0.7	Polychaetes	Maldanidae	1	0.067
377	0.7	Polychaetes	Maldanidae	11	0.737
385	0.7	Polychaetes	Maldanidae	1	0.067
316	0.7	Nemertean	Nemertean	5	1.060

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
361	0.7	Nemertean	Nemertean	1	0.210
377	0.7	Nemertean	Nemertean	1	0.210
385	0.7	Nemertean	Nemertean	2	1.890
501	0.7	Nemertean	Nemertean	1	0.049
307	0.7	Polychaetes	Polychaete	2	0.134
308	0.7	Polychaetes	Polychaete	1	0.067
316	0.7	Polychaetes	Polychaete	5	0.335
318	0.7	Polychaetes	Polychaete	10	0.670
332	0.7	Polychaetes	Polychaete	85	5.695
336	0.7	Polychaetes	Polychaete	6	0.402
353	0.7	Polychaetes	Polychaete	44	2.948
356	0.7	Polychaetes	Polychaete	23	1.541
361	0.7	Polychaetes	Polychaete	87	5.829
372	0.7	Polychaetes	Polychaete	87	5.829
377	0.7	Polychaetes	Polychaete	5	0.335
385	0.7	Polychaetes	Polychaete	3	0.201
501	0.7	Polychaetes	Polychaete	11	0.737
318	0.7	Crustacean Other	Tanaid	4	0.232
308	1.0	Amphipoda	Amphipoda	1	0.143
316	1.0	Amphipoda	Amphipoda	2	0.286
332	1.0	Amphipoda	Amphipoda	1	0.143
353	1.0	Amphipoda	Amphipoda	18	2.574
361	1.0	Amphipoda	Amphipoda	1	0.143
501	1.0	Amphipoda	Amphipoda	2	0.286
307	1.0	Bivalva	Bivalva	2	0.304
308	1.0	Bivalva	Bivalva	1	0.152
332	1.0	Bivalva	Bivalva	4	0.608
353	1.0	Bivalva	Bivalva	3	0.456
361	1.0	Bivalva	Bivalva	3	0.456
372	1.0	Bivalva	Bivalva	4	0.608
385	1.0	Bivalva	Bivalva	1	0.152
353	1.0	Crustacean Other	Cumacean	1	0.143
332	1.0	Gastropoda	Gastropoda	1	0.152
361	1.0	Gastropoda	Gastropoda	2	0.304
308	1.0	Amphipoda	Haustoriidae	4	0.572
347	1.0	Amphipoda	Haustoriidae	1	0.143
356	1.0	Amphipoda	Haustoriidae	2	0.286
377	1.0	Amphipoda	Haustoriidae	11	1.573
308	1.0	Isopoda	Isopoda	1	0.143
361	1.0	Isopoda	Isopoda	1	0.143
297	1.0	Lancelet	Lancelet	1	0.940
308	1.0	Lancelet	Lancelet	1	0.370
297	1.0	Polychaetes	Maldanidae	1	0.166
332	1.0	Polychaetes	Maldanidae	12	1.992
353	1.0	Polychaetes	Maldanidae	1	0.166
361	1.0	Polychaetes	Maldanidae	10	1.660
501	1.0	Polychaetes	Maldanidae	1	0.166

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
307	1.0	Nemertean	Nemertean	1	0.720
361	1.0	Nemertean	Nemertean	1	1.430
500	1.0	Nemertean	Nemertean	1	0.020
353	1.0	Phoronid	Phoronid	1	0.260
297	1.0	Polychaetes	Polychaete	5	0.830
307	1.0	Polychaetes	Polychaete	2	0.332
308	1.0	Polychaetes	Polychaete	2	0.332
316	1.0	Polychaetes	Polychaete	2	0.332
332	1.0	Polychaetes	Polychaete	2	0.332
336	1.0	Polychaetes	Polychaete	3	0.498
347	1.0	Polychaetes	Polychaete	1	0.166
353	1.0	Polychaetes	Polychaete	26	4.316
356	1.0	Polychaetes	Polychaete	1	0.166
372	1.0	Polychaetes	Polychaete	1	0.166
377	1.0	Polychaetes	Polychaete	5	0.830
500	1.0	Polychaetes	Polychaete	5	0.830
501	1.0	Polychaetes	Polychaete	4	0.664
509	1.0	Polychaetes	Polychaete	3	0.498
308	1.0	Echinoderm	Sand Dollar	1	0.040
377	1.0	Echinoderm	Sea Urchin	3	0.180
308	1.4	Amphipoda	Amphipoda	4	1.440
332	1.4	Amphipoda	Amphipoda	1	0.360
353	1.4	Amphipoda	Amphipoda	2	0.720
361	1.4	Amphipoda	Amphipoda	1	0.360
372	1.4	Amphipoda	Amphipoda	4	1.440
500	1.4	Amphipoda	Amphipoda	1	0.360
501	1.4	Amphipoda	Amphipoda	3	1.080
308	1.4	Bivalva	Bivalva	1	0.400
316	1.4	Bivalva	Bivalva	1	0.400
318	1.4	Bivalva	Bivalva	1	0.400
332	1.4	Bivalva	Bivalva	3	1.200
353	1.4	Bivalva	Bivalva	1	0.400
361	1.4	Bivalva	Bivalva	2	0.800
500	1.4	Crustacean Other	Cumacean	1	0.360
332	1.4	Gastropoda	Gastropoda	1	0.400
353	1.4	Gastropoda	Gastropoda	1	0.400
361	1.4	Gastropoda	Gastropoda	6	2.400
377	1.4	Gastropoda	Gastropoda	1	0.400
297	1.4	Amphipoda	Haustoriidae	1	0.360
307	1.4	Amphipoda	Haustoriidae	1	0.360
308	1.4	Amphipoda	Haustoriidae	3	1.080
316	1.4	Amphipoda	Haustoriidae	9	3.240
318	1.4	Amphipoda	Haustoriidae	5	1.800
336	1.4	Amphipoda	Haustoriidae	6	2.160
356	1.4	Amphipoda	Haustoriidae	13	4.680
377	1.4	Amphipoda	Haustoriidae	6	2.160
385	1.4	Amphipoda	Haustoriidae	2	0.720

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
500	1.4	Amphipoda	Haustoriidae	2	0.720
501	1.4	Amphipoda	Haustoriidae	2	0.720
353	1.4	Decapod	Hermit Crab	1	0.360
332	1.4	Lancelet	Lancelet	1	2.060
336	1.4	Lancelet	Lancelet	1	0.910
347	1.4	Lancelet	Lancelet	1	3.620
353	1.4	Polychaetes	Maldanidae	1	0.370
361	1.4	Polychaetes	Maldanidae	4	1.480
297	1.4	Nemertean	Nemertean	1	0.586
385	1.4	Nemertean	Nemertean	1	14.810
307	1.4	Polychaetes	Polychaete	1	0.370
308	1.4	Polychaetes	Polychaete	1	0.370
332	1.4	Polychaetes	Polychaete	2	0.740
336	1.4	Polychaetes	Polychaete	1	0.370
353	1.4	Polychaetes	Polychaete	5	1.850
361	1.4	Polychaetes	Polychaete	2	0.740
372	1.4	Polychaetes	Polychaete	6	2.220
377	1.4	Polychaetes	Polychaete	2	0.740
500	1.4	Polychaetes	Polychaete	1	0.370
501	1.4	Polychaetes	Polychaete	1	0.370
361	2.0	Amphipoda	Amphipoda	1	0.910
372	2.0	Amphipoda	Amphipoda	2	1.820
377	2.0	Amphipoda	Amphipoda	1	0.910
307	2.0	Bivalva	Bivalva	1	1.030
316	2.0	Bivalva	Bivalva	2	2.060
361	2.0	Bivalva	Bivalva	1	1.030
372	2.0	Bivalva	Bivalva	2	2.060
385	2.0	Bivalva	Bivalva	1	1.030
361	2.0	Gastropoda	Gastropoda	1	1.030
361	2.0	Gastropoda	Gastropoda	1	1.030
308	2.0	Amphipoda	Haustoriidae	5	4.550
316	2.0	Amphipoda	Haustoriidae	1	0.910
318	2.0	Amphipoda	Haustoriidae	1	0.910
336	2.0	Amphipoda	Haustoriidae	5	4.550
356	2.0	Amphipoda	Haustoriidae	6	5.460
501	2.0	Amphipoda	Haustoriidae	1	0.910
509	2.0	Amphipoda	Haustoriidae	2	1.820
361	2.0	Isopoda	Isopoda	1	0.910
316	2.0	Polychaetes	Maldanidae	1	0.880
316	2.0	Polychaetes	Polychaete	2	1.760
332	2.0	Polychaetes	Polychaete	7	6.160
353	2.0	Polychaetes	Polychaete	3	2.640
356	2.0	Polychaetes	Polychaete	1	0.880
361	2.0	Polychaetes	Polychaete	5	4.400
500	2.0	Polychaetes	Polychaete	2	1.760
501	2.0	Polychaetes	Polychaete	1	0.880
509	2.0	Polychaetes	Polychaete	1	0.880

Station	Sieve Size (mm)	Taxa	Taxa Comment	Number of Individuals	Biomass (mg AFDW)
353	2.0	Bivalva	Razor Clam	1	1.030
361	2.0	Echinoderm	Sand Dollar	1	0.390
332	2.8	Amphipoda	Amphipoda	2	4.600
353	2.8	Amphipoda	Amphipoda	1	2.300
361	2.8	Amphipoda	Amphipoda	1	2.300
318	2.8	Bivalva	Bivalva	1	2.670
332	2.8	Bivalva	Bivalva	2	5.340
353	2.8	Bivalva	Bivalva	1	2.670
361	2.8	Bivalva	Bivalva	1	2.670
372	2.8	Bivalva	Bivalva	1	2.670
501	2.8	Bivalva	Bivalva	1	2.670
509	2.8	Bivalva	Bivalva	1	2.670
297	2.8	Gastropoda	Gastropoda	1	2.670
372	2.8	Gastropoda	Gastropoda	1	2.670
501	2.8	Gastropoda	Gastropoda	1	2.670
308	2.8	Amphipoda	Haustoriidae	1	2.300
316	2.8	Amphipoda	Haustoriidae	1	2.300
361	2.8	Decapod	Hermit Crab	2	4.600
316	2.8	Lancelet	Lancelet	1	14.200
509	2.8	Lancelet	Lancelet	1	22.249
297	2.8	Polychaetes	Polychaete	1	2.090
361	2.8	Polychaetes	Polychaete	1	2.090
308	4.0	Bivalva	Bivalva	1	7.000
318	4.0	Bivalva	Bivalva	1	7.000
332	4.0	Bivalva	Bivalva	2	14.000
353	4.0	Bivalva	Bivalva	1	7.000
372	4.0	Bivalva	Bivalva	1	7.000
501	4.0	Bivalva	Bivalva	1	7.000
361	4.0	Gastropoda	Gastropoda	1	7.000
372	4.0	Gastropoda	Gastropoda	1	7.000
332	4.0	Amphipoda	Haustoriidae	2	11.600
353	4.0	Decapod	Hermit Crab	2	11.600
500	5.6	Decapod	Hermit Crab	1	14.700
372	5.6	Bivalva	Razor Clam	1	18.100
385	9.0	Bivalva	Bivalva	1	0.042
316	9.0	Echinoderm	Sand Dollar	1	281.900

Appendix E – 1

Trawl Data – 2002

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
2002	Borrow	307	#1	Lagodon rhomboides	Pinfish	1	80
2002	Borrow	307	#1	Paralichthys sp.	Flounder	1	80
2002	Borrow	307	#1	Paralichthys sp.	Flounder	2	65
2002	Borrow	307	#1	Paralichthys sp.	Flounder	3	70
2002	Borrow	307	#1	Prionotus sp.	Sea robin	1	85
2002	Borrow	307	#1	Prionotus sp.	Sea robin	2	80
2002	Borrow	307	#1	Prionotus sp.	Sea robin	3	87
2002	Borrow	307	#1	Prionotus sp.	Sea robin	4	81
2002	Borrow	307	#1	Prionotus sp.	Sea robin	5	88
2002	Borrow	307	#1	Prionotus sp.	Sea robin	6	98
2002	Borrow	307	#1	Libinia emarginata	Spider crab	1	
2002	Borrow	307	#1	Raja sp.	Clear nose skate	1	484
2002	Borrow	307	#2	Hippocampus sp.	Sea horse	1	25
2002	Borrow	307	#2	Nassarius vibex	mud snail	1	
2002	Borrow	307	#3	Prionotus sp.	Sea robin	1	75
2002	Borrow	307	#3	Prionotus sp.	Sea robin	2	78
2002	Borrow	307	#3	Prionotus sp.	Sea robin	3	77
2002	Borrow	307	#3	Prionotus sp.	Sea robin	4	80
2002	Borrow	307	#3	Prionotus sp.	Sea robin	5	70
2002	Borrow	307	#3	Prionotus sp.	Sea robin	6	88
2002	Borrow	307	#3	Prionotus sp.	Sea robin	7	70
2002	Borrow	307	#3	Prionotus sp.	Sea robin	8	62
2002	Borrow	307	#3	Pagurus sp.	Hermit crab	1	
2002	Borrow	307	#3	Polinices duplicatus	Moon snail	1	
2002	Borrow	307	#3	Lagodon rhomboides	Pinfish	1	51
2002	Borrow	307	#4	Raja sp.	Clear nose skate	1	620
2002	Borrow	307	#4	Nassarius vibex	mud snail	1	
2002	Borrow	307	#4	Etropis microustomus	smallmouth flounder	1	71
2002	Borrow	307	#4	Etropis microustomus	smallmouth flounder	2	126
2002	Borrow	307	#4	Prionotus sp.	Sea robin	1	107
2002	Borrow	307	#4	Prionotus sp.	Sea robin	2	82
2002	Borrow	307	#4	Prionotus sp.	Sea robin	3	80
2002	Borrow	307	#4	Prionotus sp.	Sea robin	4	101
2002	Borrow	307	#4	Prionotus sp.	Sea robin	5	76
2002	Borrow	307	#4	Prionotus sp.	Sea robin	6	87
2002	Borrow	307	#4	Prionotus sp.	Sea robin	7	87
2002	Borrow	307	#4	Prionotus sp.	Sea robin	8	72
2002	Borrow	307	#4	Prionotus sp.	Sea robin	9	72
2002	Borrow	307	#4	Prionotus sp.	Sea robin	10	80
2002	Borrow	307	#4	Prionotus sp.	Sea robin	11	78
2002	Borrow	307	#4	Prionotus sp.	Sea robin	12	88
2002	Borrow	307	#4	Prionotus sp.	Sea robin	13	75
2002	Borrow	307	#4	Prionotus sp.	Sea robin	14	82
2002	Borrow	307	#4	Prionotus sp.	Sea robin	15	86
2002	Borrow	307	#4	Prionotus sp.	Sea robin	16	96
2002	Borrow	307	#4	Prionotus sp.	Sea robin	17	96
2002	Borrow	307	#4	Prionotus sp.	Sea robin	18	84
2002	Borrow	307	#4	Prionotus sp.	Sea robin	19	77
2002	Borrow	307	#4	Prionotus sp.	Sea robin	20	77
2002	Borrow	307	#4	Lagodon rhomboides	Pinfish	1	43

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
2002	Borrow	307	#4	Synodus foetens	Lizardfish	1	250
2002	East of Borrow	390	#1	Paralichthys sp.	Summer Flounder	1	445
2002	East of Borrow	390	#1	Centropristis striata	Black sea bass	1	80
2002	East of Borrow	390	#1	Centropristis striata	Black sea bass	2	77
2002	East of Borrow	390	#1	Paralichthys sp.	Flounder	1	81
2002	East of Borrow	390	#1	Paralichthys sp.	Flounder	2	81
2002	East of Borrow	390	#1	Paralichthys sp.	Flounder	3	76
2002	East of Borrow	390	#1	Paralichthys sp.	Flounder	4	77
2002	East of Borrow	390	#1	Paralichthys sp.	Flounder	5	72
2002	East of Borrow	390	#1	Paralichthys sp.	Flounder	6	59
2002	East of Borrow	390	#1	Paralichthys sp.	Flounder	7	58
2002	East of Borrow	390	#1	Paralichthys sp.	Flounder	8	57
2002	East of Borrow	390	#1	Paralichthys sp.	Flounder	9	58
2002	East of Borrow	390	#1	Lagodon rhomboides	Pinfish	1	53
2002	East of Borrow	390	#1	Lagodon rhomboides	Pinfish	2	81
2002	East of Borrow	390	#1	Lagodon rhomboides	Pinfish	3	93
2002	East of Borrow	390	#1	Lagodon rhomboides	Pinfish	4	81
2002	East of Borrow	390	#1	Lagodon rhomboides	Pinfish	5	60
2002	East of Borrow	390	#1	Lagodon rhomboides	Pinfish	6	82
2002	East of Borrow	390	#1	Lagodon rhomboides	Pinfish	7	80
2002	East of Borrow	390	#1	Pagurus sp.	Hermit crab	1	
2002	East of Borrow	390	#1	Pagurus sp.	Hermit crab	2	
2002	East of Borrow	390	#1	Pagurus sp.	Hermit crab	3	
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	1	77
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	2	80
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	3	76
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	4	72
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	5	79
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	6	99
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	7	98
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	8	98
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	9	93
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	10	98
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	11	112
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	12	84
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	13	87
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	14	105
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	15	86
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	16	106
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	17	100
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	18	65
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	19	96
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	20	84
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	21	92
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	22	76
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	23	105
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	24	97
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	25	108
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	26	60
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	27	100

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	28	93
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	29	82
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	30	94
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	31	93
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	32	97
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	33	90
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	34	76
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	35	73
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	36	100
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	37	97
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	38	85
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	39	79
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	40	94
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	41	92
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	42	97
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	43	81
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	44	79
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	45	83
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	46	84
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	47	93
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	48	95
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	49	97
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	50	87
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	51	82
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	52	75
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	53	87
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	54	92
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	55	92
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	56	106
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	57	79
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	58	80
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	59	92
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	60	89
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	61	98
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	62	79
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	63	93
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	64	87
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	65	81
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	66	89
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	67	80
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	68	66
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	69	74
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	70	85
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	71	62
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	72	102
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	73	86
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	74	84
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	75	76
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	76	89
2002	East of Borrow	390	#1	Prionotus sp.	Sea robin	77	86

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
2002	East of Borrow	390	#2	Lolliguncula brevis	Squid	1	88
2002	East of Borrow	390	#2	Raja sp.	Clear nose skate	1	511
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	1	79
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	2	82
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	3	81
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	4	77
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	5	81
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	6	93
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	7	75
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	8	81
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	9	80
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	10	74
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	11	84
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	12	75
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	13	74
2002	East of Borrow	390	#2	Lagodon rhomboides	Pinfish	14	85
2002	East of Borrow	390	#2	Centropristis striata	Black sea bass	1	100
2002	East of Borrow	390	#2	Centropristis striata	Black sea bass	2	91
2002	East of Borrow	390	#2	Centropristis striata	Black sea bass	3	86
2002	East of Borrow	390	#2	Centropristis striata	Black sea bass	4	91
2002	East of Borrow	390	#2	Etropis microustomus	Small flounder (Etropis)	1	80
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	1	87
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	2	85
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	3	98
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	4	103
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	5	114
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	6	97
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	7	106
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	8	105
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	9	94
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	10	107
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	11	93
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	12	80
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	13	108
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	14	85
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	15	100
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	16	85
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	17	94
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	18	92
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	19	92
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	20	77
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	21	89
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	22	110
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	23	88
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	24	86
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	25	75
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	26	92
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	27	91
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	28	91
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	29	90

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	30	87
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	31	92
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	32	85
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	33	94
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	34	96
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	35	87
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	36	97
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	37	82
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	38	93
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	39	90
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	40	89
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	41	88
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	42	93
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	43	93
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	44	92
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	45	92
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	46	78
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	47	77
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	48	78
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	49	94
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	50	77
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	51	94
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	52	75
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	53	96
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	54	100
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	55	91
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	56	106
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	57	91
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	58	88
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	59	87
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	60	68
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	61	96
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	62	90
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	63	74
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	64	82
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	65	98
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	66	73
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	67	93
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	68	95
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	69	79
2002	East of Borrow	390	#2	Prionotus sp.	Sea robin	70	81
2002	East of Borrow	390	#2	Pagurus sp.	Hermit crab	1	
2002	Shoal	356	#1	Lolliguncula brevis	Squid (L. brevis)	1	70
2002	Shoal	356	#1	Lolliguncula brevis	Squid (L. brevis)	2	50
2002	Shoal	356	#1	Raja sp.	Clear nose skate	1	690
2002	Shoal	356	#1	Raja sp.	Clear nose skate	2	540
2002	Shoal	356	#1	Mellita quinquiesperforata	Sand dollar	1	
2002	Shoal	356	#1	Pagurus sp.	Hermit crab	1	
2002	Shoal	356	#1	Pagurus sp.	Hermit crab	2	
2002	Shoal	356	#1	Pagurus sp.	Hermit crab	3	

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
2002	Shoal	356	#1	Pagurus sp.	Hermit crab	4	
2002	Shoal	356	#1	Ovalipes stephensoni	Lady crab	1	
2002	Shoal	356	#1	Ovalipes stephensoni	Lady crab	2	
2002	Shoal	356	#1	Prionotus sp.	Sea robin	1	84
2002	Shoal	356	#1	Prionotus sp.	Sea robin	2	77
2002	Shoal	356	#1	Prionotus sp.	Sea robin	3	90
2002	Shoal	356	#1	Prionotus sp.	Sea robin	4	70
2002	Shoal	356	#1	Etropis microustomus	Flounder (Etropis)	1	107
2002	Shoal	356	#1	Lagodon rhomboides	Pinfish	1	77
2002	Shoal	356	#2	Mellita quinquiesperforata	Sand dollar	1	
2002	Shoal	356	#2	Mellita quinquiesperforata	Sand dollar	2	
2002	Shoal	356	#2	Pagurus sp.	Hermit crab	1	
2002	Shoal	356	#2	Pagurus sp.	Hermit crab	2	
2002	Shoal	356	#2	Nassarious vibex	mud snail	1	
2002	Shoal	356	#2	Etropis microustomus	Flounder (Etropis)	1	55
2002	Shoal	356	#2	Etropis microustomus	Flounder (Etropis)	2	107
2002	Shoal	356	#2	Lagodon rhomboides	Pinfish	1	80
2002	Shoal	356	#2	Lagodon rhomboides	Pinfish	2	81
2002	Shoal	356	#2	Lagodon rhomboides	Pinfish	3	79
2002	Shoal	356	#2	Lagodon rhomboides	Pinfish	4	77
2002	Shoal	356	#2	Lagodon rhomboides	Pinfish	5	74
2002	Shoal	356	#2	Prionotus sp.	Sea robin	1	91
2002	Shoal	356	#2	Prionotus sp.	Sea robin	2	85
2002	Shoal	356	#2	Prionotus sp.	Sea robin	3	98
2002	Shoal	356	#2	Prionotus sp.	Sea robin	4	92
2002	Shoal	356	#2	Prionotus sp.	Sea robin	5	101
2002	Shoal	356	#2	Prionotus sp.	Sea robin	6	72
2002	Shoal	356	#2	Prionotus sp.	Sea robin	7	75
2002	Shoal	356	#2	Prionotus sp.	Sea robin	8	93
2002	Shoal	356	#2	Prionotus sp.	Sea robin	9	89
2002	Shoal	356	#2	Prionotus sp.	Sea robin	10	77
2002	Shoal	356	#2	Prionotus sp.	Sea robin	11	74
2002	Shoal	356	#2	Prionotus sp.	Sea robin	12	68
2002	Shoal	356	#2	Prionotus sp.	Sea robin	13	100
2002	Shoal	356	#2	Prionotus sp.	Sea robin	14	83
2002	Shoal	356	#2	Prionotus sp.	Sea robin	15	73
2002	Shoal	356	#2	Prionotus sp.	Sea robin	16	74
2002	Shoal	356	#2	Prionotus sp.	Sea robin	17	71
2002	Shoal	356	#2	Prionotus sp.	Sea robin	18	81
2002	Shoal	356	#2	Prionotus sp.	Sea robin	19	85
2002	West of shoal	394	#1	Prionotus sp.	Sea robin	20	85
2002	West of shoal	394	#2	Lagodon rhomboides	pinfish	1	55
2002	West of shoal	394	#2	Lagodon rhomboides	pinfish	2	58
2002	West of shoal	394	#2	Lagodon rhomboides	pinfish	3	99
2002	West of shoal	394	#2	Lagodon rhomboides	pinfish	4	82
2002	West of shoal	394	#2	Lagodon rhomboides	pinfish	5	96
2002	West of shoal	394	#2	Lagodon rhomboides	pinfish	6	81
2002	West of shoal	394	#2	Lagodon rhomboides	pinfish	7	55
2002	West of shoal	394	#2	Lagodon rhomboides	pinfish	8	83
2002	West of shoal	394	#2	Lagodon rhomboides	pinfish	9	50

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	1	68
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	2	65
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	3	66
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	4	95
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	5	87
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	6	102
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	7	127
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	8	100
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	9	108
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	10	97
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	11	90
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	12	84
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	13	85
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	14	55
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	15	76
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	16	98
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	17	99
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	18	63
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	19	58
2002	West of shoal	394	#2	Centropristis striata	Black sea bass	20	62
2002	West of shoal	394	#2	Prionotus sp.	Sea robin	1	90
2002	West of shoal	394	#2	Prionotus sp.	Sea robin	2	84
2002	West of shoal	394	#2	Prionotus sp.	Sea robin	3	85
2002	West of shoal	394	#2	Prionotus sp.	Sea robin	4	84
2002	West of shoal	394	#2	Prionotus sp.	Sea robin	5	99
2002	West of shoal	394	#2	Prionotus sp.	Sea robin	6	113
2002	West of shoal	394	#2	Prionotus sp.	Sea robin	7	114
2002	West of shoal	394	#2	Prionotus sp.	Sea robin	8	96
2002	West of shoal	394	#2	Etropis microustomus	Flounder (Etropis)	1	89
2002	West of shoal	394	#2		Northern pipefish **	1	168
2002	West of shoal	394	#2		Anemone	1	
2002	West of shoal	394	#2	Libinia emarginata	Spider crab	1	
2002	West of shoal	394	#2	Libinia emarginata	Spider crab	2	
2002	West of shoal	394	#2	Cancer irroratus	Cancer crab	1	

Appendix E – 2

Trawl Data – 2003

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
19-Aug-03	Borrow Area	307	1	Cancer sp.	cancer crab	1	30
19-Aug-03	Borrow Area	307	1	Cancer sp.	cancer crab	2	18
19-Aug-03	Borrow Area	307	1	Cancer sp.	cancer crab	3	20
19-Aug-03	Borrow Area	307	1	Cancer sp.	cancer crab	4	21
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	1	19
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	2	19
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	3	17
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	4	21
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	5	14
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	6	13
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	7	15
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	8	19
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	9	13
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	10	20
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	11	21
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	12	16
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	13	20
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	14	19
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	15	13
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	16	19
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	17	14
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	18	12
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	19	12
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	20	12
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	21	12
19-Aug-03	Borrow Area	307	2	Cancer sp.	cancer crab	22	11
19-Aug-03	Borrow Area	307	3	Cancer sp.	cancer crab	1	20
19-Aug-03	Borrow Area	307	3	Cancer sp.	cancer crab	2	20
19-Aug-03	Borrow Area	307	3	Cancer sp.	cancer crab	3	22
19-Aug-03	Borrow Area	307	3	Cancer sp.	cancer crab	4	21
19-Aug-03	Borrow Area	307	3	Cancer sp.	cancer crab	5	20
19-Aug-03	Borrow Area	307	3	Cancer sp.	cancer crab	6	12
19-Aug-03	Borrow Area	307	3	Cancer sp.	cancer crab	7	10
19-Aug-03	Borrow Area	307	3	Cancer sp.	cancer crab	8	13
19-Aug-03	Borrow Area	307	4	Cancer sp.	cancer crab	1	19
19-Aug-03	Borrow Area	307	4	Cancer sp.	cancer crab	2	19
19-Aug-03	Borrow Area	307	4	Cancer sp.	cancer crab	3	12
19-Aug-03	Borrow Area	307	4	Cancer sp.	cancer crab	4	20
19-Aug-03	Borrow Area	307	4	Cancer sp.	cancer crab	5	15
19-Aug-03	Borrow Area	307	4	Cancer sp.	cancer crab	6	13
19-Aug-03	Borrow Area	307	4	Cancer sp.	cancer crab	7	12
19-Aug-03	Borrow Area	307	4	Cancer sp.	cancer crab	8	12
19-Aug-03	Borrow Area	307	4	Cancer sp.	cancer crab	9	10
19-Aug-03	Borrow Area	307	1	Crangon septimspinosa	sand shrimp	1	-
19-Aug-03	Borrow Area	307	1	Crangon septimspinosa	sand shrimp	2	-
19-Aug-03	Borrow Area	307	1	Crangon septimspinosa	sand shrimp	3	-
19-Aug-03	Borrow Area	307	1	Crangon septimspinosa	sand shrimp	4	-
19-Aug-03	Borrow Area	307	1	Crangon septimspinosa	sand shrimp	5	-
19-Aug-03	Borrow Area	307	2	Crangon septimspinosa	sand shrimp	1	
19-Aug-03	Borrow Area	307	2	Crangon septimspinosa	sand shrimp	2	
19-Aug-03	Borrow Area	307	2	Crangon septimspinosa	sand shrimp	3	
19-Aug-03	Borrow Area	307	2	Crangon septimspinosa	sand shrimp	4	
19-Aug-03	Borrow Area	307	2	Crangon septimspinosa	sand shrimp	5	
19-Aug-03	Borrow Area	307	2	Crangon septimspinosa	sand shrimp	6	
19-Aug-03	Borrow Area	307	2	Crangon septimspinosa	sand shrimp	7	
19-Aug-03	Borrow Area	307	2	Crangon septimspinosa	sand shrimp	8	
19-Aug-03	Borrow Area	307	3	Crangon septimspinosa	sand shrimp	1	
19-Aug-03	Borrow Area	307	3	Crangon septimspinosa	sand shrimp	2	
19-Aug-03	Borrow Area	307	3	Crangon septimspinosa	sand shrimp	3	
19-Aug-03	Borrow Area	307	3	Crangon septimspinosa	sand shrimp	4	
19-Aug-03	Borrow Area	307	3	Crangon septimspinosa	sand shrimp	5	
19-Aug-03	Borrow Area	307	3	Crangon septimspinosa	sand shrimp	6	
19-Aug-03	Borrow Area	307	3	Crangon septimspinosa	sand shrimp	7	
19-Aug-03	Borrow Area	307	3	Crangon septimspinosa	sand shrimp	8	
19-Aug-03	Borrow Area	307	3	Crangon septimspinosa	sand shrimp	9	
19-Aug-03	Borrow Area	307	3	Crangon septimspinosa	sand shrimp	10	

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	1	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	2	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	3	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	4	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	5	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	6	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	7	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	8	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	9	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	10	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	11	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	12	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	13	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	14	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	15	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	16	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	17	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	18	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	19	
19-Aug-03	Borrow Area	307	4	Crangon septimspinosa	sand shrimp	20	
19-Aug-03	Borrow Area	307	1	Etropus microstomus	smallmouth flounder	1	69
19-Aug-03	Borrow Area	307	1	Etropus microstomus	smallmouth flounder	2	97
19-Aug-03	Borrow Area	307	2	Etropus microstomus	smallmouth flounder	1	95
19-Aug-03	Borrow Area	307	2	Etropus microstomus	smallmouth flounder	2	92
19-Aug-03	Borrow Area	307	2	Etropus microstomus	smallmouth flounder	3	87
19-Aug-03	Borrow Area	307	3	Etropus microstomus	smallmouth flounder	1	82
19-Aug-03	Borrow Area	307	3	Etropus microstomus	smallmouth flounder	2	102
19-Aug-03	Borrow Area	307	3	Etropus microstomus	smallmouth flounder	3	102
19-Aug-03	Borrow Area	307	4	Etropus microstomus	smallmouth flounder	1	98
19-Aug-03	Borrow Area	307	4	Etropus microstomus	smallmouth flounder	2	96
19-Aug-03	Borrow Area	307	1	Nassarius sp.	mud snail	1	
19-Aug-03	Borrow Area	307	1	Nassarius sp.	mud snail	2	
19-Aug-03	Borrow Area	307	1	Nassarius sp.	mud snail	3	
19-Aug-03	Borrow Area	307	1	Nassarius sp.	mud snail	4	
19-Aug-03	Borrow Area	307	1	Nassarius sp.	mud snail	5	
19-Aug-03	Borrow Area	307	2	Nassarius sp.	mud snail	1	
19-Aug-03	Borrow Area	307	2	Nassarius sp.	mud snail	2	
19-Aug-03	Borrow Area	307	2	Nassarius sp.	mud snail	3	
19-Aug-03	Borrow Area	307	2	Nassarius sp.	mud snail	4	
19-Aug-03	Borrow Area	307	2	Nassarius sp.	mud snail	5	
19-Aug-03	Borrow Area	307	3	Nassarius sp.	mud snail	1	
19-Aug-03	Borrow Area	307	3	Nassarius sp.	mud snail	2	
19-Aug-03	Borrow Area	307	3	Nassarius sp.	mud snail	3	
19-Aug-03	Borrow Area	307	3	Nassarius sp.	mud snail	4	
19-Aug-03	Borrow Area	307	3	Nassarius sp.	mud snail	5	
19-Aug-03	Borrow Area	307	3	Nassarius sp.	mud snail	6	
19-Aug-03	Borrow Area	307	3	Nassarius sp.	mud snail	7	
19-Aug-03	Borrow Area	307	2	Ovalipes ocellatus	lady crab	1	17
19-Aug-03	Borrow Area	307	3	Ovalipes ocellatus	lady crab	1	24
19-Aug-03	Borrow Area	307	1	Pagurus pollicaris	flat-claw hermit crab	1	-
19-Aug-03	Borrow Area	307	1	Pagurus pollicaris	flat-claw hermit crab	2	-
19-Aug-03	Borrow Area	307	1	Pagurus pollicaris	flat-claw hermit crab	3	-
19-Aug-03	Borrow Area	307	1	Pagurus pollicaris	flat-claw hermit crab	4	-
19-Aug-03	Borrow Area	307	1	Pagurus pollicaris	flat-claw hermit crab	5	-
19-Aug-03	Borrow Area	307	3	Pagurus pollicaris	flat-claw hermit crab	1	-
19-Aug-03	Borrow Area	307	3	Pagurus pollicaris	flat-claw hermit crab	2	-
19-Aug-03	Borrow Area	307	3	Pagurus pollicaris	flat-claw hermit crab	3	-
19-Aug-03	Borrow Area	307	4	Pagurus pollicaris	flat-claw hermit crab	1	
19-Aug-03	Borrow Area	307	4	Pagurus pollicaris	flat-claw hermit crab	2	
19-Aug-03	Borrow Area	307	4	Pagurus pollicaris	flat-claw hermit crab	3	
19-Aug-03	Borrow Area	307	4	Pagurus pollicaris	flat-claw hermit crab	4	
19-Aug-03	Borrow Area	307	1	Pagurus spp.	hermit crab (small)	1	-
19-Aug-03	Borrow Area	307	1	Pagurus spp.	hermit crab (small)	2	-
19-Aug-03	Borrow Area	307	1	Pagurus spp.	hermit crab (small)	3	-
19-Aug-03	Borrow Area	307	1	Pagurus spp.	hermit crab (small)	4	-
19-Aug-03	Borrow Area	307	1	Pagurus spp.	hermit crab (small)	5	-

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	1	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	2	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	3	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	4	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	5	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	6	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	7	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	8	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	9	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	10	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	11	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	12	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	13	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	14	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	15	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	16	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	17	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	18	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	19	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	20	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	21	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	22	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	23	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	24	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	25	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	26	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	27	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	28	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	29	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	30	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	31	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	32	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	33	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	34	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	35	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	36	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	37	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	38	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	39	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	40	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	41	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	42	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	43	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	44	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	45	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	46	
19-Aug-03	Borrow Area	307	2	Pagurus spp.	hermit crab (small)	47	
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	1	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	2	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	3	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	4	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	5	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	6	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	7	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	8	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	9	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	10	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	11	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	12	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	13	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	14	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	15	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	16	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	17	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	18	-
19-Aug-03	Borrow Area	307	3	Pagurus spp.	hermit crab (small)	19	-

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	1	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	2	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	3	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	4	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	5	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	6	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	7	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	8	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	9	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	10	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	11	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	12	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	13	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	14	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	15	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	16	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	17	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	18	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	19	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	20	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	21	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	22	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	23	
19-Aug-03	Borrow Area	307	4	Pagurus spp.	hermit crab (small)	24	
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	1	44
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	2	40
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	3	39
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	4	41
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	5	39
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	6	32
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	7	40
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	8	28
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	9	36
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	10	36
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	11	38
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	12	30
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	13	41
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	14	36
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	15	44
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	16	47
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	17	46
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	18	41
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	19	30
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	20	30
19-Aug-03	Borrow Area	307	3	Peprilus triacanthus	butterfish	21	46
19-Aug-03	Borrow Area	307	4	Peprilus triacanthus	butterfish	1	32
19-Aug-03	Borrow Area	307	4	Peprilus triacanthus	butterfish	2	37
19-Aug-03	Borrow Area	307	4	Peprilus triacanthus	butterfish	3	35
19-Aug-03	Borrow Area	307	4	Peprilus triacanthus	butterfish	4	35
19-Aug-03	Borrow Area	307	4	Peprilus triacanthus	butterfish	5	31
19-Aug-03	Borrow Area	307	4	Peprilus triacanthus	butterfish	6	37
19-Aug-03	Borrow Area	307	4	Peprilus triacanthus	butterfish	7	24
19-Aug-03	Borrow Area	307	4	Peprilus triacanthus	butterfish	8	33
19-Aug-03	Borrow Area	307	2	Polinices duplicatus	moon snail	1	-
19-Aug-03	Borrow Area	307	2	Polinices duplicatus	moon snail	2	-
19-Aug-03	Borrow Area	307	4	Raja eglanteria	clear nose skate	1	715
19-Aug-03	Borrow Area	307	1	Urophycis regia	spotted hake	1	181
19-Aug-03	Borrow Area	307	1	Urophycis regia	spotted hake	2	182
19-Aug-03	Borrow Area	307	2	Urophycis regia	spotted hake	1	153
19-Aug-03	Borrow Area	307	2	Urophycis regia	spotted hake	2	185
19-Aug-03	Borrow Area	307	2	Urophycis regia	spotted hake	3	156
19-Aug-03	Borrow Area	307	3	Urophycis regia	spotted hake	1	181
19-Aug-03	Borrow Area	307	3	Urophycis regia	spotted hake	2	165
19-Aug-03	Borrow Area	307	4	Urophycis regia	spotted hake	1	153
19-Aug-03	Borrow Area	307	4	Urophycis regia	spotted hake	2	148
19-Aug-03	Borrow Area	307	2	Prionotus sp.	sea robin	1	85

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
19-Aug-03	Borrow Area	307	2	Prionotus sp.	sea robin	2	87
19-Aug-03	Borrow Area	307	2	Prionotus sp.	sea robin	3	86
19-Aug-03	Borrow Area	307	2	Prionotus sp.	sea robin	4	115
19-Aug-03	Borrow Area	307	2	Prionotus sp.	sea robin	5	112
19-Aug-03	Borrow Area	307	3	Prionotus sp.	sea robin	1	71
19-Aug-03	Borrow Area	307	3	Prionotus sp.	sea robin	2	77
19-Aug-03	Borrow Area	307	4	Prionotus sp.	sea robin	1	115
19-Aug-03	Borrow Area	307	4	Prionotus sp.	sea robin	2	92
19-Aug-03	Borrow Area	307	4	Prionotus sp.	sea robin	3	105
19-Aug-03	Borrow Area	307	4	Prionotus sp.	sea robin	4	71
19-Aug-03	Borrow Area	307	4	Prionotus sp.	sea robin	5	60
18-Aug-03	Shoal	356	1	Paralichthys sp.	small flounder	1	185
18-Aug-03	Shoal	356	1	Cancer sp.	cancer crab	1	20
18-Aug-03	Shoal	356	1	Cancer sp.	cancer crab	2	27
19-Aug-03	Shoal	356	1b	Cancer sp.	cancer crab	1	20
18-Aug-03	Shoal	356	2	Centropristis striata	black sea bass	1	100
19-Aug-03	Shoal	356	1b	Lolliguncula brevis	squid	1	20
18-Aug-03	Shoal	356	2	Etropus microstomus	smallmouth flounder	1	73
19-Aug-03	Shoal	356	1b	Etropus microstomus	smallmouth flounder	1	75
19-Aug-03	Shoal	356	1b	Etropus microstomus	smallmouth flounder	2	135
19-Aug-03	Shoal	356	1b	Etropus microstomus	smallmouth flounder	3	80
19-Aug-03	Shoal	356	2b	Hippocampus erectus	sea horse	1	55
18-Aug-03	Shoal	356	1	Lagodon rhomboides	pinfish	1	63
19-Aug-03	Shoal	356	1b	Lagodon rhomboides	pinfish	1	77
19-Aug-03	Shoal	356	1b	Lagodon rhomboides	pinfish	2	73
19-Aug-03	Shoal	356	1b	Lagodon rhomboides	pinfish	3	75
19-Aug-03	Shoal	356	1b	Lagodon rhomboides	pinfish	4	80
19-Aug-03	Shoal	356	1b	Lagodon rhomboides	pinfish	5	92
19-Aug-03	Shoal	356	1b	Lagodon rhomboides	pinfish	6	72
19-Aug-03	Shoal	356	1b	Lagodon rhomboides	pinfish	7	76
19-Aug-03	Shoal	356	1b	Lagodon rhomboides	pinfish	8	77
19-Aug-03	Shoal	356	1b	Lagodon rhomboides	pinfish	9	66
19-Aug-03	Shoal	356	1b	Lagodon rhomboides	pinfish	10	79
19-Aug-03	Shoal	356	1b	Lagodon rhomboides	pinfish	11	72
19-Aug-03	Shoal	356	1b	Lagodon rhomboides	pinfish	12	79
19-Aug-03	Shoal	356	1b	Lagodon rhomboides	pinfish	13	78
19-Aug-03	Shoal	356	2b	Peprilus triacanthus	butterfish	1	45
19-Aug-03	Shoal	356	2b	Peprilus triacanthus	butterfish	2	42
19-Aug-03	Shoal	356	2b	Peprilus triacanthus	butterfish	3	45
19-Aug-03	Shoal	356	2b	Peprilus triacanthus	butterfish	4	47
19-Aug-03	Shoal	356	2b	Peprilus triacanthus	butterfish	5	25
18-Aug-03	Shoal	356	1	Mellita quinquiesperforata	keyhole urchin	1	-
19-Aug-03	Shoal	356	2b	Mellita quinquiesperforata	keyhole urchin	1	40
18-Aug-03	Shoal	356	2	Pagurus pollicaris	flat-claw hermit crab	1	-
19-Aug-03	Shoal	356	1b	Pagurus pollicaris	flat-claw hermit crab	1	
19-Aug-03	Shoal	356	1b	Pagurus pollicaris	flat-claw hermit crab	2	
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	1	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	2	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	3	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	4	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	5	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	6	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	7	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	8	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	9	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	10	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	11	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	12	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	13	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	14	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	15	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	16	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	17	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	18	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	19	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	20	-

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	21	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	22	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	23	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	24	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	25	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	26	-
18-Aug-03	Shoal	356	1	Pagurus spp.	hermit crab (small)	27	-
18-Aug-03	Shoal	356	2	Pagurus spp.	narrow-claw hermit crab	1	-
18-Aug-03	Shoal	356	2	Pagurus spp.	narrow-claw hermit crab	2	-
18-Aug-03	Shoal	356	2	Pagurus spp.	narrow-claw hermit crab	3	-
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	1	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	2	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	3	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	4	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	5	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	6	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	7	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	8	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	9	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	10	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	11	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	12	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	13	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	14	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	15	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	16	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	17	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	18	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	19	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	20	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	21	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	22	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	23	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	24	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	25	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	26	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	27	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	28	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	29	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	30	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	31	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	32	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	33	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	34	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	35	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	36	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	37	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	38	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	39	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	40	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	41	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	42	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	43	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	44	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	45	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	46	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	47	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	48	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	49	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	50	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	51	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	52	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	53	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	54	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	55	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	56	

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	57	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	58	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	59	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	60	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	61	
19-Aug-03	Shoal	356	1b	Pagurus spp.	hermit crab (small)	62	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	1	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	2	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	3	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	4	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	5	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	6	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	7	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	8	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	9	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	10	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	11	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	12	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	13	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	14	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	15	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	16	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	17	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	18	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	19	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	20	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	21	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	22	
19-Aug-03	Shoal	356	2b	Pagurus spp.	hermit crab (small)	23	
18-Aug-03	Shoal	356	1	Peprilus triacanthus	butterfish	1	57
18-Aug-03	Shoal	356	1	Peprilus triacanthus	butterfish	2	36
18-Aug-03	Shoal	356	1	Peprilus triacanthus	butterfish	3	40
18-Aug-03	Shoal	356	1	Peprilus triacanthus	butterfish	4	31
18-Aug-03	Shoal	356	2	Peprilus triacanthus	butterfish	1	34
18-Aug-03	Shoal	356	2	Peprilus triacanthus	butterfish	2	39
18-Aug-03	Shoal	356	2	Peprilus triacanthus	butterfish	3	37
18-Aug-03	Shoal	356	2	Peprilus triacanthus	butterfish	4	37
18-Aug-03	Shoal	356	2	Peprilus triacanthus	butterfish	5	30
18-Aug-03	Shoal	356	2	Peprilus triacanthus	butterfish	6	36
18-Aug-03	Shoal	356	2	Peprilus triacanthus	butterfish	7	38
18-Aug-03	Shoal	356	2	Peprilus triacanthus	butterfish	8	32
18-Aug-03	Shoal	356	2	Peprilus triacanthus	butterfish	9	34
18-Aug-03	Shoal	356	2	Peprilus triacanthus	butterfish	10	35
19-Aug-03	Shoal	356	2b	Raja eglanteria	clear nose skate	1	545
18-Aug-03	Shoal	356	1	Urophycis regia	spotted hake	1	208
19-Aug-03	Shoal	356	1b	Urophycis regia	spotted hake	1	116
19-Aug-03	Shoal	356	1b	Urophycis regia	spotted hake	2	170
19-Aug-03	Shoal	356	1b	Urophycis regia	spotted hake	3	201
19-Aug-03	Shoal	356	2b	Urophycis regia	spotted hake	1	217
19-Aug-03	Shoal	356	1b	Prionotus sp.	sea robin	1	111
19-Aug-03	Shoal	356	1b	Prionotus sp.	sea robin	2	105
19-Aug-03	Shoal	356	1b	Prionotus sp.	sea robin	3	116
19-Aug-03	Shoal	356	1b	Prionotus sp.	sea robin	4	100
19-Aug-03	Shoal	356	1b	Prionotus sp.	sea robin	5	107
19-Aug-03	Shoal	356	1b	Prionotus sp.	sea robin	6	105
19-Aug-03	Shoal	356	2b	Prionotus sp.	sea robin	1	98
18-Aug-03	East of Shoal	390	1	Tunicate	unknown blobs of sediment; cf tunicate	-	
18-Aug-03	East of Shoal	390	1	Cancer sp.	cancer crab	1	30
18-Aug-03	East of Shoal	390	1	Etropus microstomus	smallmouth flounder	1	76
18-Aug-03	East of Shoal	390	1	Etropus microstomus	smallmouth flounder	2	82
19-Aug-03	East of Shoal	390	2b	Etropus microstomus	smallmouth flounder	1	
19-Aug-03	East of Shoal	390	2b	Etropus microstomus	smallmouth flounder	2	
18-Aug-03	East of Shoal	390	1	Lagodon rhomboides	pinfish	1	82
18-Aug-03	East of Shoal	390	1	Lagodon rhomboides	pinfish	2	85
18-Aug-03	East of Shoal	390	1	Lagodon rhomboides	pinfish	3	81
18-Aug-03	East of Shoal	390	1	Lagodon rhomboides	pinfish	4	82

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
18-Aug-03	East of Shoal	390	1	Lagodon rhomboides	pinfish	5	83
18-Aug-03	East of Shoal	390	1	Lagodon rhomboides	pinfish	6	75
18-Aug-03	East of Shoal	390	1	Lagodon rhomboides	pinfish	7	85
19-Aug-03	East of Shoal	390	2b	Lagodon rhomboides	pinfish	1	78
19-Aug-03	East of Shoal	390	2b	Lagodon rhomboides	pinfish	2	67
19-Aug-03	East of Shoal	390	2b	Lagodon rhomboides	pinfish	3	82
19-Aug-03	East of Shoal	390	2b	Lagodon rhomboides	pinfish	4	72
18-Aug-03	East of Shoal	390	1	Marginella apicina	common atlantic marginella	1	-
18-Aug-03	East of Shoal	390	1	Mellita quinquiesperforata	keyhole urchin	1	62
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	1	20
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	2	47
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	3	55
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	4	55
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	5	50
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	6	57
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	7	55
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	8	56
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	9	65
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	10	56
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	11	56
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	12	59
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	13	57
19-Aug-03	East of Shoal	390	2b	Mellita quinquiesperforata	keyhole urchin	14	57
19-Aug-03	East of Shoal	390	2b	Nassarius sp.	mud snail	1	
19-Aug-03	East of Shoal	390	2b	Nassarius sp.	mud snail	2	
19-Aug-03	East of Shoal	390	2b	Nassarius sp.	mud snail	3	
19-Aug-03	East of Shoal	390	2b	Nassarius sp.	mud snail	4	
19-Aug-03	East of Shoal	390	2b	Nassarius sp.	mud snail	5	
19-Aug-03	East of Shoal	390	2b	Pagurus pollicaris	flat-claw hermit crab	1	
19-Aug-03	East of Shoal	390	2b	Pagurus pollicaris	flat-claw hermit crab	2	
19-Aug-03	East of Shoal	390	2b	Pagurus pollicaris	flat-claw hermit crab	3	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	1	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	2	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	3	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	4	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	5	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	6	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	7	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	8	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	9	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	10	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	11	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	12	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	13	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	14	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	15	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	16	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	17	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	18	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	19	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	20	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	21	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	22	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	23	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	24	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	25	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	26	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	27	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	28	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	29	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	30	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	31	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	32	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	33	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	34	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	35	

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	36	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	37	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	38	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	39	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	40	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	41	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	42	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	43	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	44	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	45	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	46	
19-Aug-03	East of Shoal	390	2b	Pagurus spp.	hermit crab (small)	47	
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	1	36
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	2	32
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	3	38
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	4	44
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	5	44
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	6	41
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	7	32
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	8	36
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	9	41
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	10	35
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	11	36
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	12	39
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	13	37
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	14	42
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	15	47
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	16	43
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	17	40
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	18	36
18-Aug-03	East of Shoal	390	2	Peprilus triacanthus	butterfish	19	35
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	1	88
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	2	44
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	3	32
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	4	44
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	5	45
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	6	46
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	7	40
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	8	36
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	9	38
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	10	42
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	11	41
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	12	45
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	13	48
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	14	38
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	15	37
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	16	45
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	17	42
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	18	46
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	19	52
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	20	35
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	21	50
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	22	42
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	23	42
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	24	44
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	25	35
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	26	41
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	27	44
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	28	30
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	29	35
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	30	50
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	31	47
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	32	52
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	33	30
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	34	38
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	35	40

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	36	35
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	37	41
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	38	32
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	39	40
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	40	42
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	41	54
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	42	42
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	43	38
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	44	37
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	45	40
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	46	35
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	47	37
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	48	40
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	49	36
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	50	43
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	51	35
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	52	40
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	53	42
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	54	40
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	55	41
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	56	34
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	57	36
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	58	45
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	59	30
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	60	42
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	61	50
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	62	40
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	63	35
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	64	40
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	65	37
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	66	36
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	67	40
18-Aug-03	East of Shoal	390	1	Peprilus triacanthus	butterfish	68	33
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	1	75
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	2	30
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	3	37
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	4	34
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	5	40
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	6	47
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	7	30
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	8	32
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	9	20
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	10	21
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	11	43
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	12	32
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	13	38
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	14	44
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	15	36
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	16	35
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	17	33
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	18	32
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	19	47
19-Aug-03	East of Shoal	390	2b	Peprilus triacanthus	butterfish	20	42
19-Aug-03	East of Shoal	390	2b	Polinices duplicatus	moon snail	1	
18-Aug-03	East of Shoal	390	1	Rossia sp.	Atlantic bob-tailed squid	1	30
18-Aug-03	East of Shoal	390	1	Prionotus sp.	searobin	1	114
18-Aug-03	East of Shoal	390	1	Prionotus sp.	searobin	2	128
18-Aug-03	East of Shoal	390	1	Prionotus sp.	searobin	3	106
18-Aug-03	East of Shoal	390	1	Prionotus sp.	searobin	4	113
18-Aug-03	East of Shoal	390	1	Prionotus sp.	searobin	5	96
18-Aug-03	East of Shoal	390	1	Prionotus sp.	searobin	6	120
18-Aug-03	East of Shoal	390	1	Prionotus sp.	searobin	7	92
18-Aug-03	East of Shoal	390	1	Prionotus sp.	searobin	8	94
18-Aug-03	East of Shoal	390	1	Prionotus sp.	searobin	9	102
18-Aug-03	East of Shoal	390	1	Prionotus sp.	searobin	10	74
18-Aug-03	East of Shoal	390	1	Prionotus sp.	searobin	11	89

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
18-Aug-03	East of Shoal	390	1	Prionotus sp.	searobin	12	95
19-Aug-03	East of Shoal	390	2b	Ark	bivalve	1	
19-Aug-03	East of Shoal	390	2b	Prionotus sp.	sea robin	1	120
19-Aug-03	East of Shoal	390	2b	Prionotus sp.	sea robin	2	118
19-Aug-03	East of Shoal	390	2b	Prionotus sp.	sea robin	3	96
19-Aug-03	East of Shoal	390	2b	Prionotus sp.	sea robin	4	92
18-Aug-03	West of Shoal	394	2	Cancer sp.	cancer crab	1	25
18-Aug-03	West of Shoal	394	2	Cancer sp.	cancer crab	2	21
18-Aug-03	West of Shoal	394	2	Cancer sp.	cancer crab	3	38
18-Aug-03	West of Shoal	394	2	Cancer sp.	cancer crab	4	20
18-Aug-03	West of Shoal	394	1	Cancer sp.	cancer crab	1	11
18-Aug-03	West of Shoal	394	1	Cancer sp.	cancer crab	2	25
18-Aug-03	West of Shoal	394	1	Cancer sp.	cancer crab	3	12
18-Aug-03	West of Shoal	394	1	Cancer sp.	cancer crab	4	14
18-Aug-03	West of Shoal	394	1	Cancer sp.	cancer crab	5	22
18-Aug-03	West of Shoal	394	2	Lolliguncula brevis	squid	1	10
18-Aug-03	West of Shoal	394	2	Cynoscion regalis	weakfish	1	226
18-Aug-03	West of Shoal	394	1	Etropus microstomus	smallmouth flounder	1	126
18-Aug-03	West of Shoal	394	1	Etropus microstomus	smallmouth flounder	2	105
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	1	101
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	2	90
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	3	12.2
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	4	11.2
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	5	10.2
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	6	92
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	7	105
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	8	105
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	9	100
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	10	97
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	11	90
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	12	117
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	13	100
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	14	95
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	15	99
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	16	100
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	17	90
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	18	91
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	19	92
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	20	110
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	21	100
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	22	119
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	23	110
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	24	100
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	25	95
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	26	99
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	27	96
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	28	104
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	29	95
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	30	92
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	31	85
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	32	90
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	33	105
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	34	109
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	35	100
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	36	99
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	37	111
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	38	100
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	39	88
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	40	94
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	41	96
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	42	80
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	43	112
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	44	86
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	45	86
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	46	95
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	47	92

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	48	90
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	49	79
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	50	96
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	51	100
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	52	112
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	53	80
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	54	100
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	55	95
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	56	102
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	57	103
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	58	86
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	59	82
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	60	91
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	61	89
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	62	96
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	63	87
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	64	110
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	65	105
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	66	89
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	67	116
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	68	113
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	69	106
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	70	85
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	71	100
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	72	87
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	73	90
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	74	115
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	75	117
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	76	114
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	77	88
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	78	99
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	79	84
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	80	95
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	81	107
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	82	113
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	83	95
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	84	94
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	85	88
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	86	109
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	87	88
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	88	109
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	89	95
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	90	112
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	91	99
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	92	114
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	93	104
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	94	105
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	95	102
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	96	91
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	97	89
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	98	108
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	99	90
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	100	107
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	101	87
18-Aug-03	West of Shoal	394	2	Lagodon rhomboides	pinfish	102	108
18-Aug-03	West of Shoal	394	1	Lagodon rhomboides	pinfish	1	90
18-Aug-03	West of Shoal	394	1	Lagodon rhomboides	pinfish	2	86
18-Aug-03	West of Shoal	394	1	Lagodon rhomboides	pinfish	3	95
18-Aug-03	West of Shoal	394	1	Lagodon rhomboides	pinfish	4	85
18-Aug-03	West of Shoal	394	2	Pagurus pollicaris	flat-claw hermit crab	1	-
18-Aug-03	West of Shoal	394	1	Pagurus pollicaris	flat-claw hermit crab	1	-
18-Aug-03	West of Shoal	394	1	Pagurus pollicaris	flat-claw hermit crab	2	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	1	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	2	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	3	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	4	-

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	5	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	6	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	7	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	8	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	9	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	10	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	11	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	12	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	13	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	14	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	15	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	16	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	17	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	18	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	19	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	20	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	21	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	22	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	23	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	24	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	25	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	26	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	27	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	28	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	29	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	30	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	31	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	32	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	33	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	34	-
18-Aug-03	West of Shoal	394	2	Pagurus spp.	hermit crab (small)	35	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	1	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	2	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	3	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	4	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	5	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	6	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	7	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	8	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	9	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	10	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	11	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	12	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	13	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	14	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	15	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	16	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	17	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	18	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	19	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	20	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	21	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	22	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	23	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	24	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	25	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	26	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	27	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	28	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	29	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	30	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	31	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	32	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	33	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	34	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	35	-

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	36	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	37	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	38	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	39	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	40	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	41	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	42	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	43	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	44	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	45	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	46	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	47	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	48	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	49	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	50	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	51	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	52	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	53	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	54	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	55	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	56	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	57	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	58	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	59	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	60	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	61	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	62	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	63	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	64	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	65	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	66	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	67	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	68	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	69	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	70	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	71	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	72	-
18-Aug-03	West of Shoal	394	1	Pagurus spp.	hermit crab (small)	73	-
18-Aug-03	West of Shoal	394	1	Peprilus triacanthus	butterfish	1	42
18-Aug-03	West of Shoal	394	1	Peprilus triacanthus	butterfish	2	36
18-Aug-03	West of Shoal	394	2	Urophycis regia	spotted hake	1	182
18-Aug-03	West of Shoal	394	2	Urophycis regia	spotted hake	2	177
18-Aug-03	West of Shoal	394	2	Urophycis regia	spotted hake	3	216
18-Aug-03	West of Shoal	394	2	Urophycis regia	spotted hake	4	190
18-Aug-03	West of Shoal	394	2	Urophycis regia	spotted hake	5	179
18-Aug-03	West of Shoal	394	1	Urophycis regia	spotted hake	1	152
18-Aug-03	West of Shoal	394	1		scaleworm	1	-
18-Aug-03	West of Shoal	394	1	Prionotus sp.	sea robin	1	56
18-Aug-03	West of Shoal	394	1	Prionotus sp.	sea robin	2	105
18-Aug-03	West of Shoal	394	1	Prionotus sp.	sea robin	3	100
18-Aug-03	West of Shoal	394	1	Prionotus sp.	sea robin	4	106

Appendix E – 3

Trawl Data – 2004

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	1	50
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	2	39
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	3	47
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	4	55
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	5	35
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	6	52
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	7	50
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	8	65
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	9	45
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	10	39
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	11	51
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	12	37
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	13	24
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	14	67
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	15	57
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	16	40
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	17	40
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	18	43
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	19	46
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	20	36
24-Jun-04		307		Crangon septimspinosa	Sand Shrimp	21	43
24-Jun-04		307		Cynoscion regalis	weakfish	1	56
24-Jun-04		307		Cynoscion regalis	weakfish	2	55
24-Jun-04		307		Cynoscion regalis	weakfish	3	52
24-Jun-04		307		Cynoscion regalis	weakfish	4	52
24-Jun-04		307		Cynoscion regalis	weakfish	5	56
24-Jun-04		307		Cynoscion regalis	weakfish	6	55
24-Jun-04		307		Etropus microstomus	Flounder	1	130
24-Jun-04		307		Etropus microstomus	Flounder	2	57
24-Jun-04		307		Etropus microstomus	Flounder	3	51
24-Jun-04		307		Etropus microstomus	Flounder	4	60
24-Jun-04		307		Etropus microstomus	Flounder	5	53
24-Jun-04		307		Etropus microstomus	Flounder	6	59
24-Jun-04		307		Etropus microstomus	Flounder	7	65
24-Jun-04		307		Etropus microstomus	Flounder	8	66
24-Jun-04		307		Etropus microstomus	Flounder	9	53
24-Jun-04		307		Etropus microstomus	Flounder	10	75
24-Jun-04		307		Etropus microstomus	Flounder	11	65
24-Jun-04		307		Etropus microstomus	Flounder	12	64
24-Jun-04		307		Etropus microstomus	Flounder	13	84
24-Jun-04		307		Etropus microstomus	Flounder	14	45
24-Jun-04		307		Etropus microstomus	Flounder	15	52
24-Jun-04		307		Etropus microstomus	Flounder	16	52
24-Jun-04		307		Etropus microstomus	Flounder	17	66
24-Jun-04		307		Etropus microstomus	Flounder	18	55
24-Jun-04		307		Etropus microstomus	Flounder	19	56
24-Jun-04		307		Etropus microstomus	Flounder	20	56
24-Jun-04		307		Lagodon rhomboides	Pinfish	1	79

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		307		Lagodon rhomboides	Pinfish	2	59
24-Jun-04		307		Lagodon rhomboides	Pinfish	3	55
24-Jun-04		307		Lagodon rhomboides	Pinfish	4	58
24-Jun-04		307		Lagodon rhomboides	Pinfish	5	47
24-Jun-04		307		Lagodon rhomboides	Pinfish	6	45
24-Jun-04		307		Lagodon rhomboides	Pinfish	7	55
24-Jun-04		307		Lagodon rhomboides	Pinfish	8	60
24-Jun-04		307		Lagodon rhomboides	Pinfish	9	55
24-Jun-04		307		Lagodon rhomboides	Pinfish	10	55
24-Jun-04		307		Lagodon rhomboides	Pinfish	11	52
24-Jun-04		307		Lagodon rhomboides	Pinfish	12	46
24-Jun-04		307		Lagodon rhomboides	Pinfish	13	47
24-Jun-04		307		Lagodon rhomboides	Pinfish	14	56
24-Jun-04		307		Lagodon rhomboides	Pinfish	15	49
24-Jun-04		307		Lagodon rhomboides	Pinfish	16	75
24-Jun-04		307		Lagodon rhomboides	Pinfish	17	84
24-Jun-04		307		Lagodon rhomboides	Pinfish	18	30
24-Jun-04		307		Lagodon rhomboides	Pinfish	19	50
24-Jun-04		307		Lagodon rhomboides	Pinfish	20	45
24-Jun-04		307		Lagodon rhomboides	Pinfish	21	55
24-Jun-04		307		Lagodon rhomboides	Pinfish	22	60
24-Jun-04		307		Lagodon rhomboides	Pinfish	23	40
24-Jun-04		307		Lagodon rhomboides	Pinfish	24	45
24-Jun-04		307		Lagodon rhomboides	Pinfish	25	48
24-Jun-04		307		Lagodon rhomboides	Pinfish	26	45
24-Jun-04		307		Lagodon rhomboides	Pinfish	27	45
24-Jun-04		307		Lagodon rhomboides	Pinfish	28	35
24-Jun-04		307		Lagodon rhomboides	Pinfish	29	52
24-Jun-04		307		Lagodon rhomboides	Pinfish	30	50
24-Jun-04		307		Lagodon rhomboides	Pinfish	31	55
24-Jun-04		307		Lagodon rhomboides	Pinfish	32	52
24-Jun-04		307		Lagodon rhomboides	Pinfish	33	56
24-Jun-04		307		Lagodon rhomboides	Pinfish	34	36
24-Jun-04		307		Lagodon rhomboides	Pinfish	35	52
24-Jun-04		307		Lagodon rhomboides	Pinfish	36	45
24-Jun-04		307		Lagodon rhomboides	Pinfish	37	56
24-Jun-04		307		Lagodon rhomboides	Pinfish	38	55
24-Jun-04		307		Lagodon rhomboides	Pinfish	39	45
24-Jun-04		307		Lagodon rhomboides	Pinfish	40	36
24-Jun-04		307		Lagodon rhomboides	Pinfish	41	55
24-Jun-04		307		Lagodon rhomboides	Pinfish	42	50
24-Jun-04		307		Lagodon rhomboides	Pinfish	43	55
24-Jun-04		307		Lagodon rhomboides	Pinfish	44	45
24-Jun-04		307		Lagodon rhomboides	Pinfish	45	45
24-Jun-04		307		Lagodon rhomboides	Pinfish	46	42
24-Jun-04		307		Lagodon rhomboides	Pinfish	47	52
24-Jun-04		307		Lagodon rhomboides	Pinfish	48	52
24-Jun-04		307		Lagodon rhomboides	Pinfish	49	50

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		307		Lagodon rhomboides	Pinfish	50	44
24-Jun-04		307		Lagodon rhomboides	Pinfish	51	50
24-Jun-04		307		Lagodon rhomboides	Pinfish	52	45
24-Jun-04		307		Lagodon rhomboides	Pinfish	53	35
24-Jun-04		307		Lagodon rhomboides	Pinfish	54	42
24-Jun-04		307		Lagodon rhomboides	Pinfish	55	39
24-Jun-04		307		Lagodon rhomboides	Pinfish	56	35
24-Jun-04		307		Lagodon rhomboides	Pinfish	57	35
24-Jun-04		307		Lagodon rhomboides	Pinfish	58	80
24-Jun-04		307		Lagodon rhomboides	Pinfish	59	45
24-Jun-04		307		Lagodon rhomboides	Pinfish	60	45
24-Jun-04		307		Lagodon rhomboides	Pinfish	61	42
24-Jun-04		307		Lagodon rhomboides	Pinfish	62	45
24-Jun-04		307		Lagodon rhomboides	Pinfish	63	50
24-Jun-04		307		Lagodon rhomboides	Pinfish	64	55
24-Jun-04		307		Lagodon rhomboides	Pinfish	65	40
24-Jun-04		307		Lagodon rhomboides	Pinfish	66	50
24-Jun-04		307		Lagodon rhomboides	Pinfish	67	45
24-Jun-04		307		Lolliguncula brevis	Squid	1	32
24-Jun-04		307		Lolliguncula brevis	Squid	2	145
24-Jun-04		307		Lolliguncula brevis	Squid	3	30
24-Jun-04		307		Lolliguncula brevis	Squid	4	42
24-Jun-04		307		Lolliguncula brevis	Squid	5	37
24-Jun-04		307		Ovalipes ocellatus	Lady Crab	1	25
24-Jun-04		307		Ovalipes ocellatus	Lady Crab	2	22
24-Jun-04		307		Ovalipes ocellatus	Lady Crab	3	19
24-Jun-04		307		Ovalipes ocellatus	Lady Crab	4	25
24-Jun-04		307		Ovalipes ocellatus	Lady Crab	5	25
24-Jun-04		307		Ovalipes ocellatus	Lady Crab	6	20
24-Jun-04		307		Pagurus sp.	Hermit Crab	1	
24-Jun-04		307		Pagurus sp.	Hermit Crab	2	
24-Jun-04		307		Pagurus sp.	Hermit Crab	3	
24-Jun-04		307		Pagurus sp.	Hermit Crab	4	
24-Jun-04		307		Pagurus sp.	Hermit Crab	5	
24-Jun-04		307		Pagurus sp.	Hermit Crab	6	
24-Jun-04		307		Pagurus sp.	Hermit Crab	7	
24-Jun-04		307		Pagurus sp.	Hermit Crab	8	
24-Jun-04		307		Pagurus sp.	Hermit Crab	9	
24-Jun-04		307		Pagurus sp.	Hermit Crab	10	
24-Jun-04		307		Pagurus sp.	Hermit Crab	11	
24-Jun-04		307		Pagurus sp.	Hermit Crab	12	
24-Jun-04		307		Pagurus sp.	Hermit Crab	13	
24-Jun-04		307		Pagurus sp.	Hermit Crab	14	
24-Jun-04		307		Pagurus sp.	Hermit Crab	15	
24-Jun-04		307		Pagurus sp.	Hermit Crab	16	
24-Jun-04		307		Pagurus sp.	Hermit Crab	17	
24-Jun-04		307		Pagurus sp.	Hermit Crab	18	
24-Jun-04		307		Pagurus sp.	Hermit Crab	19	

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		307		Pagurus sp.	Hermit Crab	20	
24-Jun-04		307		Pagurus sp.	Hermit Crab	21	
24-Jun-04		307		Pagurus sp.	Hermit Crab	22	
24-Jun-04		307		Pagurus sp.	Hermit Crab	23	
24-Jun-04		307		Pagurus sp.	Hermit Crab	24	
24-Jun-04		307		Pagurus sp.	Hermit Crab	25	
24-Jun-04		307		Pagurus sp.	Hermit Crab	26	
24-Jun-04		307		Pagurus sp.	Hermit Crab	27	
24-Jun-04		307		Pagurus sp.	Hermit Crab	28	
24-Jun-04		307		Pagurus sp.	Hermit Crab	29	
24-Jun-04		307		Pagurus sp.	Hermit Crab	30	
24-Jun-04		307		Pagurus sp.	Hermit Crab	31	
24-Jun-04		307		Pagurus sp.	Hermit Crab	32	
24-Jun-04		307		Pagurus sp.	Hermit Crab	33	
24-Jun-04		307		Pagurus sp.	Hermit Crab	34	
24-Jun-04		307		Pagurus sp.	Hermit Crab	35	
24-Jun-04		307		Pagurus sp.	Hermit Crab	36	
24-Jun-04		307		Pagurus sp.	Hermit Crab	37	
24-Jun-04		307		Pagurus sp.	Hermit Crab	38	
24-Jun-04		307		Pagurus sp.	Hermit Crab	39	
24-Jun-04		307		Pagurus sp.	Hermit Crab	40	
24-Jun-04		307		Pagurus sp.	Hermit Crab	41	
24-Jun-04		307		Pagurus sp.	Hermit Crab	42	
24-Jun-04		307		Pagurus sp.	Hermit Crab	43	
24-Jun-04		307		Pagurus sp.	Hermit Crab	44	
24-Jun-04		307		Pagurus sp.	Hermit Crab	45	
24-Jun-04		307		Pagurus sp.	Hermit Crab	46	
24-Jun-04		307		Pagurus sp.	Hermit Crab	47	
24-Jun-04		307		Peprilus triacanthus	Butterfish	1	35
24-Jun-04		307		Peprilus triacanthus	Butterfish	2	40
24-Jun-04		307		Peprilus triacanthus	Butterfish	3	25
24-Jun-04		307		Peprilus triacanthus	Butterfish	4	33
24-Jun-04		307		Peprilus triacanthus	Butterfish	5	20
24-Jun-04		307		Peprilus triacanthus	Butterfish	6	17
24-Jun-04		307		Peprilus triacanthus	Butterfish	7	23
24-Jun-04		307		Peprilus triacanthus	Butterfish	8	20
24-Jun-04		307		Peprilus triacanthus	Butterfish	9	20
24-Jun-04		307		Peprilus triacanthus	Butterfish	10	17
24-Jun-04		307		Peprilus triacanthus	Butterfish	11	17
24-Jun-04		307		Peprilus triacanthus	Butterfish	12	15
24-Jun-04		307		Peprilus triacanthus	Butterfish	13	29
24-Jun-04		307		Peprilus triacanthus	Butterfish	14	25
24-Jun-04		307		Prinotus sp.	Sea Robin	1	65
24-Jun-04		307		Prinotus sp.	Sea Robin	2	85
24-Jun-04		307		Prinotus sp.	Sea Robin	3	75
24-Jun-04		307		Prinotus sp.	Sea Robin	4	70
24-Jun-04		307		Prinotus sp.	Sea Robin	5	82
24-Jun-04		307		Prinotus sp.	Sea Robin	6	70

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		307		Prinotus sp.	Sea Robin	7	55
24-Jun-04		307		Prinotus sp.	Sea Robin	8	75
24-Jun-04		307		Prinotus sp.	Sea Robin	9	80
24-Jun-04		307		Prinotus sp.	Sea Robin	10	65
24-Jun-04		307		Prinotus sp.	Sea Robin	11	54
24-Jun-04		307		Prinotus sp.	Sea Robin	12	60
24-Jun-04		307		Prinotus sp.	Sea Robin	13	62
24-Jun-04		307		Prinotus sp.	Sea Robin	14	70
24-Jun-04		307		Prinotus sp.	Sea Robin	15	80
24-Jun-04		307		Prinotus sp.	Sea Robin	16	50
24-Jun-04		307		Prinotus sp.	Sea Robin	17	92
24-Jun-04		307		Prinotus sp.	Sea Robin	18	62
24-Jun-04		307		Prinotus sp.	Sea Robin	19	60
24-Jun-04		307		Prinotus sp.	Sea Robin	20	75
24-Jun-04		307		Prinotus sp.	Sea Robin	21	62
24-Jun-04		307		Prinotus sp.	Sea Robin	22	60
24-Jun-04		307		Prinotus sp.	Sea Robin	23	70
24-Jun-04		307		Prinotus sp.	Sea Robin	24	82
24-Jun-04		307		Prinotus sp.	Sea Robin	25	59
24-Jun-04		307		Prinotus sp.	Sea Robin	26	52
24-Jun-04		307		Prinotus sp.	Sea Robin	27	82
24-Jun-04		307		Prinotus sp.	Sea Robin	28	95
24-Jun-04		307		Prinotus sp.	Sea Robin	29	85
24-Jun-04		307		Prinotus sp.	Sea Robin	30	65
24-Jun-04		307		Prinotus sp.	Sea Robin	31	82
24-Jun-04		307		Prinotus sp.	Sea Robin	32	65
24-Jun-04		307		Prinotus sp.	Sea Robin	33	75
24-Jun-04		307		Prinotus sp.	Sea Robin	34	75
24-Jun-04		307		Prinotus sp.	Sea Robin	35	72
24-Jun-04		307		Prinotus sp.	Sea Robin	36	65
24-Jun-04		307		Prinotus sp.	Sea Robin	37	50
24-Jun-04		307		Prinotus sp.	Sea Robin	38	87
24-Jun-04		307		Prinotus sp.	Sea Robin	39	76
24-Jun-04		307		Prinotus sp.	Sea Robin	40	66
24-Jun-04		307		Prinotus sp.	Sea Robin	41	66
24-Jun-04		307		Prinotus sp.	Sea Robin	42	57
24-Jun-04		307		Prinotus sp.	Sea Robin	43	66
24-Jun-04		307		Prinotus sp.	Sea Robin	44	65
24-Jun-04		307		Raja eglanteria	Skate	1	485
24-Jun-04		307		Raja eglanteria	Skate	2	664
24-Jun-04		307		Raja eglanteria	Skate	3	695
24-Jun-04		307		Urophycis regia	Spotted Hake	1	155
24-Jun-04		307		Urophycis regia	Spotted Hake	2	152
24-Jun-04		307		Urophycis regia	Spotted Hake	3	120
24-Jun-04		307		Urophycis regia	Spotted Hake	4	97
24-Jun-04		307		Urophycis regia	Spotted Hake	5	100
24-Jun-04		307		Urophycis regia	Spotted Hake	6	110
24-Jun-04		307		Urophycis regia	Spotted Hake	7	124

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		307		Urophycis regia	Spotted Hake	8	102
24-Jun-04		307		Urophycis regia	Spotted Hake	9	79
24-Jun-04		307		Urophycis regia	Spotted Hake	10	90
24-Jun-04		307		Urophycis regia	Spotted Hake	11	84
24-Jun-04		307		Menhaden	Menhaden	1	46
24-Jun-04		356	2	Crangon septimspinosa	Sand Shrimp	1	52
24-Jun-04		356	2	Crangon septimspinosa	Sand Shrimp	2	53
24-Jun-04		356	2	Crangon septimspinosa	Sand Shrimp	3	52
24-Jun-04		356	2	Crangon septimspinosa	Sand Shrimp	4	55
24-Jun-04		356	2	Crangon septimspinosa	Sand Shrimp	5	60
24-Jun-04		356	2	Crangon septimspinosa	Sand Shrimp	6	56
24-Jun-04		356	2	Crangon septimspinosa	Sand Shrimp	7	51
24-Jun-04		356	2	Crangon septimspinosa	Sand Shrimp	8	57
24-Jun-04		356	2	Crangon septimspinosa	Sand Shrimp	9	57
24-Jun-04		356	2	Crangon septimspinosa	Sand Shrimp	10	57
24-Jun-04		356	2	Crangon septimspinosa	Sand Shrimp	11	39
24-Jun-04		356	1	Cynoscion regalis	weakfish	1	55
24-Jun-04		356	1	Cynoscion regalis	weakfish	2	66
24-Jun-04		356	1	Etropus microstomus	Flounder	1	50
24-Jun-04		356	1	Etropus microstomus	Flounder	2	56
24-Jun-04		356	1	Etropus microstomus	Flounder	3	54
24-Jun-04		356	2	Etropus microstomus	Flounder	1	93
24-Jun-04		356	2	Etropus microstomus	Flounder	2	103
24-Jun-04		356	2	Etropus microstomus	Flounder	3	97
24-Jun-04		356	2	Etropus microstomus	Flounder	4	309
24-Jun-04		356	2	Etropus microstomus	Flounder	5	77
24-Jun-04		356	2	Etropus microstomus	Flounder	6	84
24-Jun-04		356	2	Etropus microstomus	Flounder	7	84
24-Jun-04		356	2	Etropus microstomus	Flounder	8	73
24-Jun-04		356	2	Etropus microstomus	Flounder	9	84
24-Jun-04		356	2	Etropus microstomus	Flounder	10	106
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	1	58
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	2	63
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	3	47
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	4	48
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	5	51
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	6	53
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	7	59
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	8	57
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	9	49
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	10	47
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	11	51
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	12	59
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	13	59
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	14	51
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	15	43
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	16	53
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	17	46

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	18	42
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	19	56
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	20	45
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	21	51
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	22	77
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	23	57
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	24	43
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	25	42
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	26	46
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	27	45
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	28	49
24-Jun-04		356	1	Lagodon rhomboides	Pinfish	29	48
24-Jun-04		356	1	Lolliguncula brevis	Squid	1	35
24-Jun-04		356	1	Lolliguncula brevis	Squid	2	75
24-Jun-04		356	1	Lolliguncula brevis	Squid	3	36
24-Jun-04		356	1	Lolliguncula brevis	Squid	4	38
24-Jun-04		356	1	Lolliguncula brevis	Squid	5	30
24-Jun-04		356	1	Lolliguncula brevis	Squid	6	32
24-Jun-04		356	1	Lolliguncula brevis	Squid	7	24
24-Jun-04		356	1	Lolliguncula brevis	Squid	8	29
24-Jun-04		356	1	Lolliguncula brevis	Squid	9	29
24-Jun-04		356	1	Lolliguncula brevis	Squid	10	31
24-Jun-04		356	1	Lolliguncula brevis	Squid	11	28
24-Jun-04		356	2	Lolliguncula brevis	Squid	1	130
24-Jun-04		356	2	Lolliguncula brevis	Squid	2	40
24-Jun-04		356	2	Lolliguncula brevis	Squid	3	30
24-Jun-04		356	2	Lolliguncula brevis	Squid	4	46
24-Jun-04		356	2	Lolliguncula brevis	Squid	5	83
24-Jun-04		356	2	Lolliguncula brevis	Squid	6	37
24-Jun-04		356	2	Lolliguncula brevis	Squid	7	33
24-Jun-04		356	2	Lolliguncula brevis	Squid	8	135
24-Jun-04		356	2	Lolliguncula brevis	Squid	9	36
24-Jun-04		356	2	Lolliguncula brevis	Squid	10	45
24-Jun-04		356	2	Lolliguncula brevis	Squid	11	30
24-Jun-04		356	2	Lolliguncula brevis	Squid	12	31
24-Jun-04		356	2	Lolliguncula brevis	Squid	13	41
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	1	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	2	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	3	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	4	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	5	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	6	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	7	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	8	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	9	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	10	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	11	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	12	

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	13	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	14	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	15	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	16	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	17	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	18	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	19	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	20	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	21	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	22	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	23	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	24	
24-Jun-04		356	1	Pagurus sp.	Hermit Crab	25	
24-Jun-04		356	2	Pagurus sp.	Hermit Crab	1	
24-Jun-04		356	2	Pagurus sp.	Hermit Crab	2	
24-Jun-04		356	2	Pagurus sp.	Hermit Crab	3	
24-Jun-04		356	2	Pagurus sp.	Hermit Crab	4	
24-Jun-04		356	2	Pagurus sp.	Hermit Crab	5	
24-Jun-04		356	2	Pagurus sp.	Hermit Crab	6	
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	1	23
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	2	27
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	3	35
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	4	21
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	5	45
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	6	24
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	7	33
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	8	37
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	9	23
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	10	27
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	11	21
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	12	23
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	13	23
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	14	36
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	15	34
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	16	37
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	17	25
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	18	21
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	19	20
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	20	30
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	21	35
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	22	33
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	23	33
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	24	42
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	25	30
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	26	42
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	27	50
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	28	30
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	29	25

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	30	15
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	31	27
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	32	30
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	33	41
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	34	45
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	35	27
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	36	30
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	37	30
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	38	50
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	39	45
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	40	20
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	41	30
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	42	34
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	43	23
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	44	37
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	45	43
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	46	36
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	47	40
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	48	33
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	49	37
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	50	33
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	51	34
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	52	32
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	53	34
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	54	25
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	55	26
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	56	41
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	57	37
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	58	31
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	59	42
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	60	47
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	61	37
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	62	35
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	63	35
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	64	26
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	65	33
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	66	37
24-Jun-04		356	1	Peprilus triacanthus	Butterfish	67	91
24-Jun-04		356	2	Peprilus triacanthus	Butterfish	1	39
24-Jun-04		356	2	Peprilus triacanthus	Butterfish	2	25
24-Jun-04		356	2	Peprilus triacanthus	Butterfish	3	25
24-Jun-04		356	2	Peprilus triacanthus	Butterfish	4	39
24-Jun-04		356	2	Peprilus triacanthus	Butterfish	5	28
24-Jun-04		356	2	Peprilus triacanthus	Butterfish	6	63
24-Jun-04		356	1	Prinotus sp.	Sea Robin	1	83
24-Jun-04		356	1	Prinotus sp.	Sea Robin	2	64
24-Jun-04		356	1	Prinotus sp.	Sea Robin	3	59
24-Jun-04		356	1	Prinotus sp.	Sea Robin	4	74

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		356	1	Prinotus sp.	Sea Robin	5	56
24-Jun-04		356	1	Prinotus sp.	Sea Robin	6	56
24-Jun-04		356	1	Prinotus sp.	Sea Robin	7	61
24-Jun-04		356	1	Prinotus sp.	Sea Robin	8	54
24-Jun-04		356	1	Prinotus sp.	Sea Robin	9	64
24-Jun-04		356	1	Prinotus sp.	Sea Robin	10	60
24-Jun-04		356	1	Prinotus sp.	Sea Robin	11	74
24-Jun-04		356	1	Prinotus sp.	Sea Robin	12	56
24-Jun-04		356	1	Prinotus sp.	Sea Robin	13	63
24-Jun-04		356	1	Prinotus sp.	Sea Robin	14	67
24-Jun-04		356	1	Prinotus sp.	Sea Robin	15	70
24-Jun-04		356	1	Prinotus sp.	Sea Robin	16	66
24-Jun-04		356	1	Prinotus sp.	Sea Robin	17	57
24-Jun-04		356	1	Prinotus sp.	Sea Robin	18	53
24-Jun-04		356	1	Prinotus sp.	Sea Robin	19	77
24-Jun-04		356	2	Prinotus sp.	Sea Robin	1	95
24-Jun-04		356	2	Prinotus sp.	Sea Robin	2	64
24-Jun-04		356	2	Prinotus sp.	Sea Robin	3	63
24-Jun-04		356	1	Urophycis regia	Spotted Hake	1	44
24-Jun-04		356	1	Urophycis regia	Spotted Hake	2	107
24-Jun-04		356	1	Urophycis regia	Spotted Hake	3	143
24-Jun-04		356	1	Urophycis regia	Spotted Hake	4	110
24-Jun-04		356	1	Urophycis regia	Spotted Hake	5	107
24-Jun-04		356	1	Urophycis regia	Spotted Hake	6	141
24-Jun-04		356	1	Urophycis regia	Spotted Hake	7	101
24-Jun-04		356	1	Urophycis regia	Spotted Hake	8	133
24-Jun-04		356	1	Urophycis regia	Spotted Hake	9	117
24-Jun-04		356	1	Urophycis regia	Spotted Hake	10	125
24-Jun-04		356	2	Urophycis regia	Spotted Hake	1	122
24-Jun-04		356	2	Urophycis regia	Spotted Hake	2	121
24-Jun-04		356	2	Urophycis regia	Spotted Hake	3	101
24-Jun-04		356	2	Urophycis regia	Spotted Hake	4	127
24-Jun-04		356	2	Urophycis regia	Spotted Hake	5	114
24-Jun-04		356	2	Urophycis regia	Spotted Hake	6	111
24-Jun-04		356	2	Urophycis regia	Spotted Hake	7	139
24-Jun-04		356	2	Urophycis regia	Spotted Hake	8	93
24-Jun-04		356	2	Urophycis regia	Spotted Hake	9	146
24-Jun-04		356	2	Urophycis regia	Spotted Hake	10	119
24-Jun-04		356	2	Urophycis regia	Spotted Hake	11	121
24-Jun-04		356	2	Urophycis regia	Spotted Hake	12	144
24-Jun-04		356	2	Urophycis regia	Spotted Hake	13	161
24-Jun-04		356	2	Urophycis regia	Spotted Hake	14	128
24-Jun-04		356	2	Urophycis regia	Spotted Hake	15	88
24-Jun-04		356	2	Urophycis regia	Spotted Hake	16	106
24-Jun-04		356	2	Urophycis regia	Spotted Hake	17	95
24-Jun-04		356	2	Urophycis regia	Spotted Hake	18	113
24-Jun-04		356	2	Urophycis regia	Spotted Hake	19	140
24-Jun-04		356	2	Urophycis regia	Spotted Hake	20	113

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		356	2	Urophycis regia	Spotted Hake	21	127
24-Jun-04		356	2	Urophycis regia	Spotted Hake	22	93
24-Jun-04		356	2	Urophycis regia	Spotted Hake	23	117
24-Jun-04		356	2	Urophycis regia	Spotted Hake	24	141
24-Jun-04		356	2	Urophycis regia	Spotted Hake	25	116
24-Jun-04		356	2	Urophycis regia	Spotted Hake	26	89
24-Jun-04		356	2	Urophycis regia	Spotted Hake	27	126
24-Jun-04		356	2	Urophycis regia	Spotted Hake	28	107
24-Jun-04		356	2	Urophycis regia	Spotted Hake	29	141
24-Jun-04		356	2	Urophycis regia	Spotted Hake	30	101
24-Jun-04		356	2	Urophycis regia	Spotted Hake	31	101
24-Jun-04		356	2	Urophycis regia	Spotted Hake	32	97
24-Jun-04		356	2	Urophycis regia	Spotted Hake	33	127
24-Jun-04		356	2	Urophycis regia	Spotted Hake	34	153
24-Jun-04		356	2	Urophycis regia	Spotted Hake	35	109
24-Jun-04		356	2	Urophycis regia	Spotted Hake	36	133
24-Jun-04		356	2	Urophycis regia	Spotted Hake	37	99
24-Jun-04		356	2	Urophycis regia	Spotted Hake	38	104
24-Jun-04		356	2	Urophycis regia	Spotted Hake	39	119
24-Jun-04		356	2	Urophycis regia	Spotted Hake	40	95
24-Jun-04		356	2	Urophycis regia	Spotted Hake	41	129
24-Jun-04		356	2	Urophycis regia	Spotted Hake	42	133
24-Jun-04		356	2	Urophycis regia	Spotted Hake	43	117
24-Jun-04		356	2	Urophycis regia	Spotted Hake	44	106
24-Jun-04		356	2	Urophycis regia	Spotted Hake	45	113
24-Jun-04		356	2	Urophycis regia	Spotted Hake	46	115
24-Jun-04		356	2	Urophycis regia	Spotted Hake	47	137
24-Jun-04		356	2	Urophycis regia	Spotted Hake	48	145
24-Jun-04		356	2	Urophycis regia	Spotted Hake	49	153
24-Jun-04		390	1	Crangon septimspinosa	Sand Shrimp	1	57
24-Jun-04		390	1	Crangon septimspinosa	Sand Shrimp	2	33
24-Jun-04		390	1	Crangon septimspinosa	Sand Shrimp	3	47
24-Jun-04		390	1	Crangon septimspinosa	Sand Shrimp	4	57
24-Jun-04		390	2	Crangon septimspinosa	Sand Shrimp	1	57
24-Jun-04		390	2	Crangon septimspinosa	Sand Shrimp	2	56
24-Jun-04		390	2	Crangon septimspinosa	Sand Shrimp	3	59
24-Jun-04		390	2	Crangon septimspinosa	Sand Shrimp	4	51
24-Jun-04		390	2	Crangon septimspinosa	Sand Shrimp	5	60
24-Jun-04		390	2	Crangon septimspinosa	Sand Shrimp	6	29
24-Jun-04		390	2	Crangon septimspinosa	Sand Shrimp	7	33
24-Jun-04		390	2	Crangon septimspinosa	Sand Shrimp	8	46
24-Jun-04		390	2	Crangon septimspinosa	Sand Shrimp	9	63
24-Jun-04		390	2	Crangon septimspinosa	Sand Shrimp	10	57
24-Jun-04		390	2	Crangon septimspinosa	Sand Shrimp	11	37
24-Jun-04		390	2	Crangon septimspinosa	Sand Shrimp	12	34
24-Jun-04		390	2	Crangon septimspinosa	Sand Shrimp	13	35
24-Jun-04		390	1	Etropus microstomus	Flounder	1	97
24-Jun-04		390	1	Etropus microstomus	Flounder	2	84

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		390	1	Etropus microstomus	Flounder	3	133
24-Jun-04		390	1	Etropus microstomus	Flounder	4	96
24-Jun-04		390	1	Etropus microstomus	Flounder	5	73
24-Jun-04		390	1	Etropus microstomus	Flounder	6	72
24-Jun-04		390	1	Etropus microstomus	Flounder	7	101
24-Jun-04		390	1	Etropus microstomus	Flounder	8	75
24-Jun-04		390	1	Etropus microstomus	Flounder	9	86
24-Jun-04		390	1	Etropus microstomus	Flounder	10	114
24-Jun-04		390	2	Etropus microstomus	Flounder	1	85
24-Jun-04		390	2	Etropus microstomus	Flounder	2	89
24-Jun-04		390	2	Etropus microstomus	Flounder	3	101
24-Jun-04		390	2	Etropus microstomus	Flounder	4	75
24-Jun-04		390	2	Etropus microstomus	Flounder	5	94
24-Jun-04		390	2	Etropus microstomus	Flounder	6	110
24-Jun-04		390	2	Etropus microstomus	Flounder	7	89
24-Jun-04		390	2	Lagodon rhomboides	pinfish	1	60
24-Jun-04		390	1	Lolliguncula brevis	Squid	1	31
24-Jun-04		390	2	Lolliguncula brevis	Squid	1	37
24-Jun-04		390	2	Lolliguncula brevis	Squid	2	36
24-Jun-04		390	2	Lolliguncula brevis	Squid	3	35
24-Jun-04		390	2	Lolliguncula brevis	Squid	4	45
24-Jun-04		390	2	Lolliguncula brevis	Squid	5	45
24-Jun-04		390	2	Lolliguncula brevis	Squid	6	43
24-Jun-04		390	2	Lolliguncula brevis	Squid	7	34
24-Jun-04		390	2	Lolliguncula brevis	Squid	8	31
24-Jun-04		390	1	Pagurus sp.	Hermit Crab	1	
24-Jun-04		390	1	Pagurus sp.	Hermit Crab	2	
24-Jun-04		390	1	Pagurus sp.	Hermit Crab	3	
24-Jun-04		390	1	Pagurus sp.	Hermit Crab	4	
24-Jun-04		390	1	Pagurus sp.	Hermit Crab	5	
24-Jun-04		390	1	Pagurus sp.	Hermit Crab	6	
24-Jun-04		390	1	Pagurus sp.	Hermit Crab	7	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	1	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	2	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	3	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	4	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	5	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	6	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	7	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	8	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	9	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	10	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	11	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	12	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	13	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	14	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	15	
24-Jun-04		390	2	Pagurus sp.	Hermit Crab	16	

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		390	1	Peprilus triacanthus	Butterfish	1	38
24-Jun-04		390	1	Peprilus triacanthus	Butterfish	2	28
24-Jun-04		390	2	Peprilus triacanthus	Butterfish	1	36
24-Jun-04		390	1	Prinotus sp.	Sea Robin	1	77
24-Jun-04		390	1	Prinotus sp.	Sea Robin	2	59
24-Jun-04		390	1	Prinotus sp.	Sea Robin	3	67
24-Jun-04		390	1	Prinotus sp.	Sea Robin	4	59
24-Jun-04		390	1	Prinotus sp.	Sea Robin	5	59
24-Jun-04		390	2	Prinotus sp.	Sea Robin	1	93
24-Jun-04		390	2	Prinotus sp.	Sea Robin	2	57
24-Jun-04		390	2	Prinotus sp.	Sea Robin	3	59
24-Jun-04		390	2	Prinotus sp.	Sea Robin	4	60
24-Jun-04		390	2	Prinotus sp.	Sea Robin	5	76
24-Jun-04		390	2	Prinotus sp.	Sea Robin	6	66
24-Jun-04		390	2	Prinotus sp.	Sea Robin	7	78
24-Jun-04		390	2	Prinotus sp.	Sea Robin	8	59
24-Jun-04		390	1	Urophycis regia	Spotted Hake	1	120
24-Jun-04		390	1	Urophycis regia	Spotted Hake	2	125
24-Jun-04		390	1	Urophycis regia	Spotted Hake	3	118
24-Jun-04		390	1	Urophycis regia	Spotted Hake	4	126
24-Jun-04		390	1	Urophycis regia	Spotted Hake	5	101
24-Jun-04		390	1	Urophycis regia	Spotted Hake	6	124
24-Jun-04		390	1	Urophycis regia	Spotted Hake	7	122
24-Jun-04		390	1	Urophycis regia	Spotted Hake	8	121
24-Jun-04		390	1	Urophycis regia	Spotted Hake	9	157
24-Jun-04		390	1	Urophycis regia	Spotted Hake	10	126
24-Jun-04		390	1	Urophycis regia	Spotted Hake	11	114
24-Jun-04		390	1	Urophycis regia	Spotted Hake	12	94
24-Jun-04		390	1	Urophycis regia	Spotted Hake	13	87
24-Jun-04		390	1	Urophycis regia	Spotted Hake	14	116
24-Jun-04		390	1	Urophycis regia	Spotted Hake	15	122
24-Jun-04		390	1	Urophycis regia	Spotted Hake	16	101
24-Jun-04		390	1	Urophycis regia	Spotted Hake	17	109
24-Jun-04		390	1	Urophycis regia	Spotted Hake	18	101
24-Jun-04		390	1	Urophycis regia	Spotted Hake	19	144
24-Jun-04		390	1	Urophycis regia	Spotted Hake	20	121
24-Jun-04		390	1	Urophycis regia	Spotted Hake	21	116
24-Jun-04		390	1	Urophycis regia	Spotted Hake	22	161
24-Jun-04		390	1	Urophycis regia	Spotted Hake	23	131
24-Jun-04		390	1	Urophycis regia	Spotted Hake	24	122
24-Jun-04		390	1	Urophycis regia	Spotted Hake	25	123
24-Jun-04		390	1	Urophycis regia	Spotted Hake	26	106
24-Jun-04		390	1	Urophycis regia	Spotted Hake	27	153
24-Jun-04		390	1	Urophycis regia	Spotted Hake	28	94
24-Jun-04		390	1	Urophycis regia	Spotted Hake	29	157
24-Jun-04		390	1	Urophycis regia	Spotted Hake	30	120
24-Jun-04		390	1	Urophycis regia	Spotted Hake	31	117
24-Jun-04		390	1	Urophycis regia	Spotted Hake	32	117

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		390	1	Urophycis regia	Spotted Hake	33	111
24-Jun-04		390	1	Urophycis regia	Spotted Hake	34	99
24-Jun-04		390	1	Urophycis regia	Spotted Hake	35	116
24-Jun-04		390	1	Urophycis regia	Spotted Hake	36	111
24-Jun-04		390	1	Urophycis regia	Spotted Hake	37	125
24-Jun-04		390	1	Urophycis regia	Spotted Hake	38	128
24-Jun-04		390	1	Urophycis regia	Spotted Hake	39	118
24-Jun-04		390	1	Urophycis regia	Spotted Hake	40	157
24-Jun-04		390	1	Urophycis regia	Spotted Hake	41	121
24-Jun-04		390	1	Urophycis regia	Spotted Hake	42	93
24-Jun-04		390	1	Urophycis regia	Spotted Hake	43	119
24-Jun-04		390	1	Urophycis regia	Spotted Hake	44	105
24-Jun-04		390	1	Urophycis regia	Spotted Hake	45	134
24-Jun-04		390	1	Urophycis regia	Spotted Hake	46	94
24-Jun-04		390	1	Urophycis regia	Spotted Hake	47	129
24-Jun-04		390	1	Urophycis regia	Spotted Hake	48	112
24-Jun-04		390	1	Urophycis regia	Spotted Hake	49	104
24-Jun-04		390	1	Urophycis regia	Spotted Hake	50	12
24-Jun-04		390	1	Urophycis regia	Spotted Hake	51	115
24-Jun-04		390	1	Urophycis regia	Spotted Hake	52	96
24-Jun-04		390	1	Urophycis regia	Spotted Hake	53	97
24-Jun-04		390	1	Urophycis regia	Spotted Hake	54	114
24-Jun-04		390	1	Urophycis regia	Spotted Hake	55	99
24-Jun-04		390	1	Urophycis regia	Spotted Hake	56	139
24-Jun-04		390	1	Urophycis regia	Spotted Hake	57	116
24-Jun-04		390	1	Urophycis regia	Spotted Hake	58	97
24-Jun-04		390	1	Urophycis regia	Spotted Hake	59	126
24-Jun-04		390	1	Urophycis regia	Spotted Hake	60	113
24-Jun-04		390	1	Urophycis regia	Spotted Hake	61	109
24-Jun-04		390	1	Urophycis regia	Spotted Hake	62	103
24-Jun-04		390	1	Urophycis regia	Spotted Hake	63	112
24-Jun-04		390	1	Urophycis regia	Spotted Hake	64	119
24-Jun-04		390	1	Urophycis regia	Spotted Hake	65	118
24-Jun-04		390	1	Urophycis regia	Spotted Hake	66	111
24-Jun-04		390	1	Urophycis regia	Spotted Hake	67	102
24-Jun-04		390	1	Urophycis regia	Spotted Hake	68	117
24-Jun-04		390	2	Urophycis regia	Spotted Hake	1	123
24-Jun-04		390	2	Urophycis regia	Spotted Hake	2	108
24-Jun-04		390	2	Urophycis regia	Spotted Hake	3	119
24-Jun-04		390	2	Urophycis regia	Spotted Hake	4	109
24-Jun-04		390	2	Urophycis regia	Spotted Hake	5	117
24-Jun-04		390	2	Urophycis regia	Spotted Hake	6	103
24-Jun-04		390	2	Urophycis regia	Spotted Hake	7	113
24-Jun-04		390	2	Urophycis regia	Spotted Hake	8	123
24-Jun-04		390	2	Urophycis regia	Spotted Hake	9	114
24-Jun-04		390	2	Urophycis regia	Spotted Hake	10	105
24-Jun-04		390	2	Urophycis regia	Spotted Hake	11	122
24-Jun-04		390	2	Urophycis regia	Spotted Hake	12	108

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		390	2	Urophycis regia	Spotted Hake	13	134
24-Jun-04		390	2	Urophycis regia	Spotted Hake	14	116
24-Jun-04		390	2	Urophycis regia	Spotted Hake	15	137
24-Jun-04		390	2	Urophycis regia	Spotted Hake	16	117
24-Jun-04		390	2	Urophycis regia	Spotted Hake	17	148
24-Jun-04		390	2	Urophycis regia	Spotted Hake	18	104
24-Jun-04		390	2	Urophycis regia	Spotted Hake	19	109
24-Jun-04		390	2	Urophycis regia	Spotted Hake	20	99
24-Jun-04		390	2	Urophycis regia	Spotted Hake	21	119
24-Jun-04		390	2	Urophycis regia	Spotted Hake	22	98
24-Jun-04		390	2	Urophycis regia	Spotted Hake	23	109
24-Jun-04		390	2	Urophycis regia	Spotted Hake	24	118
24-Jun-04		390	2	Urophycis regia	Spotted Hake	25	99
24-Jun-04		390	2	Urophycis regia	Spotted Hake	26	129
24-Jun-04		390	2	Urophycis regia	Spotted Hake	27	113
24-Jun-04		390	2	Urophycis regia	Spotted Hake	28	136
24-Jun-04		390	2	Urophycis regia	Spotted Hake	29	114
24-Jun-04		390	2	Urophycis regia	Spotted Hake	30	139
24-Jun-04		390	2	Urophycis regia	Spotted Hake	31	109
24-Jun-04		390	2	Urophycis regia	Spotted Hake	32	129
24-Jun-04		390	2	Urophycis regia	Spotted Hake	33	93
24-Jun-04		390	2	Urophycis regia	Spotted Hake	34	89
24-Jun-04		390	2	Urophycis regia	Spotted Hake	35	111
24-Jun-04		390	2	Urophycis regia	Spotted Hake	36	121
24-Jun-04		390	2	Urophycis regia	Spotted Hake	37	123
24-Jun-04		390	2	Urophycis regia	Spotted Hake	38	99
24-Jun-04		390	2	Urophycis regia	Spotted Hake	39	109
24-Jun-04		390	2	Urophycis regia	Spotted Hake	40	95
24-Jun-04		390	2	Urophycis regia	Spotted Hake	41	114
24-Jun-04		390	2	Urophycis regia	Spotted Hake	42	95
24-Jun-04		390	2	Urophycis regia	Spotted Hake	43	121
24-Jun-04		390	2	Urophycis regia	Spotted Hake	44	122
24-Jun-04		390	2	Urophycis regia	Spotted Hake	45	98
24-Jun-04		390	2	Urophycis regia	Spotted Hake	46	114
24-Jun-04		390	2	Urophycis regia	Spotted Hake	47	101
24-Jun-04		390	2	Urophycis regia	Spotted Hake	48	110
24-Jun-04		390	2	Urophycis regia	Spotted Hake	49	121
24-Jun-04		390	2	Urophycis regia	Spotted Hake	50	101
24-Jun-04		390	2	Urophycis regia	Spotted Hake	51	112
24-Jun-04		390	2	Urophycis regia	Spotted Hake	52	107
24-Jun-04		390	2	Urophycis regia	Spotted Hake	53	124
24-Jun-04		390	2	Urophycis regia	Spotted Hake	54	122
24-Jun-04		390	2	Urophycis regia	Spotted Hake	55	124
24-Jun-04		390	2	Urophycis regia	Spotted Hake	56	106
24-Jun-04		390	2	Urophycis regia	Spotted Hake	57	95
24-Jun-04		390	2	Urophycis regia	Spotted Hake	58	120
24-Jun-04		390	2	Urophycis regia	Spotted Hake	59	101
24-Jun-04		390	2	Urophycis regia	Spotted Hake	60	110

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		390	2	Urophycis regia	Spotted Hake	61	90
24-Jun-04		390	2	Urophycis regia	Spotted Hake	62	106
24-Jun-04		390	2	Urophycis regia	Spotted Hake	63	93
24-Jun-04		390	2	Urophycis regia	Spotted Hake	64	114
24-Jun-04		390	2	Urophycis regia	Spotted Hake	65	113
24-Jun-04		390	2	Urophycis regia	Spotted Hake	66	126
24-Jun-04		390	2	Urophycis regia	Spotted Hake	67	56
24-Jun-04		390	2		Starfish	1	115
24-Jun-04		390	2	Libinia emarginata	Spider Crab	1	55
24-Jun-04		390	2	Menippe sp.	Stone Crab	1	35
24-Jun-04		390	2	Menippe sp.	Stone Crab	2	25
24-Jun-04		390	2	Menippe sp.	Stone Crab	3	21
24-Jun-04		390	2	Menippe sp.	Stone Crab	4	20
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	1	63
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	2	62
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	3	58
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	4	62
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	5	54
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	6	43
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	7	39
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	8	47
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	9	38
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	10	39
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	11	47
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	12	35
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	13	53
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	14	37
24-Jun-04		394	1	Crangon septimspinosa	Sand Shrimp	15	49
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	1	49
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	2	42
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	3	66
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	4	59
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	5	59
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	6	54
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	7	59
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	8	51
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	9	59
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	10	53
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	11	43
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	12	63
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	13	54
24-Jun-04		394	2	Crangon septimspinosa	Sand Shrimp	14	56
24-Jun-04		394	1	Etropus microstomus	Flounder	1	105
24-Jun-04		394	1	Etropus microstomus	Flounder	2	93
24-Jun-04		394	2	Etropus microstomus	Flounder	1	93
24-Jun-04		394	2	Etropus microstomus	Flounder	2	73
24-Jun-04		394	2	Etropus microstomus	Flounder	3	57
24-Jun-04		394	2	Etropus microstomus	Flounder	4	64

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		394	2	Etropus microstomus	Flounder	5	87
24-Jun-04		394	2	Etropus microstomus	Flounder	6	79
24-Jun-04		394	2	Etropus microstomus	Flounder	7	61
24-Jun-04		394	1	Lagodon rhomboides	Pinfish	1	47
24-Jun-04		394	1	Lagodon rhomboides	Pinfish	2	62
24-Jun-04		394	1	Lagodon rhomboides	Pinfish	3	53
24-Jun-04		394	2	Lagodon rhomboides	Pinfish	1	77
24-Jun-04		394	2	Lagodon rhomboides	Pinfish	2	57
24-Jun-04		394	2	Lagodon rhomboides	Pinfish	3	61
24-Jun-04		394	2	Lagodon rhomboides	Pinfish	4	53
24-Jun-04		394	2	Lagodon rhomboides	Pinfish	5	143
24-Jun-04		394	2	Lagodon rhomboides	Pinfish	6	56
24-Jun-04		394	2	Lagodon rhomboides	Pinfish	7	50
24-Jun-04		394	1	Lolliguncula brevis	Squid	1	62
24-Jun-04		394	1	Lolliguncula brevis	Squid	2	57
24-Jun-04		394	1	Lolliguncula brevis	Squid	3	47
24-Jun-04		394	1	Lolliguncula brevis	Squid	4	26
24-Jun-04		394	1	Lolliguncula brevis	Squid	5	36
24-Jun-04		394	1	Lolliguncula brevis	Squid	6	39
24-Jun-04		394	1	Lolliguncula brevis	Squid	7	39
24-Jun-04		394	1	Lolliguncula brevis	Squid	8	50
24-Jun-04		394	1	Lolliguncula brevis	Squid	9	31
24-Jun-04		394	1	Lolliguncula brevis	Squid	10	34
24-Jun-04		394	1	Lolliguncula brevis	Squid	11	32
24-Jun-04		394	1	Lolliguncula brevis	Squid	12	41
24-Jun-04		394	1	Lolliguncula brevis	Squid	13	39
24-Jun-04		394	1	Lolliguncula brevis	Squid	14	39
24-Jun-04		394	1	Lolliguncula brevis	Squid	15	24
24-Jun-04		394	2	Lolliguncula brevis	Squid	1	39
24-Jun-04		394	2	Lolliguncula brevis	Squid	2	39
24-Jun-04		394	2	Lolliguncula brevis	Squid	3	37
24-Jun-04		394	2	Lolliguncula brevis	Squid	4	29
24-Jun-04		394	2	Lolliguncula brevis	Squid	5	46
24-Jun-04		394	2	Pagurus sp.	Hermit Crab	1	
24-Jun-04		394	2	Pagurus sp.	Hermit Crab	2	
24-Jun-04		394	1	Peprilus triacanthus	Butterfish	1	42
24-Jun-04		394	1	Peprilus triacanthus	Butterfish	2	29
24-Jun-04		394	1	Peprilus triacanthus	Butterfish	3	33
24-Jun-04		394	1	Peprilus triacanthus	Butterfish	4	30
24-Jun-04		394	1	Peprilus triacanthus	Butterfish	5	24
24-Jun-04		394	1	Peprilus triacanthus	Butterfish	6	32
24-Jun-04		394	1	Peprilus triacanthus	Butterfish	7	22
24-Jun-04		394	1	Peprilus triacanthus	Butterfish	8	26
24-Jun-04		394	1	Peprilus triacanthus	Butterfish	9	18
24-Jun-04		394	1	Prinotus sp.	Sea Robin	1	69
24-Jun-04		394	1	Prinotus sp.	Sea Robin	2	66
24-Jun-04		394	1	Prinotus sp.	Sea Robin	3	63
24-Jun-04		394	1	Prinotus sp.	Sea Robin	4	89

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		394	1	Prinotus sp.	Sea Robin	5	53
24-Jun-04		394	2	Prinotus sp.	Sea Robin	1	66
24-Jun-04		394	2	Prinotus sp.	Sea Robin	2	61
24-Jun-04		394	2	Prinotus sp.	Sea Robin	3	83
24-Jun-04		394	2	Prinotus sp.	Sea Robin	4	86
24-Jun-04		394	2	Prinotus sp.	Sea Robin	5	74
24-Jun-04		394	2	Prinotus sp.	Sea Robin	6	94
24-Jun-04		394	2	Prinotus sp.	Sea Robin	7	69
24-Jun-04		394	2	Prinotus sp.	Sea Robin	8	74
24-Jun-04		394	2	Prinotus sp.	Sea Robin	9	83
24-Jun-04		394	2	Prinotus sp.	Sea Robin	10	59
24-Jun-04		394	2	Prinotus sp.	Sea Robin	11	59
24-Jun-04		394	2	Prinotus sp.	Sea Robin	12	54
24-Jun-04		394	1	Urophycis regia	Spotted Hake	1	136
24-Jun-04		394	1	Urophycis regia	Spotted Hake	2	126
24-Jun-04		394	1	Urophycis regia	Spotted Hake	3	144
24-Jun-04		394	1	Urophycis regia	Spotted Hake	4	104
24-Jun-04		394	1	Urophycis regia	Spotted Hake	5	119
24-Jun-04		394	1	Urophycis regia	Spotted Hake	6	123
24-Jun-04		394	1	Urophycis regia	Spotted Hake	7	124
24-Jun-04		394	1	Urophycis regia	Spotted Hake	8	106
24-Jun-04		394	1	Urophycis regia	Spotted Hake	9	113
24-Jun-04		394	1	Urophycis regia	Spotted Hake	10	116
24-Jun-04		394	1	Urophycis regia	Spotted Hake	11	156
24-Jun-04		394	1	Urophycis regia	Spotted Hake	12	114
24-Jun-04		394	1	Urophycis regia	Spotted Hake	13	128
24-Jun-04		394	1	Urophycis regia	Spotted Hake	14	119
24-Jun-04		394	1	Urophycis regia	Spotted Hake	15	99
24-Jun-04		394	1	Urophycis regia	Spotted Hake	16	129
24-Jun-04		394	1	Urophycis regia	Spotted Hake	17	119
24-Jun-04		394	1	Urophycis regia	Spotted Hake	18	103
24-Jun-04		394	1	Urophycis regia	Spotted Hake	19	103
24-Jun-04		394	1	Urophycis regia	Spotted Hake	20	115
24-Jun-04		394	1	Urophycis regia	Spotted Hake	21	143
24-Jun-04		394	1	Urophycis regia	Spotted Hake	22	106
24-Jun-04		394	1	Urophycis regia	Spotted Hake	23	103
24-Jun-04		394	1	Urophycis regia	Spotted Hake	24	113
24-Jun-04		394	1	Urophycis regia	Spotted Hake	25	96
24-Jun-04		394	1	Urophycis regia	Spotted Hake	26	117
24-Jun-04		394	1	Urophycis regia	Spotted Hake	27	115
24-Jun-04		394	1	Urophycis regia	Spotted Hake	28	119
24-Jun-04		394	1	Urophycis regia	Spotted Hake	29	99
24-Jun-04		394	1	Urophycis regia	Spotted Hake	30	112
24-Jun-04		394	1	Urophycis regia	Spotted Hake	31	143
24-Jun-04		394	1	Urophycis regia	Spotted Hake	32	99
24-Jun-04		394	1	Urophycis regia	Spotted Hake	33	131
24-Jun-04		394	1	Urophycis regia	Spotted Hake	34	139
24-Jun-04		394	1	Urophycis regia	Spotted Hake	35	123

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		394	1	Urophycis regia	Spotted Hake	36	141
24-Jun-04		394	1	Urophycis regia	Spotted Hake	37	114
24-Jun-04		394	1	Urophycis regia	Spotted Hake	38	129
24-Jun-04		394	1	Urophycis regia	Spotted Hake	39	128
24-Jun-04		394	1	Urophycis regia	Spotted Hake	40	139
24-Jun-04		394	1	Urophycis regia	Spotted Hake	41	108
24-Jun-04		394	1	Urophycis regia	Spotted Hake	42	114
24-Jun-04		394	1	Urophycis regia	Spotted Hake	43	115
24-Jun-04		394	1	Urophycis regia	Spotted Hake	44	137
24-Jun-04		394	1	Urophycis regia	Spotted Hake	45	111
24-Jun-04		394	1	Urophycis regia	Spotted Hake	46	107
24-Jun-04		394	1	Urophycis regia	Spotted Hake	47	102
24-Jun-04		394	1	Urophycis regia	Spotted Hake	48	125
24-Jun-04		394	1	Urophycis regia	Spotted Hake	49	126
24-Jun-04		394	1	Urophycis regia	Spotted Hake	50	117
24-Jun-04		394	1	Urophycis regia	Spotted Hake	51	109
24-Jun-04		394	1	Urophycis regia	Spotted Hake	52	123
24-Jun-04		394	1	Urophycis regia	Spotted Hake	53	93
24-Jun-04		394	1	Urophycis regia	Spotted Hake	54	111
24-Jun-04		394	1	Urophycis regia	Spotted Hake	55	104
24-Jun-04		394	1	Urophycis regia	Spotted Hake	56	109
24-Jun-04		394	1	Urophycis regia	Spotted Hake	57	115
24-Jun-04		394	1	Urophycis regia	Spotted Hake	58	103
24-Jun-04		394	1	Urophycis regia	Spotted Hake	59	87
24-Jun-04		394	1	Urophycis regia	Spotted Hake	60	91
24-Jun-04		394	1	Urophycis regia	Spotted Hake	61	104
24-Jun-04		394	1	Urophycis regia	Spotted Hake	62	106
24-Jun-04		394	1	Urophycis regia	Spotted Hake	63	103
24-Jun-04		394	1	Urophycis regia	Spotted Hake	64	96
24-Jun-04		394	1	Urophycis regia	Spotted Hake	65	87
24-Jun-04		394	1	Urophycis regia	Spotted Hake	66	117
24-Jun-04		394	1	Urophycis regia	Spotted Hake	67	99
24-Jun-04		394	1	Urophycis regia	Spotted Hake	68	101
24-Jun-04		394	2	Urophycis regia	Spotted Hake	1	167
24-Jun-04		394	2	Urophycis regia	Spotted Hake	2	133
24-Jun-04		394	2	Urophycis regia	Spotted Hake	3	120
24-Jun-04		394	2	Urophycis regia	Spotted Hake	4	104
24-Jun-04		394	2	Urophycis regia	Spotted Hake	5	200
24-Jun-04		394	2	Urophycis regia	Spotted Hake	6	93
24-Jun-04		394	2	Urophycis regia	Spotted Hake	7	129
24-Jun-04		394	2	Urophycis regia	Spotted Hake	8	105
24-Jun-04		394	2	Urophycis regia	Spotted Hake	9	126
24-Jun-04		394	2	Urophycis regia	Spotted Hake	10	120
24-Jun-04		394	2	Urophycis regia	Spotted Hake	11	134
24-Jun-04		394	2	Urophycis regia	Spotted Hake	12	129
24-Jun-04		394	2	Urophycis regia	Spotted Hake	13	121
24-Jun-04		394	2	Urophycis regia	Spotted Hake	14	129
24-Jun-04		394	2	Urophycis regia	Spotted Hake	15	131

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		394	2	Urophycis regia	Spotted Hake	16	135
24-Jun-04		394	2	Urophycis regia	Spotted Hake	17	133
24-Jun-04		394	2	Urophycis regia	Spotted Hake	18	113
24-Jun-04		394	2	Urophycis regia	Spotted Hake	19	126
24-Jun-04		394	2	Urophycis regia	Spotted Hake	20	119
24-Jun-04		394	2	Urophycis regia	Spotted Hake	21	131
24-Jun-04		394	2	Urophycis regia	Spotted Hake	22	143
24-Jun-04		394	2	Urophycis regia	Spotted Hake	23	106
24-Jun-04		394	2	Urophycis regia	Spotted Hake	24	119
24-Jun-04		394	2	Urophycis regia	Spotted Hake	25	165
24-Jun-04		394	2	Urophycis regia	Spotted Hake	26	115
24-Jun-04		394	2	Urophycis regia	Spotted Hake	27	141
24-Jun-04		394	2	Urophycis regia	Spotted Hake	28	116
24-Jun-04		394	2	Urophycis regia	Spotted Hake	29	130
24-Jun-04		394	2	Urophycis regia	Spotted Hake	30	94
24-Jun-04		394	2	Urophycis regia	Spotted Hake	31	133
24-Jun-04		394	2	Urophycis regia	Spotted Hake	32	113
24-Jun-04		394	2	Urophycis regia	Spotted Hake	33	116
24-Jun-04		394	2	Urophycis regia	Spotted Hake	34	113
24-Jun-04		394	2	Urophycis regia	Spotted Hake	35	116
24-Jun-04		394	2	Urophycis regia	Spotted Hake	36	104
24-Jun-04		394	2	Urophycis regia	Spotted Hake	37	140
24-Jun-04		394	2	Urophycis regia	Spotted Hake	38	139
24-Jun-04		394	2	Urophycis regia	Spotted Hake	39	110
24-Jun-04		394	2	Urophycis regia	Spotted Hake	40	124
24-Jun-04		394	2	Urophycis regia	Spotted Hake	41	117
24-Jun-04		394	2	Urophycis regia	Spotted Hake	42	119
24-Jun-04		394	2	Urophycis regia	Spotted Hake	43	110
24-Jun-04		394	2	Urophycis regia	Spotted Hake	44	117
24-Jun-04		394	2	Urophycis regia	Spotted Hake	45	114
24-Jun-04		394	2	Urophycis regia	Spotted Hake	46	107
24-Jun-04		394	2	Urophycis regia	Spotted Hake	47	102
24-Jun-04		394	2	Urophycis regia	Spotted Hake	48	111
24-Jun-04		394	2	Urophycis regia	Spotted Hake	49	139
24-Jun-04		394	2	Urophycis regia	Spotted Hake	50	105
24-Jun-04		394	2	Urophycis regia	Spotted Hake	51	126
24-Jun-04		394	2	Urophycis regia	Spotted Hake	52	115
24-Jun-04		394	2	Urophycis regia	Spotted Hake	53	111
24-Jun-04		394	2	Urophycis regia	Spotted Hake	54	116
24-Jun-04		394	2	Urophycis regia	Spotted Hake	55	95
24-Jun-04		394	2	Menippe sp.	Stone Crab	1	40
24-Jun-04		500		Centropristis striata	Black Sea Bass	1	90
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	1	57.2
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	2	65
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	3	55
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	4	63.2
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	5	52
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	6	34

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	7	31
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	8	40.2
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	9	60
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	10	51.6
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	11	60
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	12	40
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	13	34.7
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	14	50
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	15	30
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	16	35
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	17	31.2
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	18	25
24-Jun-04		500		Crangon septimspinosa	Sand Shrimp	19	31.7
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	1	63
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	2	45
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	3	43
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	4	50
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	5	42
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	6	55
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	7	60
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	8	65
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	9	65
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	10	42
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	11	40
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	12	36
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	13	40
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	14	44
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	15	34
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	16	39
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	17	35
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	18	39
24-Jun-04		501		Crangon septimspinosa	Sand Shrimp	19	25
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	1	70
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	2	45
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	3	55
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	4	45
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	5	50
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	6	60
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	7	60
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	8	70
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	9	52
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	10	65
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	11	70
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	12	60
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	13	39
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	14	50
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	15	63
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	16	45

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	17	56
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	18	53
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	19	56
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	20	57
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	21	63
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	22	52
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	23	45
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	24	39
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	25	40
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	26	44
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	27	62
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	28	34
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	29	52
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	30	60
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	31	35
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	32	60
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	33	45
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	34	52
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	35	56
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	36	55
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	37	37
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	38	42
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	39	55
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	40	54
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	41	37
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	42	39
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	43	45
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	44	50
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	45	20
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	46	47
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	47	32
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	48	50
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	49	30
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	50	37
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	51	40
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	52	21
24-Jun-04		502		Crangon septimspinosa	Sand Shrimp	53	50
25-Jun-04		503		Crangon septimspinosa	Sand Shrimp	54	40
26-Jun-04		504		Crangon septimspinosa	Sand Shrimp	55	7
24-Jun-04		500		Etropus microstomus	Flounder	1	75
24-Jun-04		500		Etropus microstomus	Flounder	2	70
24-Jun-04		500		Etropus microstomus	Flounder	3	65
24-Jun-04		500		Etropus microstomus	Flounder	4	62
24-Jun-04		500		Etropus microstomus	Flounder	5	75
24-Jun-04		500		Etropus microstomus	Flounder	6	62
24-Jun-04		500		Etropus microstomus	Flounder	7	60
24-Jun-04		500		Etropus microstomus	Flounder	8	60
24-Jun-04		500		Etropus microstomus	Flounder	9	57

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		500		Etropus microstomus	Flounder	10	55
24-Jun-04		500		Etropus microstomus	Flounder	11	60
24-Jun-04		500		Etropus microstomus	Flounder	12	65
24-Jun-04		500		Etropus microstomus	Flounder	13	65
24-Jun-04		500		Etropus microstomus	Flounder	14	70
24-Jun-04		500		Etropus microstomus	Flounder	15	52
24-Jun-04		500		Etropus microstomus	Flounder	16	72
24-Jun-04		500		Etropus microstomus	Flounder	17	60
24-Jun-04		500		Etropus microstomus	Flounder	18	72
24-Jun-04		500		Etropus microstomus	Flounder	19	57
24-Jun-04		500		Etropus microstomus	Flounder	20	60
24-Jun-04		500		Etropus microstomus	Flounder	21	61
24-Jun-04		500		Etropus microstomus	Flounder	22	65
24-Jun-04		500		Etropus microstomus	Flounder	23	35
24-Jun-04		500		Etropus microstomus	Flounder	24	63
24-Jun-04		500		Etropus microstomus	Flounder	25	50
24-Jun-04		501		Etropus microstomus	Flounder	1	52
24-Jun-04		501		Etropus microstomus	Flounder	2	55
24-Jun-04		501		Etropus microstomus	Flounder	3	66
24-Jun-04		501		Etropus microstomus	Flounder	4	57
24-Jun-04		501		Etropus microstomus	Flounder	5	58
24-Jun-04		501		Etropus microstomus	Flounder	6	60
24-Jun-04		502		Etropus microstomus	Flounder	2	75
24-Jun-04		502		Etropus microstomus	Flounder	3	75
24-Jun-04		502		Etropus microstomus	Flounder	4	77
24-Jun-04		502		Etropus microstomus	Flounder	5	70
24-Jun-04		502		Etropus microstomus	Flounder	6	60
24-Jun-04		502		Etropus microstomus	Flounder	7	50
24-Jun-04		502		Etropus microstomus	Flounder	8	70
24-Jun-04		502		Etropus microstomus	Flounder	9	63
24-Jun-04		502		Etropus microstomus	Flounder	10	65
24-Jun-04		502		Etropus microstomus	Flounder	11	70
24-Jun-04		502		Etropus microstomus	Flounder	12	72
24-Jun-04		502		Etropus microstomus	Flounder	13	79
24-Jun-04		502		Etropus microstomus	Flounder	14	56
24-Jun-04		502		Etropus microstomus	Flounder	15	60
24-Jun-04		500		Lagodon rhomboides	Pinfish	1	75
24-Jun-04		500		Lagodon rhomboides	Pinfish	2	90
24-Jun-04		500		Lagodon rhomboides	Pinfish	3	90
24-Jun-04		500		Lagodon rhomboides	Pinfish	4	75
24-Jun-04		500		Lagodon rhomboides	Pinfish	5	80
24-Jun-04		500		Lagodon rhomboides	Pinfish	6	55
24-Jun-04		502		Lagodon rhomboides	Pinfish	1	85
24-Jun-04		500		Lolliguncula brevis	Squid	1	45.5
24-Jun-04		500		Lolliguncula brevis	Squid	2	50.5
24-Jun-04		500		Lolliguncula brevis	Squid	3	53.6
24-Jun-04		500		Lolliguncula brevis	Squid	4	33.3
24-Jun-04		500		Lolliguncula brevis	Squid	5	47.9

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		500		Lolliguncula brevis	Squid	6	35.7
24-Jun-04		500		Lolliguncula brevis	Squid	7	28.1
24-Jun-04		500		Lolliguncula brevis	Squid	8	37.4
24-Jun-04		500		Lolliguncula brevis	Squid	9	34.3
24-Jun-04		500		Lolliguncula brevis	Squid	10	42
24-Jun-04		500		Lolliguncula brevis	Squid	11	31
24-Jun-04		500		Lolliguncula brevis	Squid	12	27.2
24-Jun-04		500		Lolliguncula brevis	Squid	13	32
24-Jun-04		500		Lolliguncula brevis	Squid	14	37.9
24-Jun-04		500		Lolliguncula brevis	Squid	15	35
24-Jun-04		500		Lolliguncula brevis	Squid	16	32
24-Jun-04		500		Lolliguncula brevis	Squid	17	29.6
24-Jun-04		500		Lolliguncula brevis	Squid	18	40
24-Jun-04		500		Lolliguncula brevis	Squid	19	35
24-Jun-04		500		Lolliguncula brevis	Squid	20	37
24-Jun-04		500		Lolliguncula brevis	Squid	21	37.2
24-Jun-04		500		Lolliguncula brevis	Squid	22	35
24-Jun-04		500		Lolliguncula brevis	Squid	23	35
24-Jun-04		500		Lolliguncula brevis	Squid	24	32.8
24-Jun-04		500		Lolliguncula brevis	Squid	25	35
24-Jun-04		500		Lolliguncula brevis	Squid	26	34.6
24-Jun-04		500		Lolliguncula brevis	Squid	27	34
24-Jun-04		500		Lolliguncula brevis	Squid	28	35
24-Jun-04		500		Lolliguncula brevis	Squid	29	32.2
24-Jun-04		500		Lolliguncula brevis	Squid	30	30
24-Jun-04		500		Lolliguncula brevis	Squid	31	30
24-Jun-04		500		Lolliguncula brevis	Squid	32	32
24-Jun-04		500		Lolliguncula brevis	Squid	33	31.8
24-Jun-04		500		Lolliguncula brevis	Squid	34	23
24-Jun-04		500		Lolliguncula brevis	Squid	35	30
24-Jun-04		500		Lolliguncula brevis	Squid	36	24.7
24-Jun-04		501		Lolliguncula brevis	Squid	1	117
24-Jun-04		501		Lolliguncula brevis	Squid	2	115
24-Jun-04		501		Lolliguncula brevis	Squid	3	139
24-Jun-04		501		Lolliguncula brevis	Squid	4	105
24-Jun-04		501		Lolliguncula brevis	Squid	5	87
24-Jun-04		501		Lolliguncula brevis	Squid	6	61
24-Jun-04		501		Lolliguncula brevis	Squid	7	77
24-Jun-04		501		Lolliguncula brevis	Squid	8	73
24-Jun-04		501		Lolliguncula brevis	Squid	9	31
24-Jun-04		501		Lolliguncula brevis	Squid	10	40
24-Jun-04		501		Lolliguncula brevis	Squid	11	29
24-Jun-04		501		Lolliguncula brevis	Squid	12	31
24-Jun-04		501		Lolliguncula brevis	Squid	13	35
24-Jun-04		501		Lolliguncula brevis	Squid	14	37
24-Jun-04		501		Lolliguncula brevis	Squid	15	29
24-Jun-04		501		Lolliguncula brevis	Squid	16	31
24-Jun-04		501		Lolliguncula brevis	Squid	17	31

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		501		Lolliguncula brevis	Squid	18	32
24-Jun-04		501		Lolliguncula brevis	Squid	19	35
24-Jun-04		501		Lolliguncula brevis	Squid	20	20
24-Jun-04		501		Lolliguncula brevis	Squid	21	33
24-Jun-04		501		Lolliguncula brevis	Squid	22	23
24-Jun-04		501		Lolliguncula brevis	Squid	23	37
24-Jun-04		501		Lolliguncula brevis	Squid	24	25
24-Jun-04		501		Lolliguncula brevis	Squid	25	24
24-Jun-04		501		Lolliguncula brevis	Squid	26	23
24-Jun-04		501		Lolliguncula brevis	Squid	27	32
24-Jun-04		501		Lolliguncula brevis	Squid	28	25
24-Jun-04		501		Lolliguncula brevis	Squid	29	25
24-Jun-04		501		Lolliguncula brevis	Squid	30	32
24-Jun-04		501		Lolliguncula brevis	Squid	31	25
24-Jun-04		501		Lolliguncula brevis	Squid	32	32
24-Jun-04		501		Lolliguncula brevis	Squid	33	34
24-Jun-04		501		Lolliguncula brevis	Squid	34	24
24-Jun-04		501		Lolliguncula brevis	Squid	35	32
24-Jun-04		501		Lolliguncula brevis	Squid	36	32
24-Jun-04		501		Lolliguncula brevis	Squid	37	25
24-Jun-04		501		Lolliguncula brevis	Squid	38	27
24-Jun-04		501		Lolliguncula brevis	Squid	39	15
24-Jun-04		501		Lolliguncula brevis	Squid	40	10
24-Jun-04		501		Lolliguncula brevis	Squid	41	26
24-Jun-04		501		Lolliguncula brevis	Squid	42	13
24-Jun-04		501		Lolliguncula brevis	Squid	43	26
24-Jun-04		501		Lolliguncula brevis	Squid	44	30
24-Jun-04		501		Lolliguncula brevis	Squid	45	25
24-Jun-04		501		Lolliguncula brevis	Squid	46	30
24-Jun-04		501		Lolliguncula brevis	Squid	47	28
24-Jun-04		502		Lolliguncula brevis	Squid	1	30
24-Jun-04		502		Lolliguncula brevis	Squid	2	33
24-Jun-04		502		Lolliguncula brevis	Squid	3	30
24-Jun-04		502		Lolliguncula brevis	Squid	4	37
24-Jun-04		502		Lolliguncula brevis	Squid	5	34
24-Jun-04		502		Lolliguncula brevis	Squid	6	27
24-Jun-04		502		Lolliguncula brevis	Squid	7	32
24-Jun-04		502		Lolliguncula brevis	Squid	8	35
24-Jun-04		502		Lolliguncula brevis	Squid	9	30
24-Jun-04		502		Lolliguncula brevis	Squid	10	35
24-Jun-04		502		Lolliguncula brevis	Squid	11	36
24-Jun-04		502		Lolliguncula brevis	Squid	12	33
24-Jun-04		502		Lolliguncula brevis	Squid	13	27
24-Jun-04		502		Lolliguncula brevis	Squid	14	47
24-Jun-04		502		Lolliguncula brevis	Squid	15	33
24-Jun-04		502		Lolliguncula brevis	Squid	16	42
24-Jun-04		502		Lolliguncula brevis	Squid	17	33
24-Jun-04		502		Lolliguncula brevis	Squid	18	46

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		502		Lolliguncula brevis	Squid	19	33
24-Jun-04		502		Lolliguncula brevis	Squid	20	34
24-Jun-04		502		Lolliguncula brevis	Squid	21	18
24-Jun-04		502		Lolliguncula brevis	Squid	22	27
24-Jun-04		502		Lolliguncula brevis	Squid	23	23
24-Jun-04		502		Lolliguncula brevis	Squid	24	35
24-Jun-04		500		Ovalipes ocellatus	Lady Crab	1	27
24-Jun-04		500		Pagurus sp.	Hermit Crab	1	
24-Jun-04		500		Pagurus sp.	Hermit Crab	2	
24-Jun-04		500		Pagurus sp.	Hermit Crab	3	
24-Jun-04		500		Pagurus sp.	Hermit Crab	4	
24-Jun-04		501		Pagurus sp.	Hermit Crab	1	
24-Jun-04		501		Pagurus sp.	Hermit Crab	2	
24-Jun-04		501		Pagurus sp.	Hermit Crab	3	
24-Jun-04		502		Pagurus sp.	Hermit Crab	1	
24-Jun-04		502		Pagurus sp.	Hermit Crab	2	
24-Jun-04		502		Pagurus sp.	Hermit Crab	3	
24-Jun-04		502		Pagurus sp.	Hermit Crab	4	
24-Jun-04		502		Pagurus sp.	Hermit Crab	5	
24-Jun-04		502		Pagurus sp.	Hermit Crab	6	
24-Jun-04		502		Pagurus sp.	Hermit Crab	7	
24-Jun-04		502		Pagurus sp.	Hermit Crab	8	
24-Jun-04		502		Pagurus sp.	Hermit Crab	9	
24-Jun-04		502		Pagurus sp.	Hermit Crab	10	
24-Jun-04		502		Pagurus sp.	Hermit Crab	11	
24-Jun-04		502		Pagurus sp.	Hermit Crab	12	
24-Jun-04		502		Pagurus sp.	Hermit Crab	13	
24-Jun-04		502		Pagurus sp.	Hermit Crab	14	
24-Jun-04		502		Paralichthys dentatus	Summer Flounder	1	115
24-Jun-04		500		Peprilus triacanthus	Butterfish	1	50
24-Jun-04		500		Peprilus triacanthus	Butterfish	2	45
24-Jun-04		500		Peprilus triacanthus	Butterfish	3	30
24-Jun-04		500		Peprilus triacanthus	Butterfish	4	35
24-Jun-04		500		Peprilus triacanthus	Butterfish	5	37
24-Jun-04		500		Peprilus triacanthus	Butterfish	6	37
24-Jun-04		500		Peprilus triacanthus	Butterfish	7	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	8	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	9	40
24-Jun-04		500		Peprilus triacanthus	Butterfish	10	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	11	30
24-Jun-04		500		Peprilus triacanthus	Butterfish	12	35
24-Jun-04		500		Peprilus triacanthus	Butterfish	13	30
24-Jun-04		500		Peprilus triacanthus	Butterfish	14	30
24-Jun-04		500		Peprilus triacanthus	Butterfish	15	35
24-Jun-04		500		Peprilus triacanthus	Butterfish	16	20
24-Jun-04		500		Peprilus triacanthus	Butterfish	17	21
24-Jun-04		500		Peprilus triacanthus	Butterfish	18	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	19	37

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		500		Peprilus triacanthus	Butterfish	20	20
24-Jun-04		500		Peprilus triacanthus	Butterfish	21	20
24-Jun-04		500		Peprilus triacanthus	Butterfish	22	22
24-Jun-04		500		Peprilus triacanthus	Butterfish	23	24
24-Jun-04		500		Peprilus triacanthus	Butterfish	24	20
24-Jun-04		500		Peprilus triacanthus	Butterfish	25	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	26	20
24-Jun-04		500		Peprilus triacanthus	Butterfish	27	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	28	22
24-Jun-04		500		Peprilus triacanthus	Butterfish	29	21
24-Jun-04		500		Peprilus triacanthus	Butterfish	30	21
24-Jun-04		500		Peprilus triacanthus	Butterfish	31	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	32	27
24-Jun-04		500		Peprilus triacanthus	Butterfish	33	20
24-Jun-04		500		Peprilus triacanthus	Butterfish	34	24
24-Jun-04		500		Peprilus triacanthus	Butterfish	35	24
24-Jun-04		500		Peprilus triacanthus	Butterfish	36	23
24-Jun-04		500		Peprilus triacanthus	Butterfish	37	22
24-Jun-04		500		Peprilus triacanthus	Butterfish	38	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	39	33
24-Jun-04		500		Peprilus triacanthus	Butterfish	40	21
24-Jun-04		500		Peprilus triacanthus	Butterfish	41	24
24-Jun-04		500		Peprilus triacanthus	Butterfish	42	22
24-Jun-04		500		Peprilus triacanthus	Butterfish	43	21
24-Jun-04		500		Peprilus triacanthus	Butterfish	44	22
24-Jun-04		500		Peprilus triacanthus	Butterfish	45	21
24-Jun-04		500		Peprilus triacanthus	Butterfish	46	22
24-Jun-04		500		Peprilus triacanthus	Butterfish	47	20
24-Jun-04		500		Peprilus triacanthus	Butterfish	48	23
24-Jun-04		500		Peprilus triacanthus	Butterfish	49	27
24-Jun-04		500		Peprilus triacanthus	Butterfish	50	24
24-Jun-04		500		Peprilus triacanthus	Butterfish	51	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	52	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	53	22
24-Jun-04		500		Peprilus triacanthus	Butterfish	54	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	55	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	56	22
24-Jun-04		500		Peprilus triacanthus	Butterfish	57	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	58	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	59	25
24-Jun-04		500		Peprilus triacanthus	Butterfish	60	21
24-Jun-04		501		Peprilus triacanthus	Butterfish	1	54
24-Jun-04		501		Peprilus triacanthus	Butterfish	2	39
24-Jun-04		501		Peprilus triacanthus	Butterfish	3	34
24-Jun-04		501		Peprilus triacanthus	Butterfish	4	25
24-Jun-04		501		Peprilus triacanthus	Butterfish	5	25
24-Jun-04		501		Peprilus triacanthus	Butterfish	6	39
24-Jun-04		501		Peprilus triacanthus	Butterfish	7	20

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		501		Peprilus triacanthus	Butterfish	8	26
24-Jun-04		501		Peprilus triacanthus	Butterfish	9	23
24-Jun-04		501		Peprilus triacanthus	Butterfish	10	27
24-Jun-04		501		Peprilus triacanthus	Butterfish	11	26
24-Jun-04		501		Peprilus triacanthus	Butterfish	12	27
24-Jun-04		501		Peprilus triacanthus	Butterfish	13	22
24-Jun-04		501		Peprilus triacanthus	Butterfish	14	24
24-Jun-04		502		Peprilus triacanthus	Butterfish	1	25
24-Jun-04		502		Peprilus triacanthus	Butterfish	2	40
24-Jun-04		502		Peprilus triacanthus	Butterfish	3	42
24-Jun-04		502		Peprilus triacanthus	Butterfish	4	32
24-Jun-04		502		Peprilus triacanthus	Butterfish	5	21
24-Jun-04		502		Peprilus triacanthus	Butterfish	6	32
24-Jun-04		502		Peprilus triacanthus	Butterfish	7	29
24-Jun-04		502		Peprilus triacanthus	Butterfish	8	27
24-Jun-04		502		Peprilus triacanthus	Butterfish	9	35
24-Jun-04		502		Peprilus triacanthus	Butterfish	10	25
24-Jun-04		502		Peprilus triacanthus	Butterfish	11	37
24-Jun-04		502		Peprilus triacanthus	Butterfish	12	28
24-Jun-04		502		Peprilus triacanthus	Butterfish	13	25
24-Jun-04		502		Peprilus triacanthus	Butterfish	14	24
24-Jun-04		502		Peprilus triacanthus	Butterfish	15	37
24-Jun-04		502		Peprilus triacanthus	Butterfish	16	36
24-Jun-04		502		Peprilus triacanthus	Butterfish	17	45
24-Jun-04		502		Peprilus triacanthus	Butterfish	18	43
24-Jun-04		502		Peprilus triacanthus	Butterfish	19	27
24-Jun-04		502		Peprilus triacanthus	Butterfish	20	27
24-Jun-04		502		Peprilus triacanthus	Butterfish	21	29
24-Jun-04		502		Peprilus triacanthus	Butterfish	22	23
24-Jun-04		502		Peprilus triacanthus	Butterfish	23	31
24-Jun-04		502		Peprilus triacanthus	Butterfish	24	26
24-Jun-04		502		Peprilus triacanthus	Butterfish	25	20
24-Jun-04		502		Peprilus triacanthus	Butterfish	26	35
24-Jun-04		502		Peprilus triacanthus	Butterfish	27	22
24-Jun-04		502		Peprilus triacanthus	Butterfish	28	25
24-Jun-04		502		Peprilus triacanthus	Butterfish	29	22
24-Jun-04		502		Peprilus triacanthus	Butterfish	30	25
24-Jun-04		502		Peprilus triacanthus	Butterfish	31	27
24-Jun-04		502		Peprilus triacanthus	Butterfish	32	25
24-Jun-04		502		Peprilus triacanthus	Butterfish	33	22
24-Jun-04		502		Peprilus triacanthus	Butterfish	34	20
24-Jun-04		502		Peprilus triacanthus	Butterfish	35	32
24-Jun-04		502		Peprilus triacanthus	Butterfish	36	30
24-Jun-04		502		Peprilus triacanthus	Butterfish	37	30
24-Jun-04		502		Peprilus triacanthus	Butterfish	38	35
24-Jun-04		502		Peprilus triacanthus	Butterfish	39	30
24-Jun-04		502		Peprilus triacanthus	Butterfish	40	35
24-Jun-04		502		Peprilus triacanthus	Butterfish	41	30

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		502		Peprilus triacanthus	Butterfish	42	26
24-Jun-04		502		Peprilus triacanthus	Butterfish	43	20
24-Jun-04		502		Peprilus triacanthus	Butterfish	44	24
24-Jun-04		502		Peprilus triacanthus	Butterfish	45	20
24-Jun-04		502		Peprilus triacanthus	Butterfish	46	18
24-Jun-04		502		Peprilus triacanthus	Butterfish	47	21
24-Jun-04		500		Prinotus sp.	Sea Robin	1	62
24-Jun-04		500		Prinotus sp.	Sea Robin	2	70
24-Jun-04		500		Prinotus sp.	Sea Robin	3	65
24-Jun-04		500		Prinotus sp.	Sea Robin	4	62
24-Jun-04		500		Prinotus sp.	Sea Robin	5	65
24-Jun-04		500		Prinotus sp.	Sea Robin	6	60
24-Jun-04		500		Prinotus sp.	Sea Robin	7	55
24-Jun-04		501		Prinotus sp.	Sea Robin	1	83
24-Jun-04		501		Prinotus sp.	Sea Robin	2	82
24-Jun-04		501		Prinotus sp.	Sea Robin	3	52
24-Jun-04		501		Prinotus sp.	Sea Robin	4	66
24-Jun-04		501		Prinotus sp.	Sea Robin	5	73
24-Jun-04		501		Prinotus sp.	Sea Robin	6	79
24-Jun-04		501		Prinotus sp.	Sea Robin	7	72
24-Jun-04		502		Prinotus sp.	Sea Robin	1	74
24-Jun-04		500		Cynoscion regalis	weakfish	1	40
24-Jun-04		500		Cynoscion regalis	weakfish	1	32
24-Jun-04		500		Cynoscion regalis	weakfish	1	40
24-Jun-04		502		Cynoscion regalis	weakfish	1	190
24-Jun-04		500		Urophycis regia	Spotted Hake	1	135
24-Jun-04		500		Urophycis regia	Spotted Hake	2	165
24-Jun-04		500		Urophycis regia	Spotted Hake	3	100
24-Jun-04		500		Urophycis regia	Spotted Hake	4	135
24-Jun-04		500		Urophycis regia	Spotted Hake	5	105
24-Jun-04		500		Urophycis regia	Spotted Hake	6	115
24-Jun-04		500		Urophycis regia	Spotted Hake	7	115
24-Jun-04		500		Urophycis regia	Spotted Hake	8	130
24-Jun-04		501		Urophycis regia	Spotted Hake	1	150
24-Jun-04		501		Urophycis regia	Spotted Hake	2	140
24-Jun-04		501		Urophycis regia	Spotted Hake	3	110
24-Jun-04		501		Urophycis regia	Spotted Hake	4	123
24-Jun-04		501		Urophycis regia	Spotted Hake	5	112
24-Jun-04		501		Urophycis regia	Spotted Hake	6	107
24-Jun-04		502		Urophycis regia	Spotted Hake	1	156
24-Jun-04		502		Urophycis regia	Spotted Hake	2	115
24-Jun-04		502		Urophycis regia	Spotted Hake	3	123
24-Jun-04		502		Urophycis regia	Spotted Hake	4	125
24-Jun-04		502		Urophycis regia	Spotted Hake	5	137
24-Jun-04		502		Urophycis regia	Spotted Hake	6	100
24-Jun-04		502		Urophycis regia	Spotted Hake	7	110
24-Jun-04		502		Urophycis regia	Spotted Hake	8	127
24-Jun-04		502		Urophycis regia	Spotted Hake	9	97

Date	Area	Station	Trawl	Taxon	Common Name	Individual No	Total Length (mm)
24-Jun-04		502		Urophycis regia	Spotted Hake	10	125
24-Jun-04		502		Urophycis regia	Spotted Hake	11	106
24-Jun-04		502		Urophycis regia	Spotted Hake	12	154
24-Jun-04		502		Urophycis regia	Spotted Hake	13	200
24-Jun-04		502		Urophycis regia	Spotted Hake	14	78
24-Jun-04		502		Urophycis regia	Spotted Hake	15	116
24-Jun-04		502		Urophycis regia	Spotted Hake	16	105
24-Jun-04		502		Urophycis regia	Spotted Hake	17	140
24-Jun-04		502		Urophycis regia	Spotted Hake	18	125
24-Jun-04		502		Urophycis regia	Spotted Hake	19	106
24-Jun-04		502		Urophycis regia	Spotted Hake	20	136
24-Jun-04		502		Urophycis regia	Spotted Hake	21	129
24-Jun-04		502		Urophycis regia	Spotted Hake	22	154
24-Jun-04		502		Urophycis regia	Spotted Hake	23	95
24-Jun-04		502		Urophycis regia	Spotted Hake	24	125
24-Jun-04		502		Urophycis regia	Spotted Hake	25	120
24-Jun-04		502		Urophycis regia	Spotted Hake	26	143
24-Jun-04		502		Urophycis regia	Spotted Hake	27	126
24-Jun-04		502		Urophycis regia	Spotted Hake	28	134
24-Jun-04		502		Urophycis regia	Spotted Hake	29	110
24-Jun-04		502		Urophycis regia	Spotted Hake	30	100
24-Jun-04		502		Urophycis regia	Spotted Hake	31	121
24-Jun-04		502		Urophycis regia	Spotted Hake	32	125
24-Jun-04		502		Urophycis regia	Spotted Hake	33	125
24-Jun-04		502		Urophycis regia	Spotted Hake	34	127
24-Jun-04		502		Urophycis regia	Spotted Hake	35	112

Appendix – F

Gut Data

Strata Final	Year	Common name	Taxon	N	Mean Length mm	SD Length	N Amphipod	N Crustacean Other
East of Shoal	2002	Black Sea Bass	Centropristis striata	3	89	2.9	0	0
East of Shoal	2002	Black Sea bass	Centropristis striata	1	77	.	0	0
West of Shoal	2002	Black Sea Bass	Centropristis striata	10	83	24.2	4	0
Area B	2002	Black Sea bass	Centropristis striata	1	82	.	0	0
East of Shoal	2002	Flounder	Paralichthys	7	64	7.7	33	3
West of Shoal	2002	Flounder	Paralichthys	1	89	.	14	0
Area B	2002	Flounder	Paralichthys	3	87	33.9	0	3
Area B	2002	Lizardfish	Synodus foetens	1	250	.	0	0
On Shoal	2002	Pinfish	Lagodon rhomboides	2	76	2.1	0	30
East of Shoal	2002	Pinfish	Lagodon rhomboides	12	78	6.7	6	18
West of Shoal	2002	Pinfish	Lagodon rhomboides	5	73	19.7	6	0
Area B	2002	Pinfish	Lagodon rhomboides	3	58	19.5	0	36
On Shoal	2002	Sea Robin	Prionotus sp.	19	79	9.7	1	14
East of Shoal	2002	Sea Robin	Prionotus sp.	18	88	15.2	10	2
West of Shoal	2002	Sea Robin	Prionotus sp.	10	90	18.6	1	2
Area B	2002	Sea Robin	Prionotus sp.	26	81	8.7	2	23
On Shoal	2003	black sea bass	Centropristis striata	1	100		0	0
East of Shoal	2003	butterfish	Peprilus triacanthus	33	43	11.0	0	134
West of Shoal	2003	butterfish	Peprilus triacanthus	4	46	1.3	0	4
On Shoal	2003	Flounder	Paralichthys	1	185		0	0
East of Shoal	2003	Flounder	Paralichthys	2	73	14.1	3	4
On Shoal	2003	pinfish	Lagodon rhomboides	14	76	6.6	0	1
East of Shoal	2003	pinfish	Lagodon rhomboides	8	78	6.2	1	2
West of Shoal	2003	pinfish	Lagodon rhomboides	27	99	8.1	10	14
On Shoal	2003	Sea Robin	Prionotus sp.	7	106	6.2	10	9
East of Shoal	2003	Sea Robin	Prionotus sp.	13	100	13.9	11	23
West of Shoal	2003	Sea Robin	Prionotus sp.	2	103	4.2	4	0
West of Shoal	2003	Sea Robin	Prionotus sp.	7	81	17.7	6	1
On Shoal	2003	smallmouth flounder	Etropus microstomus	4	91	29.6	3	2
East of Shoal	2003	smallmouth flounder	Etropus microstomus	2	78	3.5	0	0
West of Shoal	2003	smallmouth flounder	Etropus microstomus	1	126		12	0
West of Shoal	2003	smallmouth flounder	Etropus microstomus	6	94	6.9	8	0

Strata Final	Year	Common name	Taxon	N	Mean Length mm	SD Length	N Amphipod	N Crustacean Other
On Shoal	2003	spotted hake	Urophycis regia	4	174	41.9	1	0
West of Shoal	2003	spotted hake	Urophycis regia	3	195	19.0	0	0
West of Shoal	2003	spotted hake	Urophycis regia	8	169	15.1	6	0
On Shoal	2004	butterfish	Peprilus triacanthus	11	44	16.7	0	0
West of Shoal	2004	butterfish	Peprilus triacanthus	1	42	.	0	0
Area B	2004	Flounder	Paralichthys	1	115	.	0	0
On Shoal	2004	pinfish	Lagodon rhomboides	16	54	8.3	0	0
Area B	2004	pinfish	Lagodon rhomboides	5	77	13.5	0	0
Area B	2004	pinfish	Lagodon rhomboides	18	57	11.6	0	0
West of Shoal	2004	pinfish	Lagodon rhomboides	4	53	6.5	0	0
On Shoal	2004	Sea Robin	Prionotus sp.	17	62	7.0	25	6
Area B	2004	Sea Robin	Prionotus sp.	6	67	9.0	17	20
Area B	2004	Sea Robin	Prionotus sp.	21	69	11.1	22	3
East of Shoal	2004	Sea Robin	Prionotus sp.	8	65	8.6	33	4
West of Shoal	2004	Sea Robin	Prionotus sp.	13	70	12.9	85	0
On Shoal	2004	smallmouth flounder	Etropis microstomus	7	80	15.6	22	0
Area B	2004	smallmouth flounder	Etropis microstomus	25	64	7.3	53	8
Area B	2004	smallmouth flounder	Etropis microstomus	5	69	11.6	8	1
East of Shoal	2004	smallmouth flounder	Etropis microstomus	13	93	18.5	38	11
West of Shoal	2004	smallmouth flounder	Etropis microstomus	9	78	17.4	27	0
On Shoal	2004	spotted hake	Urophycis regia	25	120	17.7	13	0
Area B	2004	spotted hake	Urophycis regia	25	124	25.2	18	0
Area B	2004	spotted hake	Urophycis regia	9	101	15.3	2	0
East of Shoal	2004	spotted hake	Urophycis regia	25	118	16.7	40	0
West of Shoal	2004	spotted hake	Urophycis regia	24	124	23.7	67	0
On Shoal	2004	Weakfish	Cynoscion regalis	2	61	7.8	0	9
Area B	2004	Weakfish	Cynoscion regalis	1	190	.	0	0
Area B	2004	Weakfish	Cynoscion regalis	6	61	17.2	6	27

Strata Final	N Decapod	N Fish	N Isopod	N Lancelet	N Mysid & Larvae	N Nemertean	N Polychaete	N Other	N Gastropod
East of Shoal	2	0	0	0	0	0	3	3	0
East of Shoal	1	0	0	0	0	0	6	0	0
West of Shoal	7	0	2	0	0	0	18	9	16
Area B	1	0	0	0	0	0	5	1	0
East of Shoal	1	0	0	0	0	0	28	6	0
West of Shoal	0	0	0	0	0	0	5	1	0
Area B	0	0	3	0	0	0	13	3	0
Area B	0	1	0	0	0	0	0	0	0
On Shoal	0	0	0	0	69	0	12	2	0
East of Shoal	0	0	0	0	22	0	99	11	0
West of Shoal	0	0	0	0	0	0	49	5	1
Area B	0	0	0	0	225	0	11	2	0
On Shoal	7	0	5	0	3	0	21	15	0
East of Shoal	10	0	8	0	0	0	95	13	0
West of Shoal	8	0	0	0	0	0	22	11	0
Area B	3	0	13	0	8	0	55	13	0
On Shoal	0	0	0	1	326	0	0	1	0
East of Shoal	0	0	0	0	97	0	59	29	0
West of Shoal	0	0	0	0	30	0	33	4	0
On Shoal	4	0	0	0	201	0	0	1	0
East of Shoal	3	0	1	1	1	0	9	2	0
On Shoal	35	0	0	0	399	0	5	13	0
East of Shoal	2	0	0	0	84	0	3	8	0
West of Shoal	4	0	1	0	875	0	107	29	0
On Shoal	20	0	0	2	33	0	2	6	0
East of Shoal	16	0	0	26	109	0	8	11	0
West of Shoal	3	0	0	0	81	0	0	2	0
West of Shoal	6	0	0	0	67	0	3	7	0
On Shoal	23	0	1	3	4	0	5	4	0
East of Shoal	1	0	0	0	0	0	9	2	0
West of Shoal	0	0	0	0	0	0	1	1	0
West of Shoal	5	0	1	0	2	0	37	5	0

Strata Final	N Decapod	N Fish	N Isopod	N Lancelet	N Mysid & Larvae	N Nemertean	N Polychaete	N Other	N Gastropod
On Shoal	3	0	0	0	3	0	25	4	0
West of Shoal	5	0	0	0	0	0	5	3	0
West of Shoal	5	2	1	0	25	0	7	7	0
On Shoal	0	0	0	0	1	0	0	6	0
West of Shoal	0	0	0	0	0	0	0	1	0
Area B	0	0	0	0	0	0	0	1	0
On Shoal	0	0	0	0	1006	0	0	0	0
Area B	3	0	0	0	61	0	3	4	0
Area B	11	0	0	0	222	1	37	5	0
West of Shoal	0	0	0	0	144	0	9	0	0
On Shoal	3	0	2	2	972	0	0	1	0
Area B	1	0	0	0	19	0	0	0	0
Area B	17	0	0	1	384	0	4	0	0
East of Shoal	8	0	0	0	59	0	0	0	0
West of Shoal	12	0	0	0	123	0	0	0	0
On Shoal	7	0	0	2	23	0	7	1	0
Area B	33	0	1	0	77	0	33	4	0
Area B	2	0	0	0	61	0	8	0	0
East of Shoal	4	0	0	11	0	0	44	4	0
West of Shoal	6	0	0	0	15	0	57	4	0
On Shoal	9	3	0	10	10	0	10	0	0
Area B	29	4	0	0	29	0	0	8	0
Area B	3	0	0	0	45	0	0	1	0
East of Shoal	9	0	0	3	21	0	0	2	0
West of Shoal	14	0	0	7	185	0	3	6	0
On Shoal	0	0	0	0	78	0	0	0	0
Area B	2	0	0	0	0	0	0	0	0
Area B	1	0	0	0	11	0	0	1	0

Strata Final	N Bivalve	***Total Number***	B Amphipod	B Crustacean Other	B Decapod	B Fish	B Isopod	B Lancelet	B Mysid & Larvae
East of Shoal	0	8	0.000	0.000	0.574	0.000	0.000	0.000	0.000
East of Shoal	0	7	0.000	0.000	0.180	0.000	0.000	0.000	0.000
West of Shoal	0	56	0.002	0.000	1.323	0.000	0.001	0.000	0.000
Area B	0	7	0.000	0.000	0.047	0.000	0.000	0.000	0.000
East of Shoal	0	71	0.042	0.000	0.005	0.000	0.000	0.000	0.000
West of Shoal	0	20	0.030	0.000	0.000	0.000	0.000	0.000	0.000
Area B	1	23	0.000	0.001	0.000	0.000	0.003	0.000	0.000
Area B	0	1	0.000	0.000	0.000	0.709	0.000	0.000	0.000
On Shoal	0	113	0.000	0.002	0.000	0.000	0.000	0.000	0.006
East of Shoal	0	156	0.032	0.001	0.000	0.000	0.000	0.000	0.008
West of Shoal	2	63	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Area B	0	274	0.000	0.006	0.000	0.000	0.000	0.000	0.046
On Shoal	84	150	0.004	0.002	0.708	0.000	0.038	0.000	0.000
East of Shoal	2	140	0.004	0.004	1.748	0.000	0.098	0.000	0.000
West of Shoal	0	44	0.000	0.000	0.238	0.000	0.000	0.000	0.000
Area B	35	152	0.001	0.003	0.135	0.000	0.266	0.000	0.002
On Shoal	0	328	0.000	0.000	0.000	0.000	0.000	0.012	0.291
East of Shoal	0	319	0.000	0.027	0.000	0.000	0.000	0.000	0.058
West of Shoal	0	71	0.000	0.001	0.000	0.000	0.000	0.000	0.016
On Shoal	0	206	0.000	0.000	0.005	0.000	0.000	0.000	1.082
East of Shoal	0	24	0.000	0.005	0.005	0.000	0.000	0.047	0.003
On Shoal	0	453	0.000	0.000	0.052	0.000	0.000	0.000	0.291
East of Shoal	0	100	0.000	0.000	0.001	0.000	0.000	0.000	0.043
West of Shoal	0	1040	0.020	0.003	0.062	0.000	0.034	0.000	4.698
On Shoal	0	82	0.011	0.006	0.163	0.000	0.000	0.072	0.073
East of Shoal	0	204	0.025	0.054	1.016	0.000	0.000	0.597	0.225
West of Shoal	0	90	0.007	0.000	0.058	0.000	0.000	0.000	0.565
West of Shoal	0	90	0.020	0.000	0.012	0.000	0.000	0.000	0.379
On Shoal	0	45	0.002	0.004	0.038	0.000	0.001	0.051	0.008
East of Shoal	0	12	0.000	0.000	0.060	0.000	0.000	0.000	0.000
West of Shoal	0	14	0.060	0.000	0.000	0.000	0.000	0.000	0.000
West of Shoal	0	58	0.022	0.000	0.004	0.000	0.003	0.000	0.001

Strata Final	N Bivalve	***Total Number***	B Amphipod	B Crustacean Other	B Decapod	B Fish	B Isopod	B Lancelet	B Mysid & Larvae
On Shoal	0	36	0.004	0.000	0.931	0.000	0.000	0.000	0.004
West of Shoal	0	13	0.000	0.000	1.705	0.000	0.000	0.000	0.000
West of Shoal	0	53	0.010	0.000	0.917	0.318	0.007	0.000	0.428
On Shoal	0	7	0.000	0.000	0.000	0.000	0.000	0.000	0.002
West of Shoal	0	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Area B	0	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
On Shoal	0	1006	0.000	0.000	0.000	0.000	0.000	0.000	0.521
Area B	0	71	0.000	0.000	0.008	0.000	0.000	0.000	0.049
Area B	0	276	0.000	0.000	0.031	0.000	0.000	0.000	0.243
West of Shoal	0	153	0.000	0.000	0.000	0.000	0.000	0.000	0.091
On Shoal	0	1011	0.046	0.003	0.116	0.000	0.015	0.210	0.971
Area B	0	57	0.017	0.060	0.083	0.000	0.000	0.000	0.032
Area B	0	431	0.073	0.003	0.954	0.000	0.000	0.011	0.695
East of Shoal	0	104	0.185	0.010	0.124	0.000	0.000	0.000	0.150
West of Shoal	0	220	0.438	0.000	0.137	0.000	0.000	0.000	0.356
On Shoal	0	62	0.087	0.000	0.054	0.000	0.000	0.057	0.020
Area B	0	209	0.154	0.010	0.077	0.000	0.001	0.000	0.069
Area B	0	80	0.039	0.001	0.006	0.000	0.000	0.000	0.080
East of Shoal	0	112	0.193	0.028	0.012	0.000	0.000	0.536	0.000
West of Shoal	0	109	0.154	0.000	0.039	0.000	0.000	0.000	0.041
On Shoal	0	55	0.126	0.000	2.718	1.035	0.000	0.577	0.033
Area B	0	88	0.100	0.000	3.915	0.731	0.000	0.000	0.077
Area B	0	51	0.015	0.000	0.273	0.000	0.000	0.000	0.182
East of Shoal	0	75	0.321	0.000	1.299	0.000	0.000	0.058	0.040
West of Shoal	0	282	0.448	0.000	1.674	0.000	0.000	0.646	1.302
On Shoal	0	87	0.000	0.004	0.000	0.000	0.000	0.000	0.062
Area B	0	2	0.000	0.000	0.101	0.000	0.000	0.000	0.000
Area B	0	46	0.009	0.017	0.001	0.000	0.000	0.000	0.036

Strata Final	B Nemertean	B Polychaete	B Other	B Gastropod	B Bivalve	Total Biomass	% Amphipod	% Crustacean Other	% Decapod
East of Shoal	0.000	0.041	0.117	0.000	0.000	0.732	0.00	0.00	0.78
East of Shoal	0.000	0.004	0.000	0.000	0.000	0.184	0.00	0.00	0.98
West of Shoal	0.000	0.547	0.773	0.105	0.000	2.751	0.00	0.00	0.48
Area B	0.000	0.013	0.001	0.000	0.000	0.062	0.00	0.00	0.77
East of Shoal	0.000	0.032	0.064	0.000	0.000	0.144	0.29	0.00	0.04
West of Shoal	0.000	0.003	0.022	0.000	0.000	0.055	0.56	0.00	0.00
Area B	0.000	0.006	0.020	0.000	0.000	0.029	0.00	0.02	0.00
Area B	0.000	0.000	0.000	0.000	0.000	0.709	0.00	0.00	0.00
On Shoal	0.000	0.001	0.086	0.000	0.000	0.095	0.00	0.02	0.00
East of Shoal	0.000	0.128	0.706	0.000	0.000	0.876	0.04	0.00	0.00
West of Shoal	0.000	0.075	0.262	0.000	0.007	0.347	0.01	0.00	0.00
Area B	0.000	0.024	0.069	0.000	0.000	0.144	0.00	0.04	0.00
On Shoal	0.000	0.131	0.304	0.000	0.036	1.222	0.00	0.00	0.58
East of Shoal	0.000	0.603	0.272	0.000	0.000	2.729	0.00	0.00	0.64
West of Shoal	0.000	0.027	1.128	0.000	0.000	1.393	0.00	0.00	0.17
Area B	0.000	0.052	0.100	0.000	0.007	0.565	0.00	0.00	0.24
On Shoal	0.000	0.000	0.113	0.000	0.000	0.416	0.00	0.00	0.00
East of Shoal	0.000	0.034	0.484	0.000	0.000	0.603	0.00	0.05	0.00
West of Shoal	0.000	0.014	0.049	0.000	0.000	0.079	0.00	0.01	0.00
On Shoal	0.000	0.000	0.063	0.000	0.000	1.150	0.00	0.00	0.00
East of Shoal	0.000	0.017	0.113	0.000	0.000	0.191	0.00	0.03	0.03
On Shoal	0.000	0.019	1.457	0.000	0.000	1.819	0.00	0.00	0.03
East of Shoal	0.000	0.053	0.449	0.000	0.000	0.547	0.00	0.00	0.00
West of Shoal	0.000	0.171	1.874	0.000	0.000	6.862	0.00	0.00	0.01
On Shoal	0.000	0.049	0.378	0.000	0.000	0.750	0.01	0.01	0.22
East of Shoal	0.000	0.052	0.355	0.000	0.000	2.324	0.01	0.02	0.44
West of Shoal	0.000	0.000	0.099	0.000	0.000	0.730	0.01	0.00	0.08
West of Shoal	0.000	0.031	0.312	0.000	0.000	0.754	0.03	0.00	0.02
On Shoal	0.000	0.352	0.106	0.000	0.000	0.562	0.00	0.01	0.07
East of Shoal	0.000	0.008	0.080	0.000	0.000	0.148	0.00	0.00	0.41
West of Shoal	0.000	0.013	0.086	0.000	0.000	0.158	0.38	0.00	0.00
West of Shoal	0.000	0.413	0.269	0.000	0.000	0.711	0.03	0.00	0.01

Strata Final	B Nemertean	B Polychaete	B Other	B Gastropod	B Bivalve	Total Biomass	% Amphipod	% Crustacean Other	% Decapod
On Shoal	0.000	0.135	0.161	0.000	0.000	1.235	0.00	0.00	0.75
West of Shoal	0.000	0.001	1.348	0.000	0.000	3.054	0.00	0.00	0.56
West of Shoal	0.000	0.838	2.335	0.000	0.000	4.853	0.00	0.00	0.19
On Shoal	0.000	0.000	0.083	0.000	0.000	0.085	0.00	0.00	0.00
West of Shoal	0.000	0.000	0.013	0.000	0.000	0.013	0.00	0.00	0.00
Area B	0.000	0.000	0.001	0.000	0.000	0.001	0.00	0.00	0.00
On Shoal	0.000	0.000	0.000	0.000	0.000	0.521	0.00	0.00	0.00
Area B	0.000	0.017	0.026	0.000	0.000	0.100	0.00	0.00	0.08
Area B	0.026	0.022	0.035	0.000	0.000	0.357	0.00	0.00	0.09
West of Shoal	0.000	0.152	0.000	0.000	0.000	0.243	0.00	0.00	0.00
On Shoal	0.000	0.000	0.057	0.000	0.000	1.418	0.03	0.00	0.08
Area B	0.000	0.000	0.000	0.000	0.000	0.192	0.09	0.31	0.43
Area B	0.000	0.010	0.000	0.000	0.000	1.746	0.04	0.00	0.55
East of Shoal	0.000	0.000	0.000	0.000	0.000	0.469	0.39	0.02	0.26
West of Shoal	0.000	0.000	0.000	0.000	0.000	0.931	0.47	0.00	0.15
On Shoal	0.000	0.085	0.016	0.000	0.000	0.319	0.27	0.00	0.17
Area B	0.000	0.087	0.033	0.000	0.000	0.431	0.36	0.02	0.18
Area B	0.000	0.016	0.000	0.000	0.000	0.142	0.27	0.01	0.04
East of Shoal	0.000	0.518	0.194	0.000	0.000	1.481	0.13	0.02	0.01
West of Shoal	0.000	0.642	0.045	0.000	0.000	0.921	0.17	0.00	0.04
On Shoal	0.000	0.371	0.000	0.000	0.000	4.860	0.03	0.00	0.56
Area B	0.000	0.000	0.245	0.000	0.000	5.068	0.02	0.00	0.77
Area B	0.000	0.000	0.023	0.000	0.000	0.493	0.03	0.00	0.55
East of Shoal	0.000	0.000	0.131	0.000	0.000	1.849	0.17	0.00	0.70
West of Shoal	0.000	0.044	0.429	0.000	0.000	4.543	0.10	0.00	0.37
On Shoal	0.000	0.000	0.000	0.000	0.000	0.066	0.00	0.06	0.00
Area B	0.000	0.000	0.000	0.000	0.000	0.101	0.00	0.00	1.00
Area B	0.000	0.000	0.007	0.000	0.000	0.070	0.13	0.24	0.01

Strata Final	% Fish	% Isopod	% Lancelet	% Mysid & Larvae	% Nemertean	% Polychaete	% Other	% Gastropod	% Bivalve
East of Shoal	0.00	0.00	0.00	0.00	0.00	0.06	0.16	0.00	0.00
East of Shoal	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.00	0.00	0.20	0.28	0.04	0.00
Area B	0.00	0.00	0.00	0.00	0.00	0.22	0.01	0.00	0.00
East of Shoal	0.00	0.00	0.00	0.00	0.00	0.22	0.44	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.00	0.00	0.05	0.39	0.00	0.00
Area B	0.00	0.11	0.00	0.00	0.00	0.19	0.68	0.00	0.01
Area B	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
On Shoal	0.00	0.00	0.00	0.06	0.00	0.01	0.90	0.00	0.00
East of Shoal	0.00	0.00	0.00	0.01	0.00	0.15	0.81	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.00	0.00	0.22	0.75	0.00	0.02
Area B	0.00	0.00	0.00	0.32	0.00	0.17	0.48	0.00	0.00
On Shoal	0.00	0.03	0.00	0.00	0.00	0.11	0.25	0.00	0.03
East of Shoal	0.00	0.04	0.00	0.00	0.00	0.22	0.10	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.00	0.00	0.02	0.81	0.00	0.00
Area B	0.00	0.47	0.00	0.00	0.00	0.09	0.18	0.00	0.01
On Shoal	0.00	0.00	0.03	0.70	0.00	0.00	0.27	0.00	0.00
East of Shoal	0.00	0.00	0.00	0.10	0.00	0.06	0.80	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.20	0.00	0.17	0.62	0.00	0.00
On Shoal	0.00	0.00	0.00	0.94	0.00	0.00	0.05	0.00	0.00
East of Shoal	0.00	0.00	0.25	0.02	0.00	0.09	0.59	0.00	0.00
On Shoal	0.00	0.00	0.00	0.16	0.00	0.01	0.80	0.00	0.00
East of Shoal	0.00	0.00	0.00	0.08	0.00	0.10	0.82	0.00	0.00
West of Shoal	0.00	0.01	0.00	0.68	0.00	0.02	0.27	0.00	0.00
On Shoal	0.00	0.00	0.10	0.10	0.00	0.06	0.50	0.00	0.00
East of Shoal	0.00	0.00	0.26	0.10	0.00	0.02	0.15	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.77	0.00	0.00	0.14	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.50	0.00	0.04	0.41	0.00	0.00
On Shoal	0.00	0.00	0.09	0.01	0.00	0.63	0.19	0.00	0.00
East of Shoal	0.00	0.00	0.00	0.00	0.00	0.05	0.54	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.00	0.00	0.08	0.54	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.00	0.00	0.58	0.38	0.00	0.00

Strata Final	% Fish	% Isopod	% Lancelet	% Mysid & Larvae	% Nemertean	% Polychaete	% Other	% Gastropod	% Bivalve
On Shoal	0.00	0.00	0.00	0.00	0.00	0.11	0.13	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00
West of Shoal	0.07	0.00	0.00	0.09	0.00	0.17	0.48	0.00	0.00
On Shoal	0.00	0.00	0.00	0.02	0.00	0.00	0.98	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Area B	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
On Shoal	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Area B	0.00	0.00	0.00	0.49	0.00	0.17	0.26	0.00	0.00
Area B	0.00	0.00	0.00	0.68	0.07	0.06	0.10	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.37	0.00	0.63	0.00	0.00	0.00
On Shoal	0.00	0.01	0.15	0.68	0.00	0.00	0.04	0.00	0.00
Area B	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00
Area B	0.00	0.00	0.01	0.40	0.00	0.01	0.00	0.00	0.00
East of Shoal	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00
On Shoal	0.00	0.00	0.18	0.06	0.00	0.27	0.05	0.00	0.00
Area B	0.00	0.00	0.00	0.16	0.00	0.20	0.08	0.00	0.00
Area B	0.00	0.00	0.00	0.56	0.00	0.11	0.00	0.00	0.00
East of Shoal	0.00	0.00	0.36	0.00	0.00	0.35	0.13	0.00	0.00
West of Shoal	0.00	0.00	0.00	0.04	0.00	0.70	0.05	0.00	0.00
On Shoal	0.21	0.00	0.12	0.01	0.00	0.08	0.00	0.00	0.00
Area B	0.14	0.00	0.00	0.02	0.00	0.00	0.05	0.00	0.00
Area B	0.00	0.00	0.00	0.37	0.00	0.00	0.05	0.00	0.00
East of Shoal	0.00	0.00	0.03	0.02	0.00	0.00	0.07	0.00	0.00
West of Shoal	0.00	0.00	0.14	0.29	0.00	0.01	0.09	0.00	0.00
On Shoal	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00
Area B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area B	0.00	0.00	0.00	0.51	0.00	0.00	0.10	0.00	0.00

Project Report

X-band Radar Wave Observation System

Submitted

to

Minerals Management Service
U. S. Department of the Interior
381 Elden Street
Herndon VA 22070

By

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Marine X-band Radar for Wave Observations

There are two C programs (killtime.c and radar.c) and one control input file (radar_single.con) in this appendix.

There are two Matlab main programs and six functions in this appendix. The first main program is “imgplt.m” which is used only to read and plot the raw radar images. This program calls two functions “read_radar_header.m” and “read_radar_image_chk.m” to carry out the job.

The other main program is “fft3d_radar.m” which is the wave analysis program. It calls the following functions “read_radar_header.m”, “read_radar_image.m”, “fft3dSNR.m”, “Jacobian.m”, and “circle.m” to accomplish the job.

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Chapter 1. Introduction

Water wave observation and analysis is one of the important and difficult jobs that is required for many purposes, *e.g.*, shore protection, harbor management, navigation safety, coastal resource management, rescue missions, etc. Traditional approaches for obtaining wave data include using wave buoys, pressure wave gauges, acoustic wave gauges, airplane or satellite video or radar observation, land-based HF-band and X-band radar. The first three techniques are well-developed for direct observation of water surface elevations or water particle velocities for estimating wave conditions. These techniques were the first developed and follow the available wave theory, mainly linear wave theory and are commonly used for wave measurement. These techniques, however, require the deployment of a sensor or a series of sensors in the water, and, thus, are expensive to maintain. In areas where fishing activities are heavy, interference between the fishing activities and the sensors is inevitable with the result that valuable instruments may be lost.

The last three approaches utilize the principals of remote sensing to obtain data for interpreting wave conditions. A remote sensing approach has the advantage of providing measurements from a large area using only one set of instrument, *e.g.*, an air-borne video or radar system.

If it is a land-based system, *e.g.*, a High-Frequency (HF) radar or X-band radar, the operational cost is relatively low, especially for the X-band radar if the required study area is within a radius of 3 to 5 km. HF radars are mainly used for large area current and wave measurements (Gurgel *et al.*, 1999). The instrumentation cost is great, on the order of millions of dollars for a system (http://www.ocean.tamu.edu/GOOS/GSCX/ GSCS_appendix_05.pdf). The principal for HF and x-band radar are the same, both use the Bragg effect to detect the scattered waves, but the wave lengths are different. HF radar uses a large electromagnetic (EM) wavelength (with the frequency range from 3 to 30 Mhz) to produce Bragg scatter waves with the gravity waves itself, but X-band radar uses short EM waves to interact with ripples on top of the gravity waves. The operational range of HF radars is large, normally on the order of 50 km but which can be extended to 200 km with an antenna array, but with relatively low resolution. Although the Hi-Res SeaSonde® from Codar Ocean Sensors is claimed having the capability of measuring waves (http://www.ocean.tamu.edu/GOOS/GSCX/ GSCS_appendix_05.pdf) however, other devices are needed for measuring the directional wave spectra.

Unlike HF radars, X-band radars are widely used for the vessel navigation purpose and are widely available on the market. For this reason, the cost for the hardware is reasonable and the use of X-band radars for wave observation, if the operational and analytical details are fully documented, would be a promising alternative.

The first attempt of using X-band radars for wave observation was reported by Young *et al.* (1985). At that time, radar images were recorded on paper then digitized for analysis of the wave data. Since that attempt, continuous efforts to develop an X-band radar wave observation system have produced several commercial products with specially designed hardware. For example, WaMos II (Borge *et al.*, 1998, 1999; Borge and Soares, 2000; Krogstad *et al.*,1999; Wyatt *et al.*, 1999; Wolf and Bell, 2001; Wyatt *et al.*, 2003) was developed by following exactly the same principals given by Young *et al.* (1985). The other type of X-band radar wave observation system is Miros wave and current radar (http://www.miros.no/). Miros has no rotating radar antenna and is only good for short-range ,< 450 m, observation of waves.

The problems associated with these commercial products are (1) the price is relatively high, about 4 to 5 times of the cost of the hardware, and (2) source codes for data analysis and system control are not provided. This means the operation is somewhat like a black box and, thus, is not good for the academic research purposes. For this reason, a study of the entire processes of using X-band radars was proposed for reveal the details and the limitations on this kind observation system.

In Chapter 2, the considerations on hardware are presented. Details on how to select a proper marine radar and other associated hardware are documented. Thus, it is possible to extend and improve for future uses.

In Chapter 3, details of the radar image data acquisition system are presented. The principal of system control and data acquisition software is explained.

In Chapter 4, the principal of wave spectrum analysis is presented. It starts with the basic 1-D Fast Fourier Transform (FFT), then advances into two-dimension (2-D) and three-dimensional (3-D) wave spectrum analysis. Clearly known signals are used to demonstrate the process of this technique.

The numbers acquired in radar images, however, do not represent water surface elevations. These numbers also are distorted because of the nature of measurements. Thus, extra processing is required before performing the 3-D FFT for analyzing wave characteristics. These processes are presented in Chapter 5.

Although the wave-energy directional distribution and wave period at the peak frequency can be obtained by following the technique given in Chapter 4 and the image process procedures presented in Chapter 5, the significant wave height has to be calculated by using the Signal Noise Ratio (SNR), which requires calibration. In Chapter 6, the details on calibration made by deploying a star wave gauge and using the results from a nearby NOAA wave station, CHLV2, are presented.

Remote access to the data and remote control of the system are convenient and sometimes necessary tools to have for successful long-term operation. Possible options of remote control using either Local Area Network (LAN) or a telephone modem are explored. The necessary software and hardware were collected and tested. Details are given in Chapter 7.

Chapter 8 presents the discussion and conclusions. The problems encountered in this project are discussed. Cautions and future works on using this kind of wave observation system are also noted.

Chapter 2. Hardware Considerations

It is well known that inexpensive, marine X-band radars can be used for wave observations. Details on how to select a suitable marine radar and other associated hardware, however, are not clearly documented, and thus, it is worth while to discuss the details and the criteria for these selections.

2.1. X-band Radar

X-band radars have a frequency range from 9.41 to 10.5 GHz. Thus, the wavelength, in air, of x-band radars is between 2.8 and 3.2 cm. This is a rather important i because this particular wavelength is approximately equal to the ripple wavelength that exists on the water surface when the wind speed is more than 3 m s^{-1}. Although the ripples are not the target for the measurements, they coexist with the much large gravity waves, which are the target. The principal of using marine X-band radar for wave measurements is the use of the Bragg effect (Valenzuela, 1978) to obtain the scatter waves generated by interactions between radio waves and ripples. The scatter waves usually are referred as the “sea clutter noise” from radar’s point of view because the scatter waves are not the usual target of a regular radar system. Because the scatter wave strength increases as the ripple wavelength approaches the EM wavelength, it is easier for a radar antenna to pick up the scatter waves. For this reason, X-band radar is a better option. The other type of marine radar (S-band radar) has a nominal frequency of 2.455 GHz. Because the wavelength is large, about 12 cm, the scatter waves strength would be weak, and thus, the detectable range would be significantly smaller when compared with X-band radar. For this reason, S-band is not suitable for wave measurement.

The useful range of X-band radars for measuring waves is limited by the radar’s capability of measuring the scatter waves, and thus, limited by the available power of X-band radars. Since X-band radar is a commercial product with a few options on the output power (*e.g.*, 2, 4, 6, 10, 25, 50 kw), the cost is reasonable when compared with other wave measurement approaches. In general, greater the X-band radar output power yeilds a larger measurement area and measurable conditions. However, it is also true that the hardware cost increases sharply for the higher power. As a practical application, for a radius of 2 to 5 km, a 25 kw X-band radar is necessary. This translates to a radar cost of $8,000 - 12,000 (in 2004 dollars), depending on the manufacture and other options. By specifying a monochromic monitor, the total cost of a 25 kw X-band radar can be below $10k. For example, a Furuno 8251 marine X-band radar meets all the above stated requirements and was selected for use in this project.

The selection of a radar antenna can affect the resolution of radar image. Because the entire radar system is a commercial product, the available antenna choices for a particular radar model usually are usually limited. For example, for the Furuno 8251 radar, one may select either a 6 ft or an 8 ft long antenna. The rotation speed or the antenna also is limited to 24 or 36 rpm. In general, the longer the antenna, the higher the spatial resolution of radar image in the radial direction. Also, the faster the antenna rotation speed, the higher the temporal resolution of analyzed results in the time domain. For this reason, an 8 ft long open-array antenna that rotates at 36 rpm was selected (Fig. 2-1) for the project.

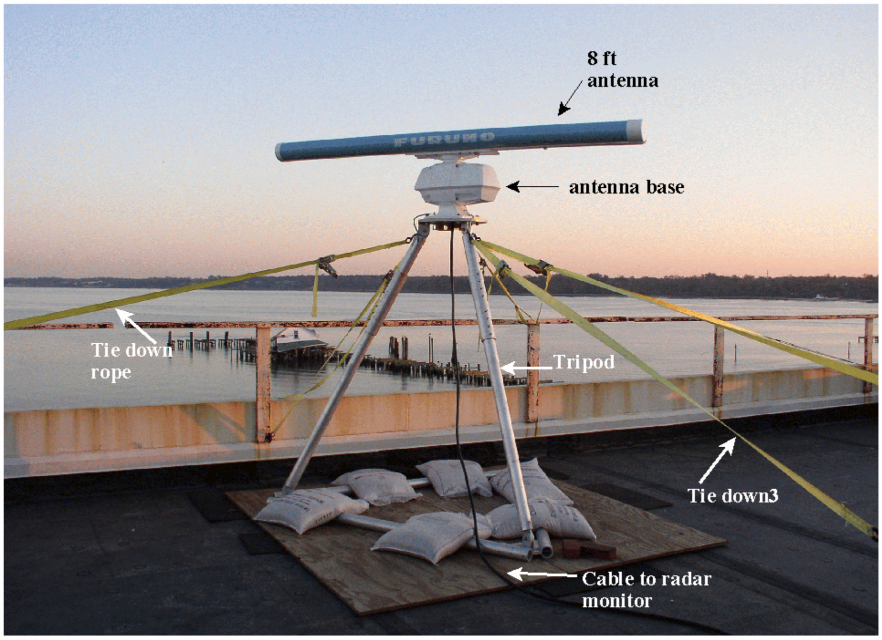

Fig. 2-1. Setup of an X-band radar at a building roof.

Another advantage of the Furuno 8251 marine radar is that a radial sector of the detecting area can be specified. For example, when using a radar at a coastal station, only the half circle image that faces the ocean is useful. With this capability, the radar antenna rotates at the constant speed but only sends out radio waves for the half circle from which data are needed. This capability avoids unnecessary exposure of radar operators or any creatures on the landside, even out of the harmful zone, which extends about 5 meters from the radar. More details on how to use this feature is given later in this chapter.

The installation height of the radar for wave observation is another critical factor. There is an optimal range for picking up the scatter wave signals. This range depends on the incident angle of the radar wave (Fig. 2-2). The EM waves that come out of the antenna usually have a vertical spreading angle of 25^{o}. At least half of the EM waves are wasted because they are broadcast above the horizon. Only the radar waves with an incident angle between 1^{o} and 10^{o} from the lower half of the vertical spread are useful. For this reason, the installation height and the radar output power are the two main factors that control the range at which waves can be observed. A simple relationship between the better observation range and the radar elevation (Fig. 2-3) indicates that an elevation of at least 30 m is necessary.

If the radar antenna can be oriented a little down from horizontal and the maximum EM wave direction can be aimed toward the sea level at a long distance, then the optimal working range may be extended, for example, up to that of the 0.5^{o} line in Fig. 2-3. Although this is still a hypothesis, it may worth while to verify it with future study.

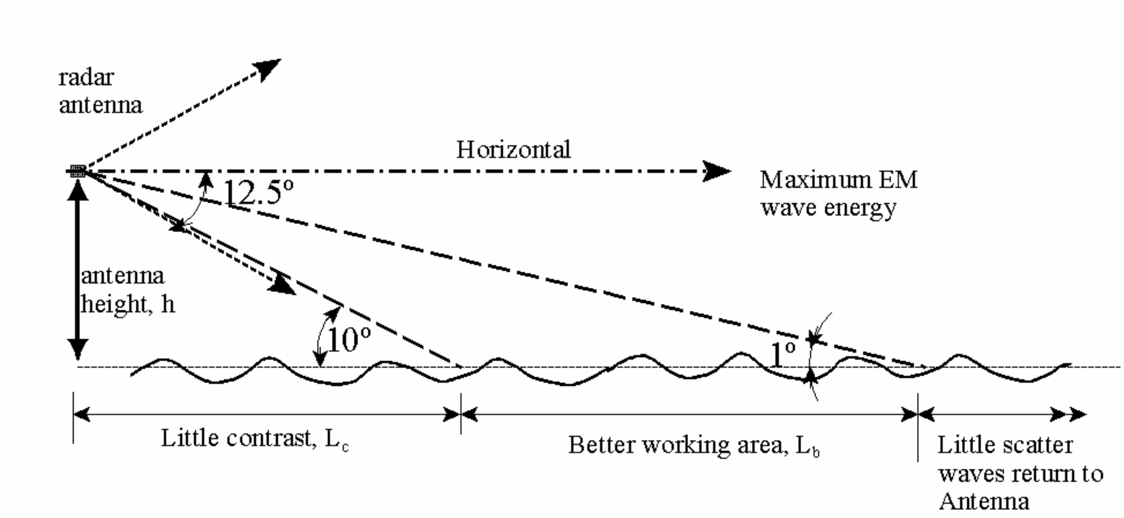

Fig. 2-2. The better working area, Lb, of a radar wave observation system.

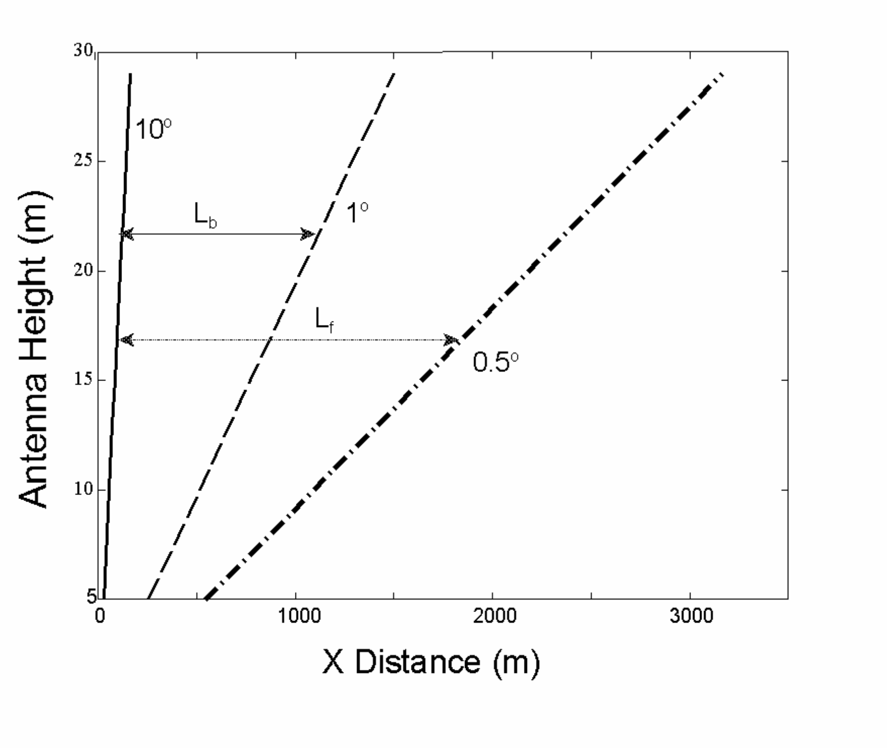

Fig. 2-3. Relationship between radar antenna height and the better working area. L_b is for an impinging angle of 1^o and L_f is for a possible extension of the better working area by decreasing the impinging angle to 0.5^o.

2.2. Basic Characteristics of Radar Images

Assuming that the "sea clutter noise" is greater than the background white noise at a distance 5 km from the radar, a maximum observation radius of 5 km was selected to show the characteristics of the collected radar. Later these characteristics are also useful for helping to determine the proper Analog to Digital Conversion (ADC) rate.

The time for radar waves to travel along a beam should be first estimated. A 5 km distance means a two-way travel distance of 10 km. Since the Electrical Magnetic (EM) wave speed is 2.99792 $x10^8$ m s^{-1}, the total time for receiving the echo from 5 km would be 32 μs (= 2 x 5000 m / $3x10^8$ m $^{-1}$).

During this 32 μs, for an antenna rotating speed of 36 rpm (*i.e.*, 0.6 rps), the antenna will rotate about $0.6*2\pi*32x10^{-6}$ s which is 0.0001206 rad or 0.0069 degrees which is rather a small angle. The swept footprint is about 0.6 m (= 0.000120685 x 5000 m) which is much smaller than the lateral EM wave spreading (0.9^o in the horizontal and 25^o in the vertical direction for a Furuno's 8 ft long open array antenna), and thus, the antenna can be considered as stationary.

The 0.9^o degree horizontal spreading of the EM waves means a 78 m (= 0.017453 * 0.9 * 5000 m) footprint at a 5 km distance. This is to say that at a distance of 5 km, a subject with only 1 meter wide will be seen by the radar as a subject with a width of around 70 m, although the target will still give the strongest image when it is directly on the center of the radar beam. This is because the spread radar beam will see the same target, but with a weaker echo signal at the edges of the spreading zone. So instead of seeing a dot subject, the radar sees an arc subject with the image fading on both ends that appears to be much wider in the angular direction than it should be.

The Furuno 8251 marine X-band radar emits 2,100 pulses per second to trigger the burst of radio wave beams for detecting subjects. For an antenna rotating speed of 36 rpm, this means a total of 3,500 bursts will be triggered for one radar image. The generation of these pulses, however, can be controlled for an angular domain that is facing the ocean (Fig. 2-4). This feature is helpful (1) to identify the time for starting image acquisition and (2) to reduce the burst line number to 1750 for a half-circle radar image.

In cases that the selected radar does not have the option of setting an angular domain for wave observation, then the whole circle image will be examined. For this situation, another signal pulse, the radar heading pulse, will be used to identify "when" the radar antenna is pointing toward a specified direction. This heading pulse also is shown in Fig. 2-4, but not used for this study.

Depending on the selected maximum detecting range, the duration of sending (or the number) EM waves in a burst is different. This is because with a larger measurement distance more the EM waves are needed to produce enough echo strength for the antenna to pickup. More EM waves means longer burst duration. Because there are many EM waves in a burst line, the radar-measured subject length is not the true subject length either. For example, for an 80 ns

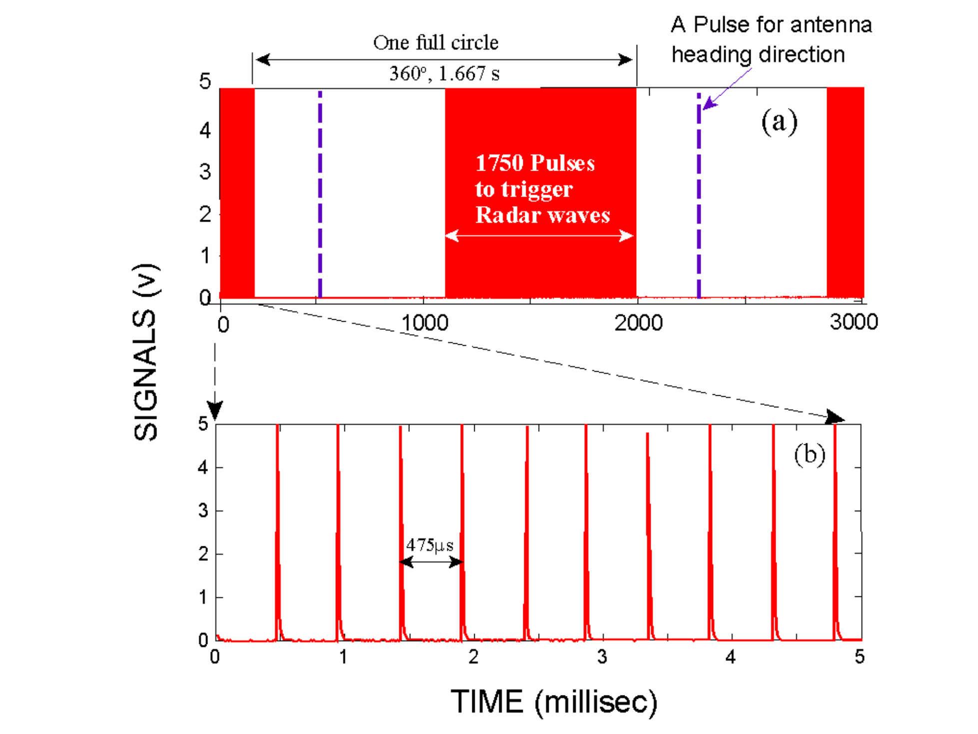

Fig. 2-4. For a FURUNO FR8251 radar, the radar scanning domain can be specified. (a) Within this domain, pulses are generated from the radar control unit at a rate of 2,100 pulse/s to trigger the burst of radar waves. (b) Detail of the pulses pattern within the scanning domain. These pulses also were used to trigger the ADC conversion.

burst duration, 800 EM waves (= 80 x 10^{-9} s * 10 x 10^{9} Hz) would be transmitted. Because all the waves will cause reflection from a subject, a one-meter long subject along the track of radar wave beam will be seen as a 24 m long subject (0.03 m * 800 waves) with the highest signal strength at the center. For this reason, the burst duration should be kept as short as possible. In other words, the operating range should be set at the shortest detection range for radar operation, when it is used for wave measurements. This is rather important information.

The characteristics of radar images discussed in the above paragraphs assume that the resolution for data digitization is infinitely high and the reflection of radar waves is perfect. In reality, however, this will not be the case, and thus, the radar images collected are somewhat smeared.

2.3. Personal Computer

When X-band radar was first used for wave measurements, the data analysis and radar control were performed with a Unix mini-computer. With the advancement of Personal Computers (PCs), control of the radar, data acquired, and data analysis was transferred to a PC. This study demonstrated that a PC with a Pentium 4 processor of 2.8 GHz and Windows 2000® operation system is sufficient. An IDE hard disk with a capacity of 100 to 150 GB is required for handling the huge size of the dataset. Memory with a size of 512 MB would be appropriate.

One critical requirement for the PC is that it should only have one PCI device (usually a high-speed ADC interface card) installed. An AGP graphic interface card should be used instead of a PCI graphic card. This is to avoid the possible delay/interference of data transfer between the high-speed ADC card and the memory or the hard disk. Although the delay/interference of data transfer does not always occur, the radar image will be corrupted once it is triggered. This phenomenon did not happen when our system was first installed, but it happened during the field experiment. Identifying the problem took about 6 months.

Since the data-transfer speed for an electronic device (*e.g.*, computer memory) is much faster than that for a mechanic device (*e.g.*, hard disk), a hard disk with a large buffer memory is necessary. Currently, a hard disk with 8 MB buffer memory is not uncommon, and thus, is suggested for the wave observation system. If this condition can be met, then other disk specifications would be immaterial.

It is worth noting that the temperature range during our experimental period may be severe enough to cause the selected hardware not function properly. For this reason, one should be aware that when the ambient temperature may fall below zero or exceed 50^{o} C, an industrial grade PC, which has a operating temperature range from -30^{o} C to $+80^{o}$ C, is necessary.

For regular operation, a monitor is not required. But it would be nice to have one for checking the processes. Any monitor would be sufficient.

2.4. Micro-controller

If the availability of power is not a concern, there is no need to add a micro-controller for saving energy. In most applications, however, power is a major concern because of the difficulty of getting AC power at a remote site. For this reason, a micro-controller, Onset Model TFX-11, was added to the PC for turning on the PC and the radar, and for turning off the radar to saving energy as well as extending the useful life of the radar. In general, a micro-controller with a real-time clock, three channels of digital output for switching the PC and the radar is the minimum requirement. An Onset TFX-11 was selected because of its simplicity for programming and its minimum power requirements.

The TFX-11 micro-controller requires 7-12 VDC, 80 mA to operate at its full load and about 4 mA for standby conditions. For this reason, a small DC-to-DC converter that changes the PC's 5V standby power to 12V was used to power the TFX-11 all the time (Fig. 2-5).

A Basic program (see Appendix I) run in the TFX-11 was used to turn on the PC and the radar. It was also used to turn down the radar. The PC will turn itself off using the free software, "Quick Shutdown."

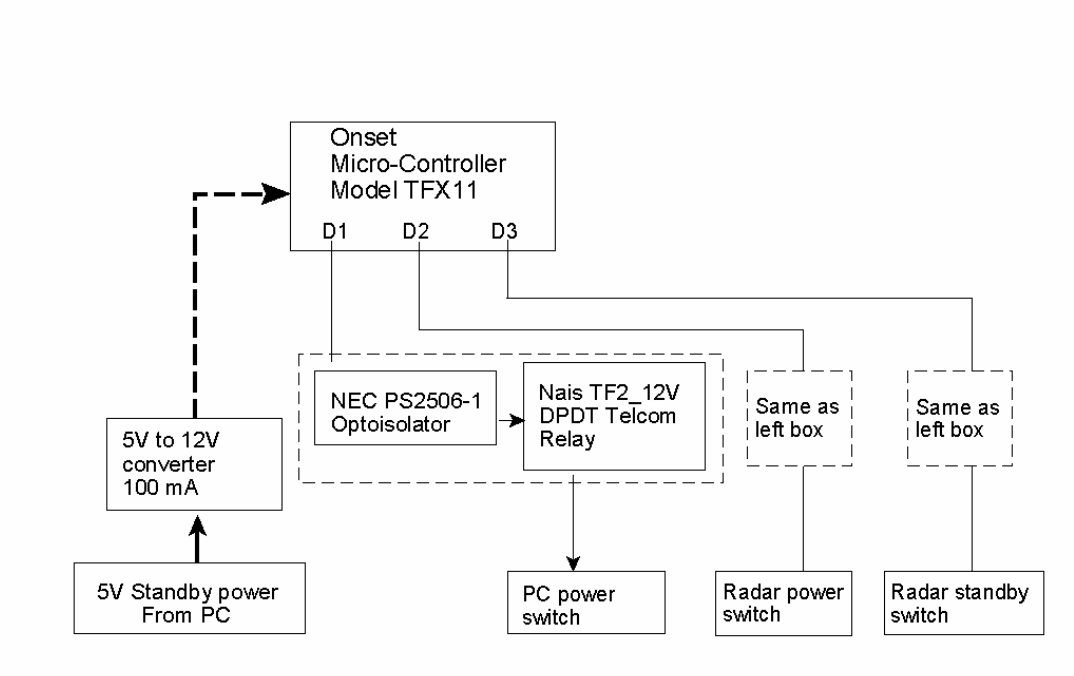

Fig. 2-5. Schematic diagram of the PC and radar auto-control.

2.5. Available High-speed ADC Interface Devices.

At the time writing (Fall 2005), four high-speed ADC devices are available on the PC market: CompuScope 12100 (from Gage Applied Technologies, Inc.), PCI-9820 (from ADLINK Technology, Inc.), UF2-3020 (Strategic Test Corp.), and Handyscope 3 (from TiePie Engineering). These four devices all have a 12 bit maximum ADC rate and meet or exceed 100 Million Samples per second (MS s^{-1}).

The reason of having a minimum requirement on the ADC rate of 100 MS s^{-1} is not the ADC rate itself, but to provide a high-enough bandwidth so as not to distort the radar signals. The radar signals that transferred from a radar antenna to the radar control and monitoring unit is an Intermediate Frequency (IF) signal with a frequency on the order of 10 Mhz. In order to maintain a high fidelity after feeding the IF signals into the ADC device, a high-enough bandwidth for the ADC card is necessary. In general, because the higher the ADC rate, the higher the bandwidth of the ADC device, so 100 MS/s for the ADC card is specified.

The first ADC device has the longest history on the market, and thus, has more functions for applications, but the product design is relatively old, and thus, consumes more energy (26 watts). It was selected because it was the only high-speed ADC card available at the time when this project started.

The second ADC device has better resolution (14 bits), a higher rate (130 MS/s), and lower power consumption (9 watts), but it has been available only since early 2004. We had the opportunity to use this card for a similar project. In general, the functions available for this card are limited to ADC only, and thus, it cannot be used as an oscilloscope. For experienced users, however, this card would be recommended because of its superior ADC quality.

The third ADC device has been available since the middle 2004, but we have not yet had the chance to test it. The above three ADC devices are all internal PCI cards and require a desktop PC.

The fourth ADC device (Handyscope 3) is an external USB-2 device and has been available only since early 2005. The advantages of this device are (1) it comes with a 14 bit signal generator and (2) it can work with a notebook for data acquisition and data analysis for less power consumption. The disadvantages, however, are (1) the software support is not completed yet and (2) the transfer speed limitation on USB-2 has not been checked for radar application. Nevertheless, this may be a future option when the power consumption is a major concern.

2.6. Selection of ADC Rate

Is it necessary to use the maximum ADC rate when digitizing a burst line image? Also, is it necessary to digitize every burst line of the radar image? These two questions are important and the answers also determine the image size.

2.6.1. Resolution in the Angular Direction: The 1,750 burst lines for a half circle yields a resolution of 0.1 degree (180 degrees/1750 scan lines). Since the antenna takes 0.833 seconds for a half circle, the time between each scanning line will be 0.833 s/1750 or 0.476 ms. The swept distance at 5 km away would be 5000 m * 0.476×10^{-3} s * 0.6 rps * 2 π which equals 8.97 m. That is to say at 5 km away, the ADC digitized spatial resolution is about 9 m. Notice that this number is much smaller than the horizontal angular spreading, 78 m, at 5 km from radar. When close to the radar, both the ADC resolution and spreading resolution increase (because of the small radius distance), but the ratio remains the same (78/9 = 8.6). This implies that there is no need to digitize every burst line. Digitizing one line image for every four lines still would be good enough because of the ratio is much less than 8.6. For this reason, we carried out a test at the early stage to compare the image quality for two options: (1) digitize every burst line and (2) digitize one line in every four lines. The results show little difference, and thus, the second option was used for the rest of data acquisition.

2.6.2. Resolution in the Radial Direction: The burst duration (also called pulse width, 80 ns in this case) also controls the image quality in the radial direction. For example, there are about 800 (80×10^{-9} s * 10×10^{9} hz) waves emitted from the antenna during the 80 ns burst. When the first wave of this wave train hit a target and is reflected, the rest of the waves are still coming and the reflection will continued until the end of the 80 ns. Thus, a radar sees the target for the entire 80 ns, and changes the subject length from 1 meter in the radial direction to an image length of 24 m (= 800 * 0.03 m, where 0.03 m is the wave length of 10 GHz EM wave). For this reason, the minimum length observed from the radar would be 24 m.

While scanning at 100 MS s^{-1} for 32 μs to cover a range of 5 km, the number of data points collected represents a distance of 5,000 m. Thus the resolution is 5000m/3200 point or

1.57 m, This resolution is significantly higher than the radar image resolution, 24 m, and thus, not necessary. If scanning with a rate of 25 MS/s, the radial resolution would be about 6.25 m, which is still much finer than that of the image resolution. For this reason, a scanning rate of 25 to 30 MS/s would be sufficient.

2.6.3. Datafile Size: For a distance of 5 km, a total of 800 data points will be collected per burst line in the duration of 32 μs for EM waves to travel 5 km and return back to the antenna. This implies a datafile size of 1.6 KB (800 point x 2 byte/point). Notice that all the sizes mentioned in this report are in binary format, not the ASCII format. If the same data were saved in ASCII format, it will take much more space and a much longer time to read and write.

For a half circle image with 437 burst line images, one radar image will take 700 KB for storage. Considering 64 radar images are suggested for data analysis, one measurement will produce an image file with size about 45 MB. In just one day, the total size of acquired image files will be around 1 GB.

2.7. Blind Zone

While a radar antenna emits a signal, it cannot be used to receive the echoes. Depending on the model of radar, there is a block out time for receiving the echoes. Usually it may take about 100 to 200 ns to clear the residual signal and switch into receiving mode. Thus, a blind zone of 15 to 30 m (0.5 * time delay * 3×10^8 m s^{-1}) is possible. Fortunately, this can be easily measured with the radar. Just looking at the radar screen and turning the nob for cursor control will let you read the blind distance directly from the radar screen.

Chapter 3. Data Acquisition

With an understanding of the hardware requirements described in Chapter 2, details of the radar image data acquisition are presented in this chapter.

3.1. System Control

The information presented in this section describes the automatic radar control system (Fig. 3-1). All the additional hardware is inside the desktop PC. The main control unit is a TFX-11 micro-controller from Onset Computer. The functions of the micro-controller are (1) to turn on the radar at 56 minutes past each hour to warm up the radar, (2) to turn on the PC at 58 minutes past the hour to prepare for data acquisition, (3) to turn on radar operation at 59 minutes past, and (4) to turn off the radar when the job is finished at 8 minutes past the hour. The schematic of this control is given in Chapter 2 whereas the control software and other details are presented here.

A BASIC program (Appendix I) sets a digital I/O port high to turn on a NEC PS2506 optoisolator for activating a Nais TF2-12v Telcom relay (Fig. 3-2). This relay closes the circuit and provides a pulse to activate one of the first three functions mentioned in the previous paragraph. For turning off the radar, two digital I/O ports are required to set high. In general, the above settings are universal for all kinds of radars and PCs. The only concern is the capability of the relay to handle the electrical current (and thus, the total power) required for the task. For example, the selected miniature relay (*i.e.*, Nais TF2-12v Telcom relay) and the miniature 80 mA DC-to-DC conversion unit (to change 5 V to 12 V) are sufficient for the Furuno 8251 radar. For a different radar model, even from the same manufacturer, the switches may be different. For example, another Furuno radar, model 1510, uses a heavy-duty switch for turning the power supply on and off, and thus, requires a heavy-duty relay in place of the Telcom relay. This replacement will affect the location of the relay and the power required for operating that relay. Thus, an experienced technician would be needed to change this part.

3.2. Batch file for controlling the PC programs

After the PC is turned on, the Windows 2000 operating system will be loaded automatically then a batch program, "radar.bat" will be launched automatically by leaving this program in the "Startup" sub-folder, which is under the folder "C:\Documents and Settings\Start Menu\administrator\." This batch program contains the following five commends

```
c:\radar\debug\killtime.exe
c:\radar\debug\radar.exe
Move rd*.h?? d:\data\
Move rd*.b?? d:\data\
c:\autologon\shutdoen\qsd –s
```

The first commend executes a program "killtime" which lets the PC idle for 100 seconds so that the rotating speed of radar antenna approaches a steady condition. The second command executes the data acquisition of radar image. The results are two files: "RDmmddyy.hhr" and "RDmmddyy.bhr" where "RD" in the filename stands for radar, "mm", "dd" and "yy" will be

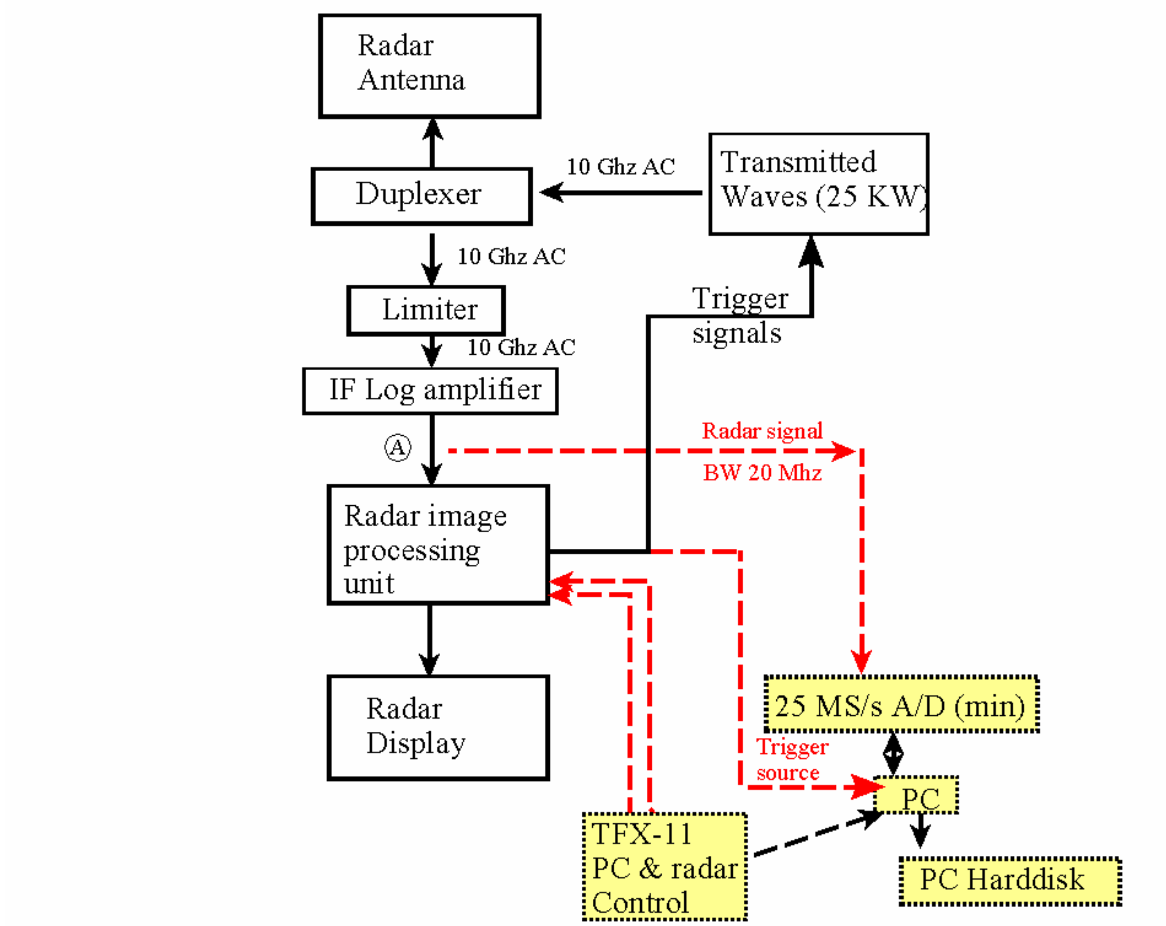

Fig. 3-1. System diagram for the radar wave observation system. The dotted boxes indicate hardware added to the system, and the dashed lines mark the flow of control signals and radar image. All solid boxes are from a radar manufacturer.

replaced by the integer number of the month, day, and year when the data were acquired. The first “h” in the file type stands for an ASCII header file, and the “hr” will be replaced by the integer number of the hour when the file was created. The first character “b” in the file type stands for a binary image data file. For example, “RD011204.h01” and “RD011204.b01” are the header file and the image file created on January 12, 2004, 01:00. The contents in the header file (*i.e.*, the setup of A/D interface card, date and time, radar operation conditions, *etc.*) are in ASCII format and can be seen by using any text editor. The image file, however, is a binary file and can only be read by using a computer program. These two files will be moved to another hard disk for storage. The last command is an auto shutdown command. It turn the PC off until the next “turn on” command is given by the micro-controller. Note that the radar data analysis program is not included in the batch file at this time. But it can easily be added later once an operational decision has been made.

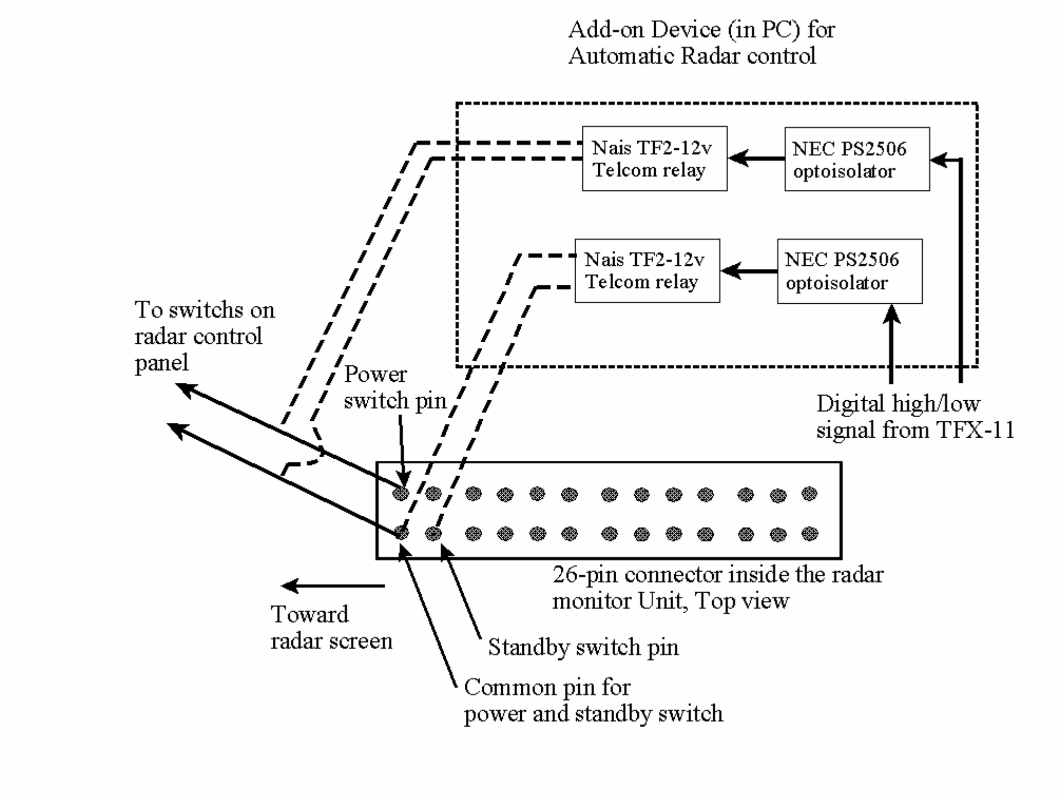

Fig. 3.2. Wiring diagram for turning a FURUNO 8251 radar on and off.

3.3. Signal wires for trigger and radar images

In general, a marine X-band radar usually uses the same antenna for transmitting and receiving signals. These two kinds of signals are quite different in terms of power level. The transmitted signal usually has a power on the order of 6 to 75 kilowatt (kw). On the other hand, the received signals can be as low as milliwatt. Thus, a signal amplifier is needed to boost the received signal. In order to prevent the strong transmission signals from destroying the receiving amplifier, two devices, a "duplexer" and a "limiter," are installed between the antenna and the radar manufacturer's receiving amplifier (Fig. 3-1). The duplexer changes to a high impedance device when a strong signal comes to it, and thus, blocks out the high power signals. Because there is a possibility that a signal from an unrelated but near-by radar that is not strong enough to initiate the duplexer but is strong enough to destroy the amplifier, a "limiter" usually is provided to limit the power that can go to the signal amplifier. The duplexer, limiter, amplifier, and rectifier are all provided by the radar manufacturer, and thus, these are not the concerns of this project. The objective of this discussion is to point out where the echo signals can be picked up.

Physically, there are two units for a marine X-band radar: (1) the radar antenna and gear head unit and (2) the control and monitor unit. Radar waves are actually generated in the first unit, but the control signals are generated in the second unit. The echo signals are also detected in the first unit, but are passed to the second for processing. There is a cable which connects these two units to allow the signals to travel between them.

Two types of signals are needed for the radar image acquisition. The first signal is for starting the ADC. The second type of signal is the radar echo that will be digitized. Both are available from radar control and monitor unit provided by the radar manufacturer (see the two dashed lines in Fig. 3-1 that come out of the radar).

The connectors that attach the radar cable to the control and monitoring unit are the places from which to get these two signals (Fig. 3-3). Usually the echo signals are run in a coaxial cable (because the weak signals require isolation from other signal lines and power lines) that is bundled with others in the main cable that connects the two radar units. It is relatively easy to find this line physically. The exact pin number on the connector for trigger signals that send to the antenna unit can be found in the user manual provided by the radar manufacture. For example, the yellow and black lines in Fig. 3-3 are for retrieving the trigger signals and ground for a Furuno 825. Although there are 4 wires in this picture, the other two wires are for the heading signals that are not needed for this application.

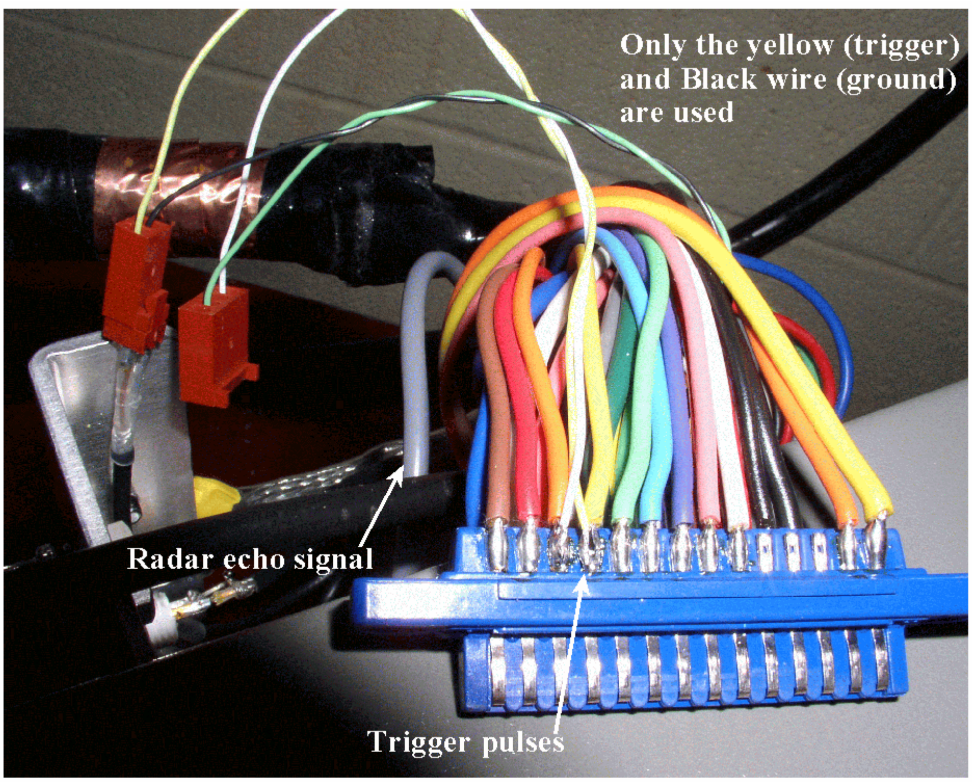

Fig. 3.3. Wires that soldered to the radar cable connector that goes to the radar control and monitoring unit for triggering signals. The echo signal wire in a coaxial cable is also marked.

3.4. C program for Radar Image Data Acquisition

In a high-speed ADC interface device, there usually are two input channels for digitization (Channel A or/and Channel B), one channel for an external trigger source, and one channel for auxiliary input. The radar echo images are fed into one of the input channel for digitization (*e.g.*, Chan A) and the radar trigger signals are fed into the channel for external trigger source. Because the capability of selecting a high input impedance (*e.g.*, 1 MΩ) for both of the channels, the hookup and splitting of the two signals will not affect the original signal strength.

In the C program, the first task is to find the first trigger pulse that represents time t_2 in Fig. 3-4. In this figure, t_1 and t_3 represent the end times of two consecutive antenna revolutions, and t_2 (with the first pulse, P_1) represents the start of radar image scanning. Because the starting time of the C program is not necessarily between t_1 and t_2, the first detected pulse has a good chance of falling between t_2 and t_3. For this reason, the first task is counting how many trigger events have been received from the external trigger source. Since the time interval between each pulse is 475 μs, if there is no trigger event for a sufficiently long time, for example, 1000 μs, then it is clear that the program has come to a time that is after t_3. So the program just starts

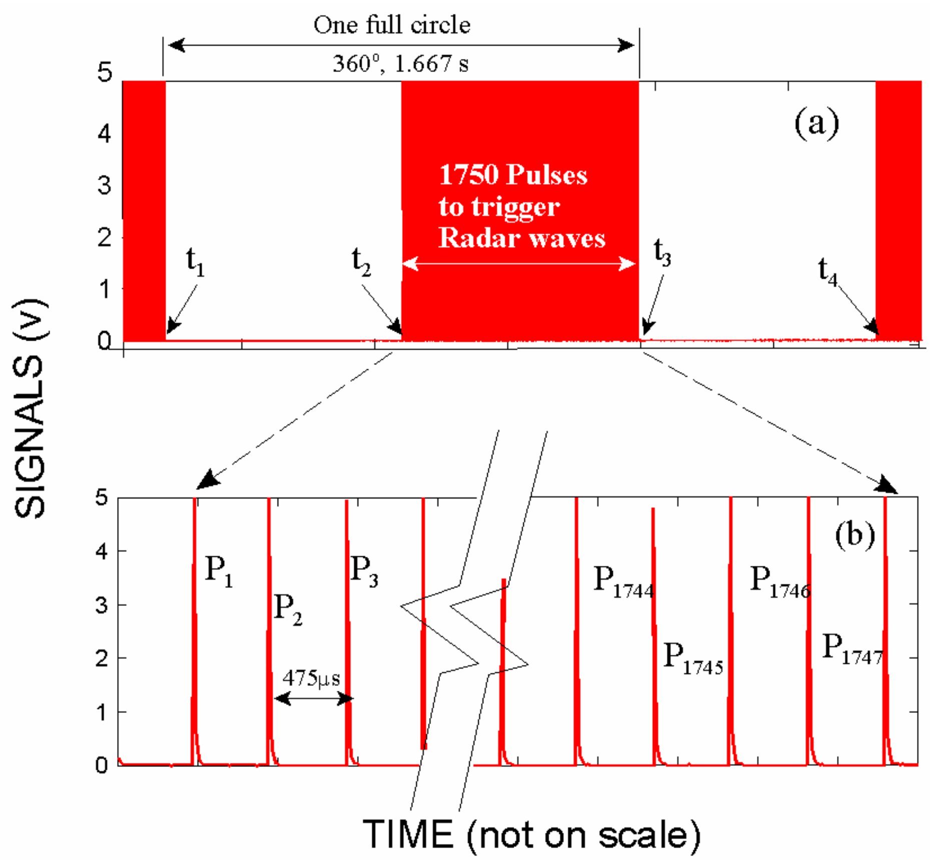

Fig. 3-4. A sketch showing the algorithm for finding the first trigger pulse, P1, when the data acquisition software starts. This algorithm requires a radar has the capability of setting a angular sector for observation. Between time t_1 and t_2, there is no trigger signal.

waiting for the next first pulse that represents at time t_4. If the program successfully counted up to 1747 pulses (slightly less than the ideal 1750 pulses) with a time interval less than 1000 μs between each pulse, this also means the program has come to a time that is close to t_3. With this situation, the program just waits a few thousand microseconds more, and then starts to wait for the next first pulse at time t_4.

The above ensures that the program always starts ADC from the first trigger event, which also represents starting ADC at the beginning of the selected observation domain. After this time, a selected number of antenna revolutions (*e.g.,* 10 turns) is skipped. During this period, the radar images are not digitized, only the number of antenna revolution is counted. The purpose of this process is to give a little more time for the antenna rotation to stabilize.

The final step is to digitize the radar image from the selected burst line images. It is mentioned in Chapter 2 that is not necessary to digitize all 1750 burst line images. This study indicates that digitizing one burst line and then skip the next three would provide sufficient image resolution; that is how the C program is coded.

The documentation of the above algorithm should be sufficient for readers to follow the C program codes, which is given in Appendix II.

The radar system was setup on the roof of the Clarion Resort and Conference Center in Virginai Beach, Va. (36^o30.036'N, 75^o34.935'W, Fig. 3-5), with an elevation about 38 m above the sea surface. The shoreline (which will be used as the x axis in radar image process) at this location has an angle about 13 degrees West from North; this will be used later to determine wave direction. For example, waves coming from E will be shown as waves coming from 77^o ($90^o - 13^o$), counted from the positive x-axis. This is equivalent of saying that waves are going toward -103^o from the radar analysis results.

An example of the radar image (Fig. 3-6) shows that a clear radar wave image can be obtained. Notice that the wave image quality is better at the center, and gradually degrades on the two sides that are close to the shoreline. This is possibly because the radar wave direction parallels the wave crest lines toward the sides of the image. In other words, the strong wave reflection from a rising slope does not return to the radar because of the nearly parallel of radar wave incident line and the wave crest line. The jetty on the north of the radar site, the two breakwaters at the Rudee Inlet, and the wave breaking line can be seen clearly in the image. The solid red semi-circle at the bottom center marks the blind zone.

Because of the relatively large, vertical spread (25^o) of the radar wave and the radar's elevation, a strong reflective subject at a distance that is close to the radar will be seen as a subject that is further away. For example, the bright (yellow) lines near the bottom center in Fig. 3-6 were caused by the strong reflection of foam on the breaking wave crests. This line should be a straight line because the shoreline is straight at this site, but it was shown as a curve in the image. This distortion is explained in Fig. 3-7 as the side lobe effect. The strength of echo at the short distances, L_b, from the side lobes of the EM waves exceeds the signal strength of the primary signal as reflected from a distance, L_t, that the travel times for the EM waves really

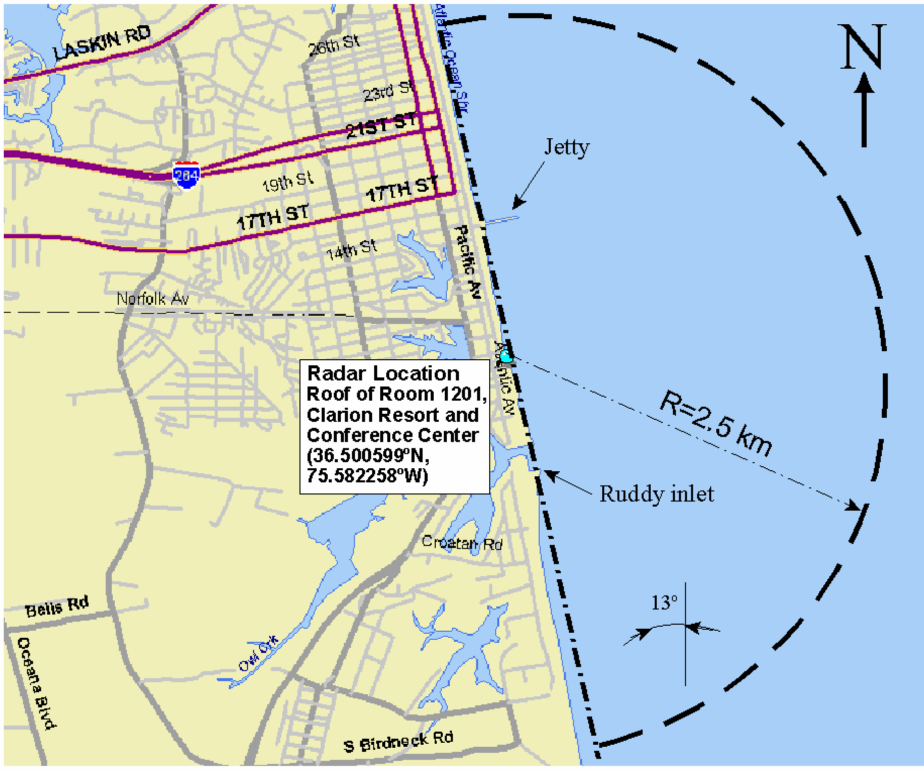

Fig. 3-5. The field experiment site, Virginia Beach, VA.

represented. If there is no side-lobe effect, then the breaking wave foam near the radar center will not be seen. If the height of radar antenna is low enough or if the subject is far enough away from the radar antenna, then the distortion will be negligible. Fig. 3.6 indicates that a distance about 500 m is needed to have a negligible image distortion.

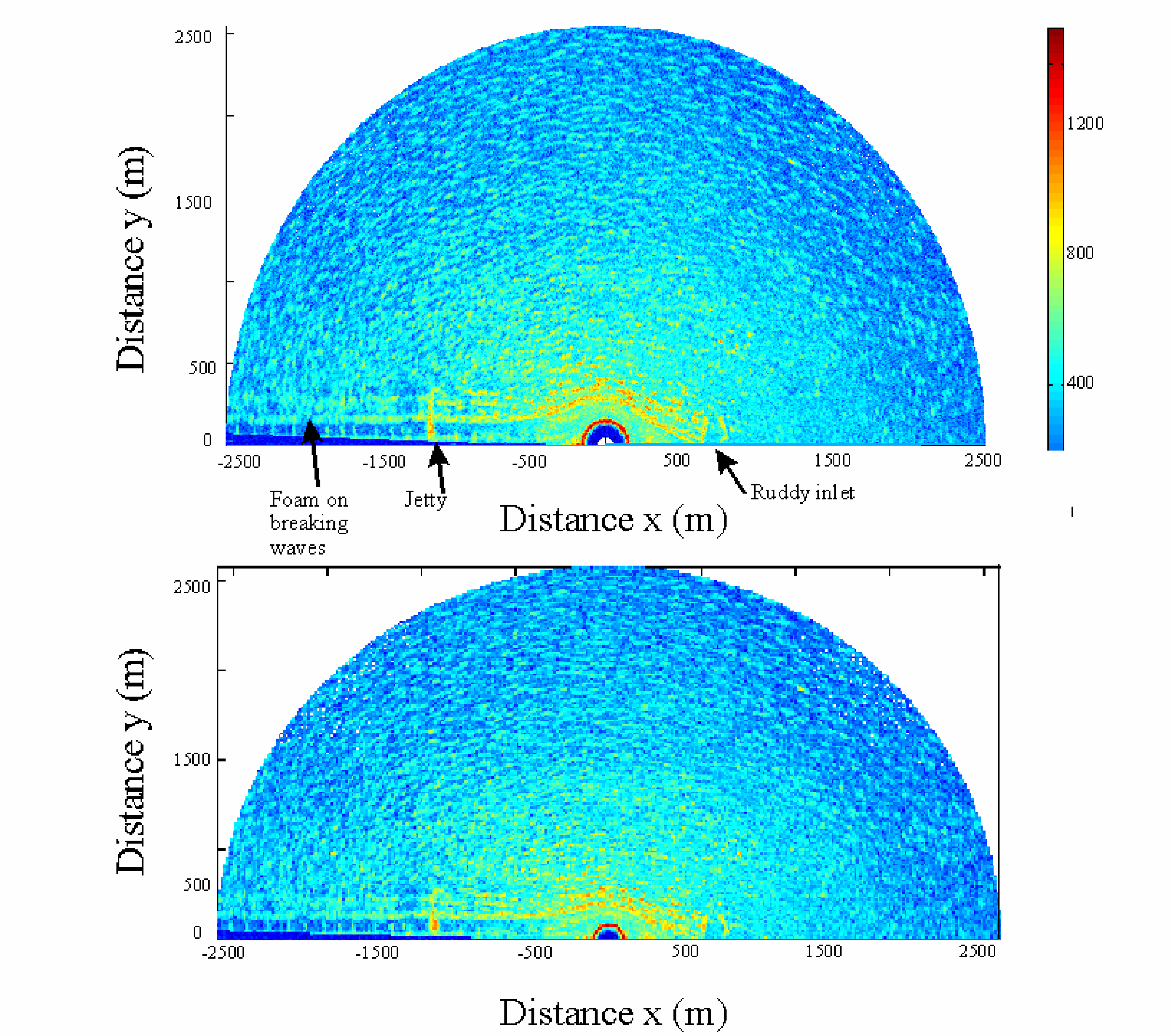

Fig. 3-6. An example of the radar images obtained at the Virginia Beach on 18:00, Feb. 17, 2004. (a) All the radar burst lines (1750) are used (b) only 437 burst lines are used for the image.

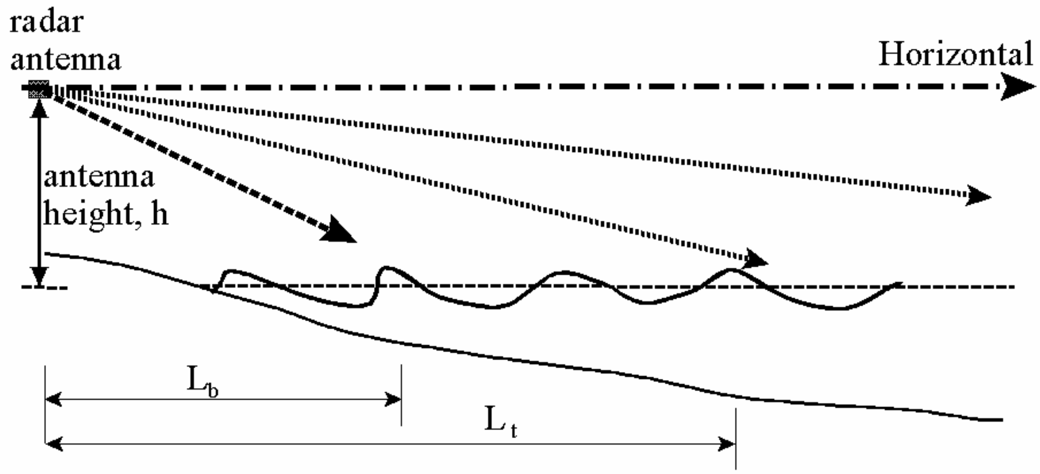

Fig. 3-7. Sketch to show the image distortion caused by side (or side lobe) effect when there is a strong echo at near field (< 500 m from radar). Echoes from breaking wave foams at a distance Lb from the radar exceeds the echo strength at the true distance L t which is calculated by the EM wave travel speed and the time duration after trig.

Chapter 4. Software for Data Analysis

This section starts with the principles of wave spectrum analysis then advances into three-dimensional (3-D) wave spectrum analysis. One-dimensional (1-D) and two-dimensional (2-D) wave spectrum analysis is briefly discussed as an introductionto the concept of Fourier Transform for wave spectrum analysis. After the sequence of data processing is explained, clearly known signals are used to demonstrate. Finally, the section describes a method of testing the program with images representing a random sea.

4.1. Principal of Data Analysis.

Basic analysis of one-dimensional (1-D) and two-dimensional (2-D) wave spectrum serves an introduction to the concept of Fourier Transform for wave spectrum analysis.

4.1.1. 1-D wave spectrum analysis

A time series record of water surface elevations, $\eta(t)$, at a particular observation site can be transferred into frequency domain by using the Fourier Transfer defined as follows.

$$F(f) = \int_{-\infty}^{\infty} \eta(t).e^{-ift}\,dt \qquad (4\text{-}1)$$

where $i = (-1)^{½}$, t is a dummy variable that represent time in this study, and f represents frequency. This definition is for an infinite time series. A Fast Fourier Transform (FFT) algorithm was developed for practical applications with a finite length of discrete data. The FFT uses a reasonable number of data points, n, which can be between 256 and 4096 (*i.e.*, $n = 2^k$ and k = 8 to 12). This algorithm is implemented in Matlab® as a function called FFT.M. Notice that the variable, t, in Eq. 4-1 can represent any physical parameter, for example, spatial distance, x or y. Because the exponential component, ift, should be non-dimensional, it is obvious that f is frequency if t is time.

The output of FFT is an 1-D complex array (*i.e.*, F(f) = R(f) + iG(f), where R and G are the real and imaginary parts of F with the same length as that of the input time series. The dot product of this complex array with its conjugate (*i.e.*, $R^2 + G^2$) is defined as the energy spectrum with a unit of $m^2\ Hz^{-1}$. The frequency resolution is given as $(n\Delta t)^{-1}$, where Δt is the time interval between the water surface elevation samples. Fig. 4-1a is an example of an artificially generated time series of 1024 points for water surface elevations with 12 wave components and $\Delta t = 2$ s. The results of the calculated energy spectrum are given in Fig. 4-1b. Note that the x-axis of Fig. 4-1b runs from 0 to a maximum of Δt^{-1} (0.5 Hz in this example). This is just for convenience in plotting the FFT results. The frequency domain should start at minus infinity ($-\infty$) and end at positive infinity ($+\infty$) for an infinite time series. For a finite length time series, the frequency domain should be from $-0.5*n*\ \Delta t^{-1}$ to $0.5*n\ *\Delta t^{-1}$ with zero frequency in the center. This is accomplished with the Matlab® function FFTSHIFT. For this 1-D case, it simply swaps the left and right halves of the computed results indicated by the dashed array between Fig. 4-1b and 4-1c. FFTSHIFT is useful for visualizing the Fourier transform with the DC component (frequency = 0) in the middle of the spectrum. The traditional way to present the spectrum is by

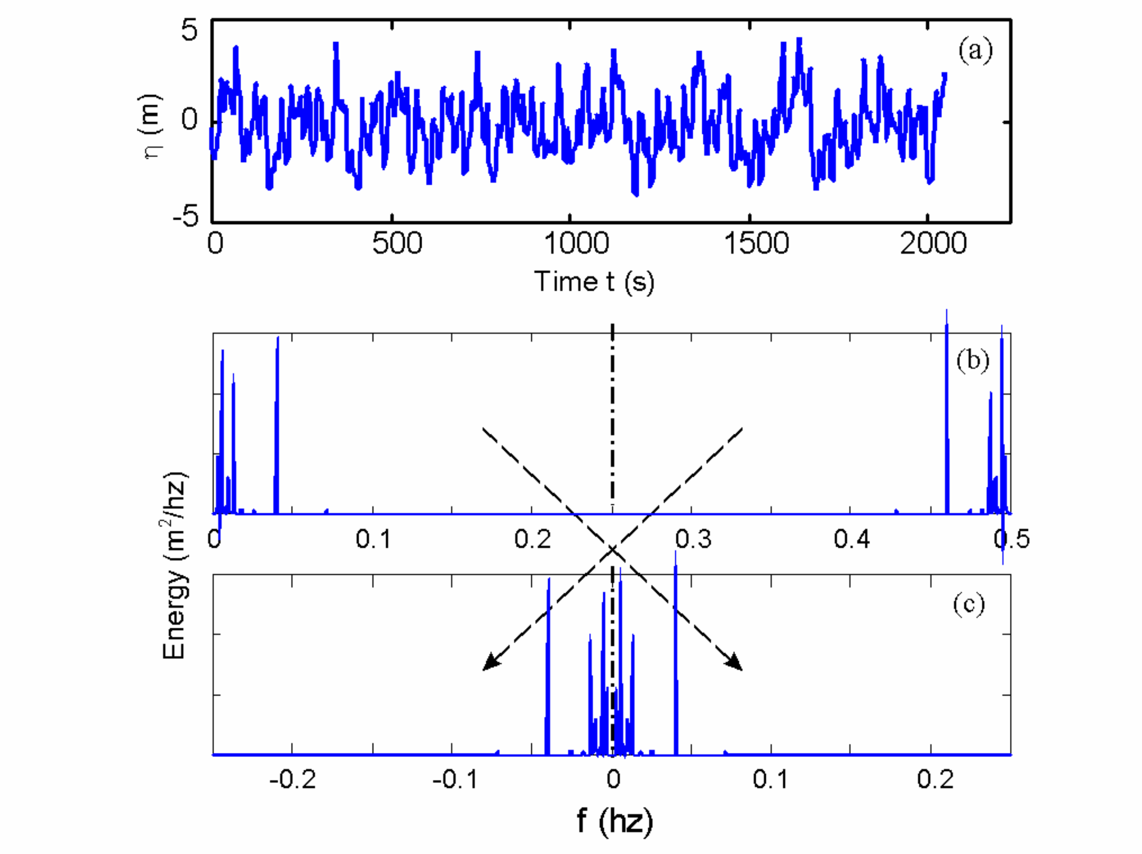

Fig. 4-1. An Example of a time series and the results of calling FFT. (a) η(t) with 12 componential waves, (b) energy spectrum by a direct dot product of F(f) and the conjugate of F(f), and (c) energy spectrum after taking FFTSHIFT.

taking the positive half of the plot (either the left half in Fig. 4-1b or the right half of Fig. 4-1c) and doubling the energy values because of the omission of energy in the negative half frequency domain.

4.1.2. 2-D wave spectrum analysis

A time series record of water surface elevations at specified observation sites along an 1-D spatial domain (here denoted x), η(t, x), can be transferred into frequency and wave number domains by using the 2-D Fourier Transfer defined as follows.

$$F(f,k) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \eta(t,x).e^{-ift} e^{-ikx} dt.dx \qquad (4\text{-}2)$$

where x represents a series of spatial locations (in units of m) where the water surface elevations were measured. Because kx must be a non-dimensional parameter, k must have the dimension of m^{-1}. For the convenience of using trigonometric functions, a coefficient of 2π is included in the definition of k, *i.e.*, k = 2π/L, where L is the wavelength. Note that there are two dummy variables in Eq. 4-2 which can be t and y or x and y. In cases where x and y are chosen as the dummy variables, the resulting function is $F(k_x, k_y)$, where the subscripts x and y represent wave number components in the x and y directions, respectively.

Similar to that for the 1-D FFT, a function for 2-D FFT for a finite length and discrete domain (FFT2.M) also is available in Matlab®. An example of using this function with an artificial signal is given next.

A snap shot of a wave field, $\eta(x, y)$, was generated according to the following equation:

$$\eta(x,y) = a_j*\cos[k_j*\cos(\theta_j)*x + k_j*\sin(\theta_j)*y - \phi_j] \qquad (4\text{-}3)$$

with five monochromatic wave trains, *i.e.*, j = 5 (Fig. 4-2). All the wave amplitudes (*i.e.*, a_i's) were 1 m, and the five wave periods were T = 4, 5 , 7 , 8 and 10 s, respectively. The five wave directions were θ = 160 ^{o}, 100 ^{o}, 60 ^{o}, -65 ^{o}, and 0 ^{o} and the five wave phases were ϕ = 30 ^{o}, 70 ^{o}, 50 ^{o}, 20 ^{o}, and 0 ^{o}. A deep water conditions was assumed, and, thus, the wave number, k, was calculated as $(2\pi)^2/(gT^2)$. The computed wave field had 128 x 64 points with a spatial resolution of 10 m in both the x and y directions (in other words, 1280 and 640 m in the x and y directions, respectively).

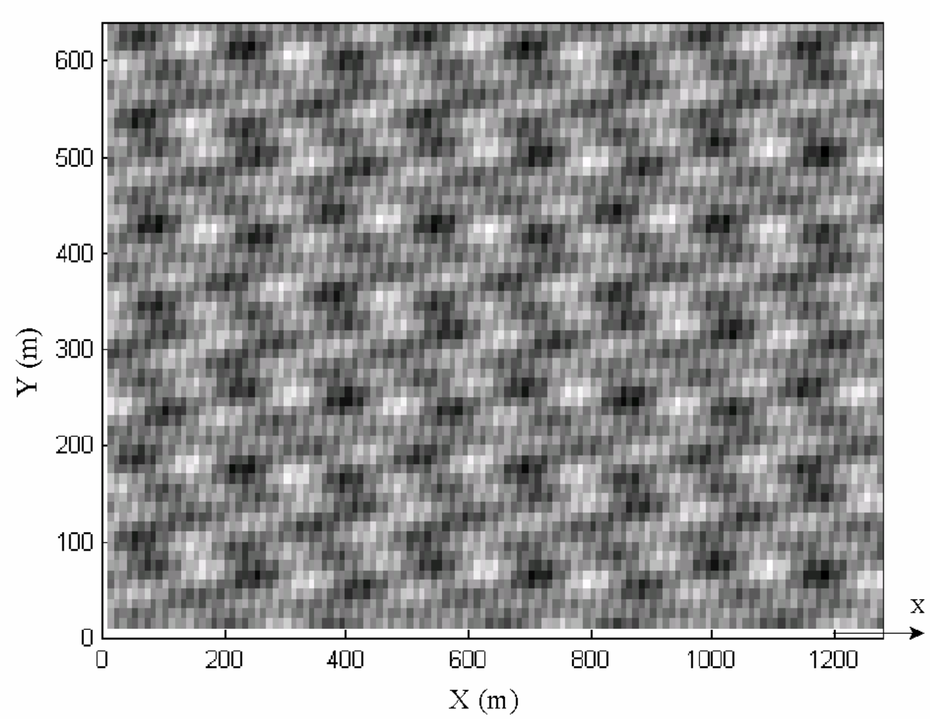

Fig. 4-2. An artificial 2-D wave image, $\eta(x, y)$, generated from an equation with 5 monochromatic waves with period = 4, 5, 7, 8 and 10 s. The wave amplitudes are the same, but the wave angles (160 ^{o}, 100 ^{o}, 60 ^{o}, -65 ^{o} and 0 ^{o}) and phases are different.

For waves in an intermediate water depth where the water depth, h, is known, the wave number can also be obtained using the linear dispersion equation, $\sigma^2 = gk \tanh(kh)$, where $\sigma = 2\pi/T$.

The results of calling FFT2, with FFTSHIFT, are given in Fig. 4-3. Because there is only one snap shot of the wave field, the wave direction cannot be addressed, and thus, the problem of directional ambiguity remains. Nevertheless, for the given wave condition, the FFT2 results clearly show all the 5 wave components. The magnitude for each of the wave components, however, cannot be equal because of the requirement for the best spatial resolution is different for each frequency.

Figure 4-3 can also be translated into energy distribution in frequency, f, and direction, θ. This task is carried out later in Sec. 4.2.

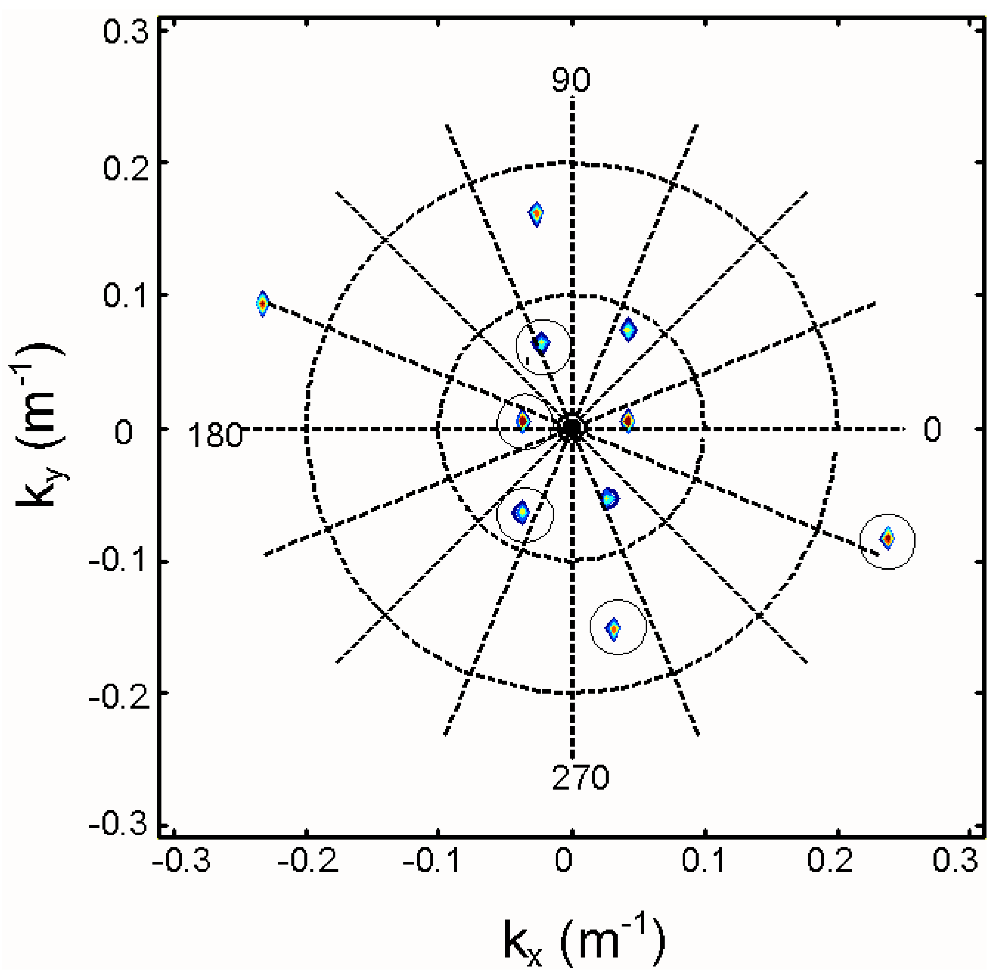

Fig. 4-3. Calculated wave directional distribution using the wave image given in the previous figure. Direction ambiguity is associated with this 2-D FFT. Energy peaks inside the small circles are the false signals.

4.1.3. 3-D wave spectrum analysis

Similar to 2-D wave spectrum analysis, a time series record of water surface elevations at specified observation sites on a horizontal 2-D domain (here denoted as x, y), $\eta(t, x, y)$, can be transferred into frequency and two wave-number (k_x and k_y) domains by using the 3-D Fourier Transfer defined as follows.

$$F(f, k_x, k_y) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \eta(t, x, y).e^{-ift} e^{-ikx} e^{-iky} dt.dx.dy \qquad (4\text{-}4)$$

A function for n-dimensional FFT with a finite length of data record (FFTN.M) is available in Matlab®. An example of using this function with an artificial signal is given next.

The wave data are n snap shots of the wave field, $\eta(x, y, t)$, which were generated according to Eq. 4-5. This equation has only one extra term (*i.e.*, σ_i t) added to produce n snap shots (Fig. 4-4 with a total of 64 snap shots with $\Delta t = 2$ s). All other parameters are the same as those given in the previous section except that $\Delta x = \Delta y = 7.7985$ m and the five wave directions are 160^o, 20^o, 60^o, -65^o, and 20^o, respectively.

$$\eta(x,y,t) = a_j*\cos[k_j*\cos(\theta_j)*x + k_j*\sin(\theta_j)*y - \sigma_j t + \phi_j] \qquad (4\text{-}5)$$

The result of calling FFTN, $F(f, k_x, k_y)$ is also a 3-D complex matrix with exactly the same dimension as that for the input $\eta(x,y,t)$: 64 frequency bands, 128 k_x bands, and 64 k_y bands. There are two ways of presenting the results in graphic form: (1) plotting the energy distribution for each frequency band, or (2) summarizing the results and plotting the directional energy distribution in one figure. In this section, the results are presented in the first form only.

There should be at least 32 plots to present all the information. However, only those frequency bands that contain a relatively large amount of energy are presented in Figs. 4-5 and 4-6. Because a series of snap shots are available, the directional ambiguity problem is addressed correctly when the frequency is reasonably lower than the Nyquist frequency (Oppenheim, 1999), *i.e.*, 1 $(2\Delta t)^{-1}$ (Fig. 4-5). When close to the Nyquist frequency, however, directional ambiguity problem remains (Fig. 4-6). This is because the time interval between two consecutive snap shots is too big to distinguish the wave propagation direction for that frequency band.

Notice that the above two figures show the energy distribution for each frequency band. Actually, there is redundant information included in the two figures because k_x and k_y also include wave frequency and wave direction information, if the linear dispersion equation, $\sigma^2 = gk \tanh(kh)$, is used. For this reason, the second way of presenting the 3-D FFT results can be summarized in a single plot and that is explained in next section.

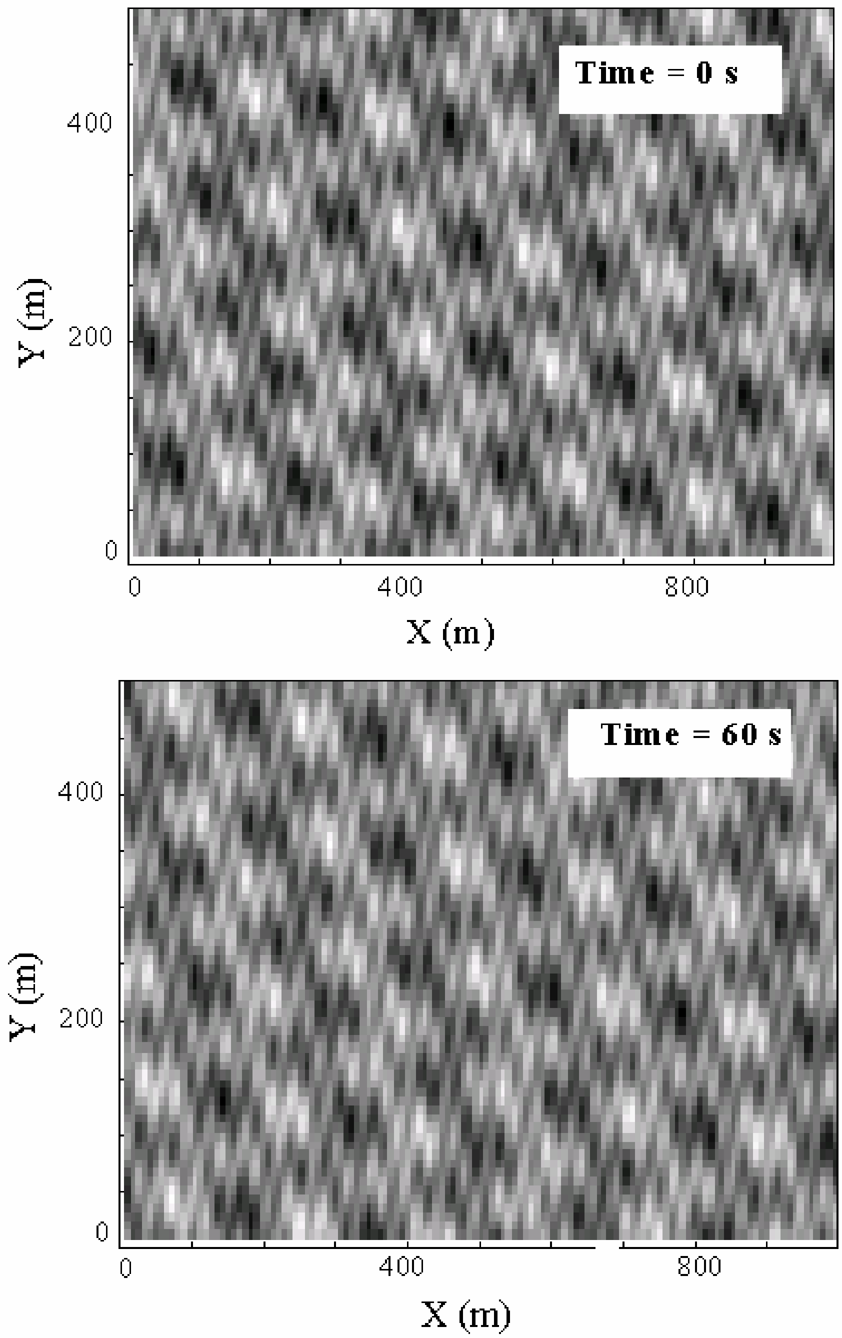

Fig. 4-4. The first and the 30th images of a series of 64 artificial 2-D wave images, η(x, y, t), generated with the conditions given in Section 4.1.3.

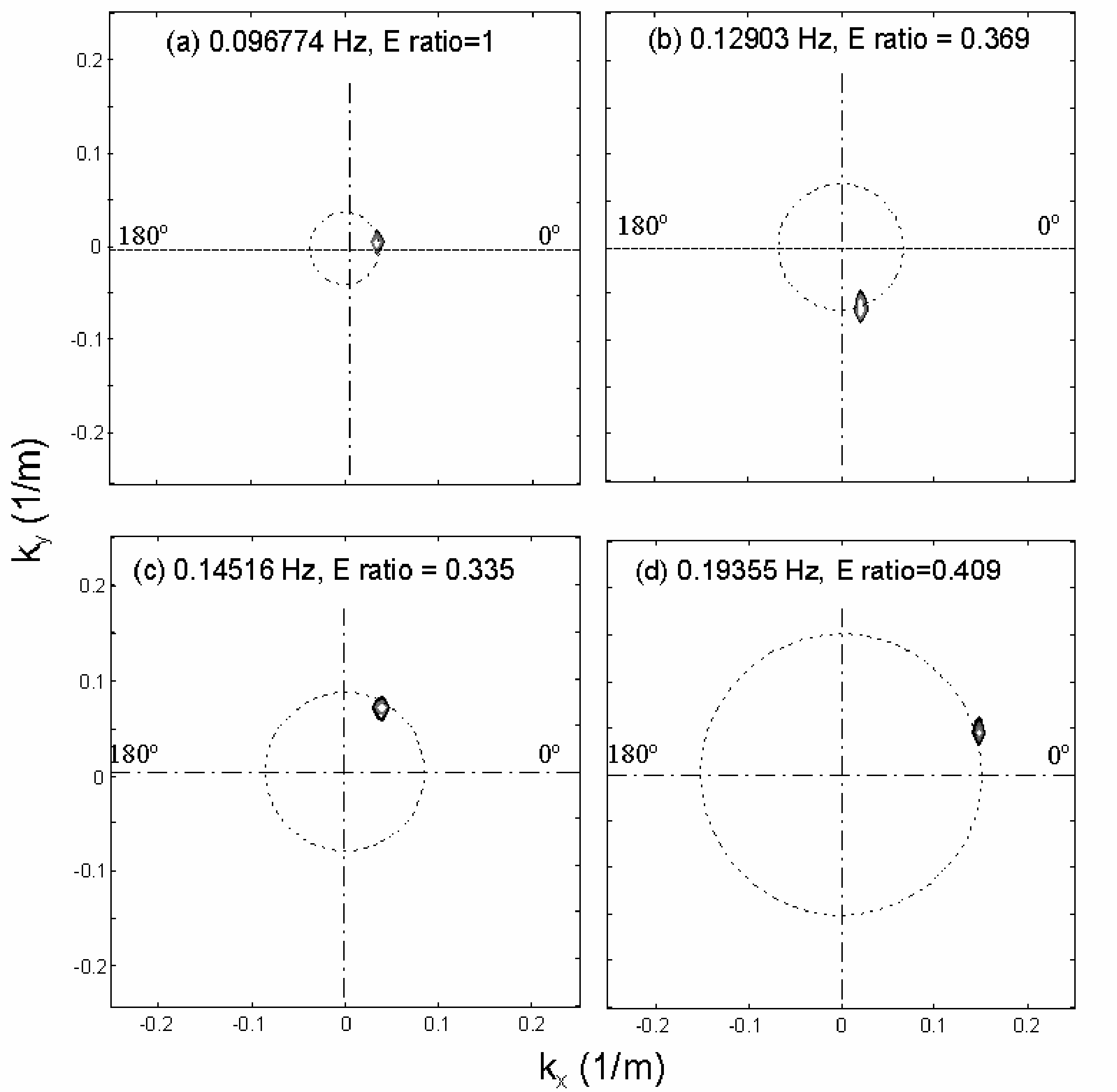

Fig. 4-5. Part of the calculated wave energy directional distribution using the time series of wave images given in the previous figure. Directional ambiguity is absent with 3-D FFT when the frequency is far below the Nyquist frequency. Only those frequencies that have a noticeable energy (E ratio > 0.2) are plotted.

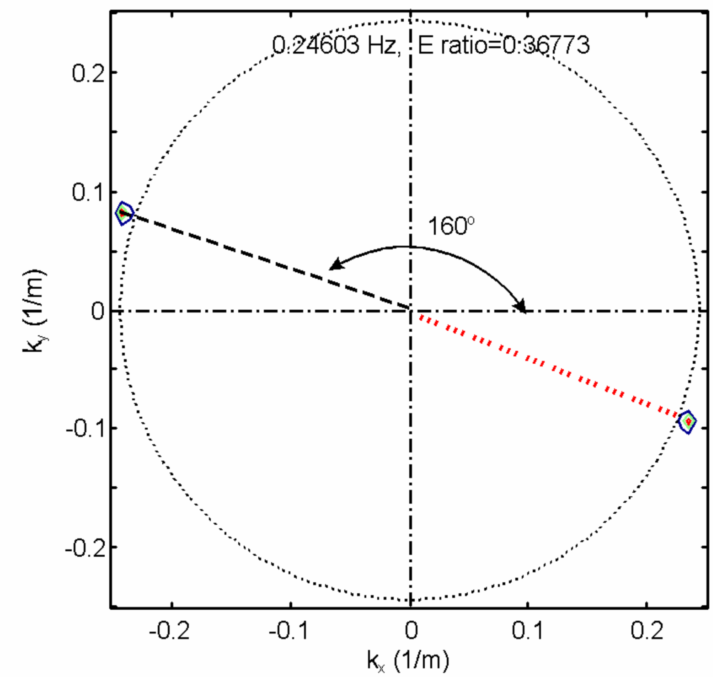

Fig. 4-6. A plot of directional wave energy distribution at a high frequency band showing that the directional ambiguity problem remains when close to the Nyquist frequency (0.5 t^{-1}) = 0.25 hz. The energy in the 4th quadrant is the false signal.

4.2. Given Regular Wave Fields

Since the 3-D FFT result is a 3-D matrix that includes information for n frequency bands, m k_x bands and L k_y bands, one way to present the summarized results is to add the n frequency bands together to form a single 2-D matrix in k_x - k_y plane. This can be done relatively easily by retrieving the energy density in the k_x - k_y plane for each frequency band and adding them together, with a multiplier of $(n/dt)^{-1}$ for the true spectrum energy.

An example of a monochromatic plane wave field (*i.e.*, j = 1 in Eq. 4-5) (Fig. 4-7) demonstrates the process. The spatial domain has 128 points in both the x and y directions, with $\Delta x = \Delta y = 7$ m. In the time domain, 32 snap shots were generated with $\Delta t = 1.66667$ s. The deep-water condition was used again for this example. After calling FFTN, the results of adding all the 32 frequency bands, $\phi(k_x, k_y)$, are given in Fig. 4-8a. The spike (because of the monochromatic waves) in the first quadrant of this sub-plot shows that the wave direction is 45°. This sub-plot has a Cartesian coordinate system with data point on a grid with equal intervals in the k_x - k_y plan, *i.e.*, $\Delta k_x = \Delta k_y = 2\pi\ (128 * 7\ \text{m})^{-1}$.

Knowing that $k_x = k \cos(\theta)$ and $k_y = k \sin(\theta)$, all the values on each grid point of this Cartesian grid can be translated into polar coordinates (k-θ) grid. The Matlab® function CART2POL.M can be used to perform the translation. Note that the energy value at each grid point also changes because of the coordinates change. The following equation was used (Young *et al.*, 1985).

$$\varphi(k,\ \theta) = k\ \phi(k_x, k_y) \qquad (4\text{-}6)$$

where φ(k, θ) is the wave energy distribution in k-θ plane.

The distances between the new grid points in the rectangular k-θ plane (Fig. 4-8b) is not the same, and thus, a new grid with equal spacing in Δk and Δθ, is needed. This calls for interpolating the energy values at each new grid point for the rectangular k-θ plane. This is done with the Matlab® function GRIDDATA. After using GRIDDATA, however, one finds that the wave energy at a few grid locations (mainly with a low k coordinate and when the θ coordinate is close to 0^o or 360^o) are specified as "nan," which stands for "not a numerical value." This is caused by not having sufficient spatial resolution to interpret wave energy at low k values (Fig. 4-8b), without data from the negative θ coordinates and without data with a θ coordinate that is larger than 360^o. A simple treatment of this problem would be to replace the "nan" with zero. This is efficient and satisfactory for coastal wave observations because there should be few waves that travel parallel to the shoreline (an angle of 0^o, 180^o, or 360^o).

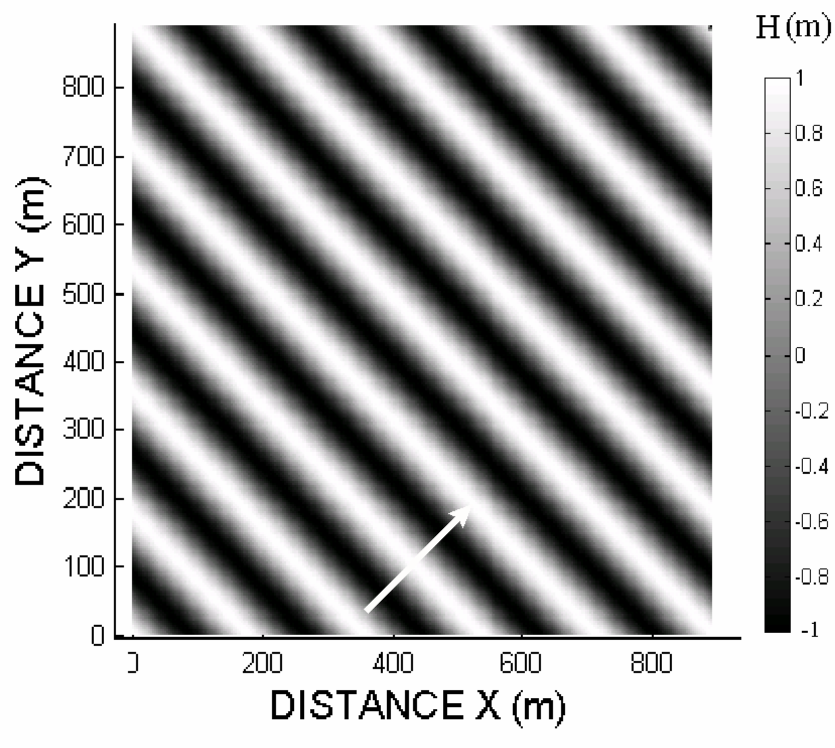

Fig. 4-7. The first image of a 10 s monochromatic wave trains was generated with H = 2 m, and traveling 45 degrees from the x axis.

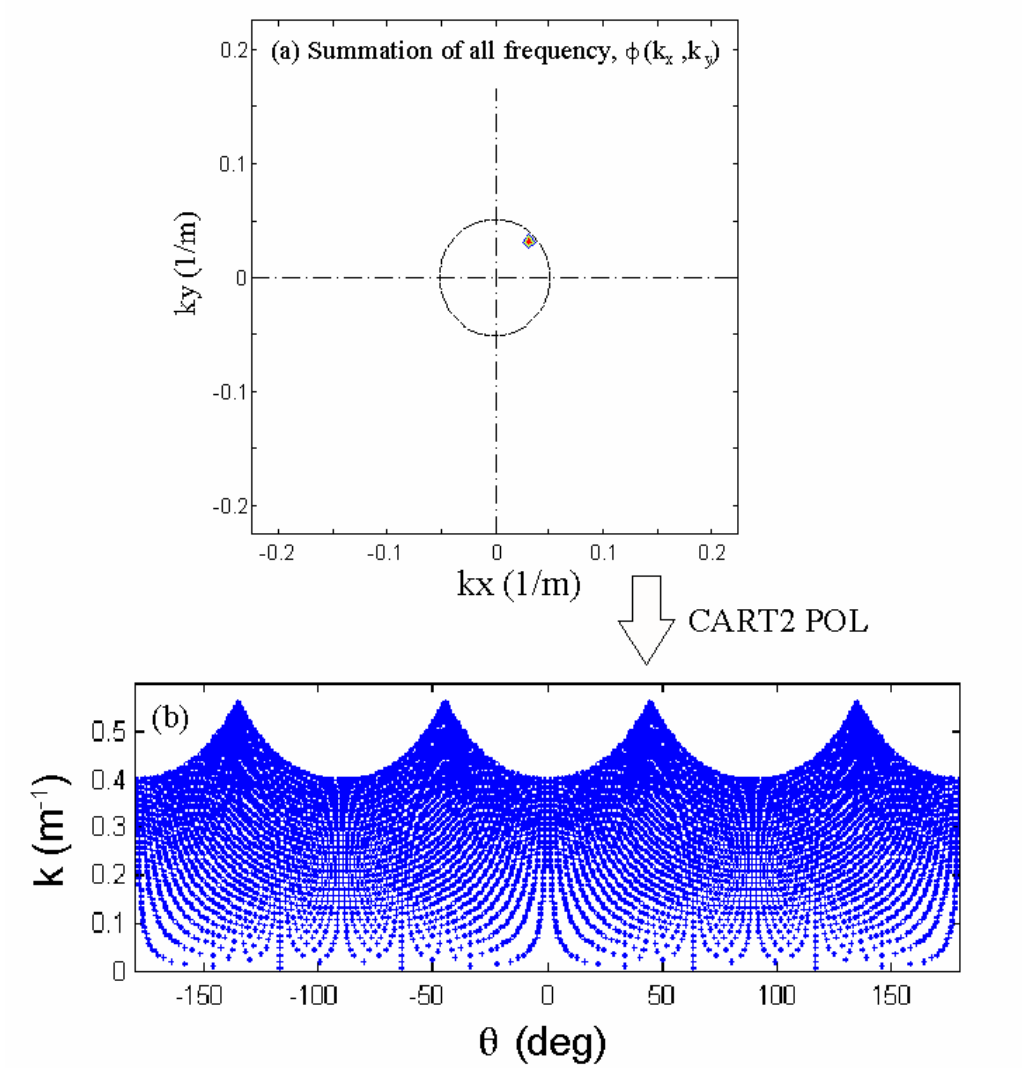

Fig. 4-8. Translation of wave energy distribution in (a) the k_x - k_y plane into (b(the k - θ plane is the first step in showing the 3-D FFT results in one plot. Dots in the k - θ plane are the locations of all available data after translating from the k_x - k_y plane. The dashed circle in the k_x - k_y plane indicates $k = 0.5\ m^{-1}$. The uneven data spacing in the k - θ plane calls for a new data grid with equal space in k and θ coordinates.

Now that the wave energy distribution is presented in the k-θ plane (Fig. 4-9a), it might be usefully to display the wave energy directional distribution in the more commonly used f-θ plane (Fig. 4-9b).

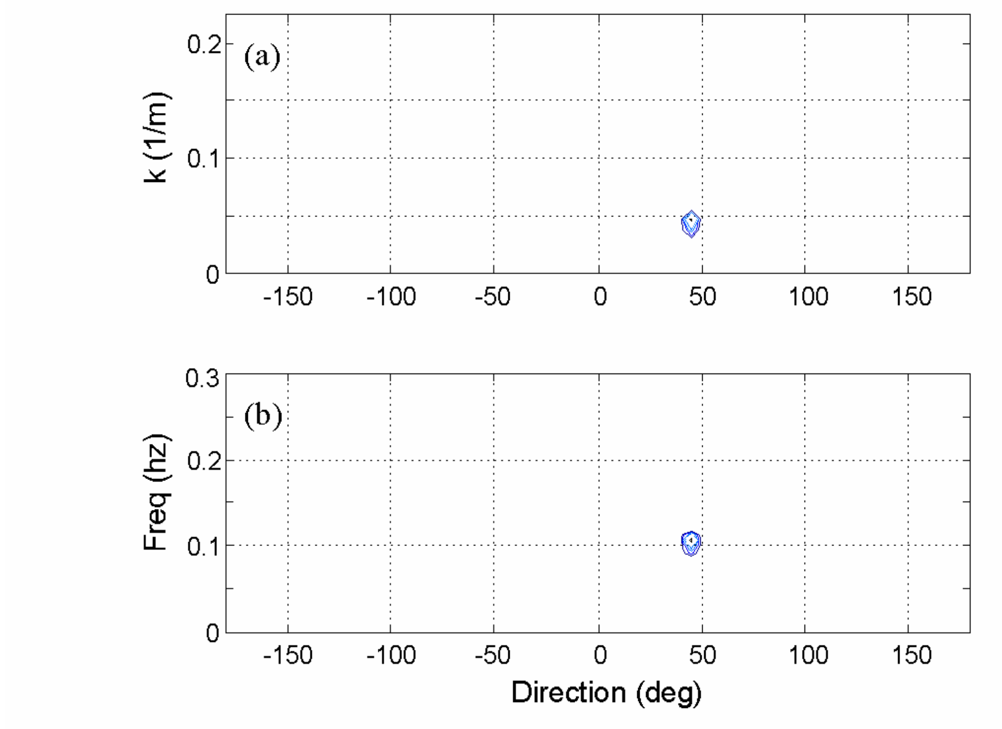

Fig. 4-9. Directional spectrum obtained from analysis of the regular wave images: T = 10 s, H = 2 m, direction = 45 deg. (a) k - θ spectrum, (b) f - θ spectrum.

This translation follows the formula given by Young *et al.* (1985) is

$$\psi(f,\theta) = \frac{dk}{df}.\varphi(k,\theta) \qquad (4\text{-}7)$$

where dk/df is the Jacobian matrix between ψ and φ. According to the wave dispersion relationship in linear wave theory, it can be calculated as

$$\frac{dk}{df} = \frac{4\pi\sqrt{gk\tanh(kh)}}{g\tanh(kh) + gkh \ \ \mathrm{sec}\,h^2(kh)} \qquad (4\text{-}8)$$

Since line spectra are frequently used, it is desirable to present the line spectrum as well. This can be done simply by summing the energy in all direction domains for each frequency band (Fig. 4-10).

No matter the coordinate system in which a wave energy distribution is presented, the total energy should remain the same. This can be verified by using the total volume, v_o, under the directional spectrum, or the total area, m_o, under the line spectrum. This is because the significant wave height, H_s, can be found as

$$H_s = 4.02\sqrt{m_o}. = 4.02\sqrt{v_o} \qquad (4\text{-}9)$$

Note, however, the H_s calculated in Eq. 4-9 is based on the random sea with a Rayleigh distribution of wave height for unit sea surface area (Dean and Dalrymple, 1992). In other words, the effect of the computing domain should be excluded. For monochromatic waves, the input wave height specified actually is the root-mean-square wave height (H_{rms}) that is $H_s * (1.414)^{-1}$ For example, the given input monochromatic wave height is 2 m which corresponds to specifying an H_s of 2.83 m. The calculated H_s during various stages of the Matlab® program FFT3D_RADAR.M (see appendix III) is around 2.84 m. This example indicates a small error of 0.01 m for the selected settings of Δx, Δy, Δt, and the simulation domain. This represents an error around 0.4%.

The results for the other tested wave periods with the same wave image domain (896 m = 128 * 7 m), image resolution (7 m x 7 m), temporal domain (53 s = 32 * 1.66667 s), and temporal resolution (1.66667 s), are given in Table 4-1. In general, the results are good except for the short period waves, *i.e.*, the 5 s wave trains. The average error is about 8% in terms of the calculated H_s, if the case for 5 s waves is excluded.

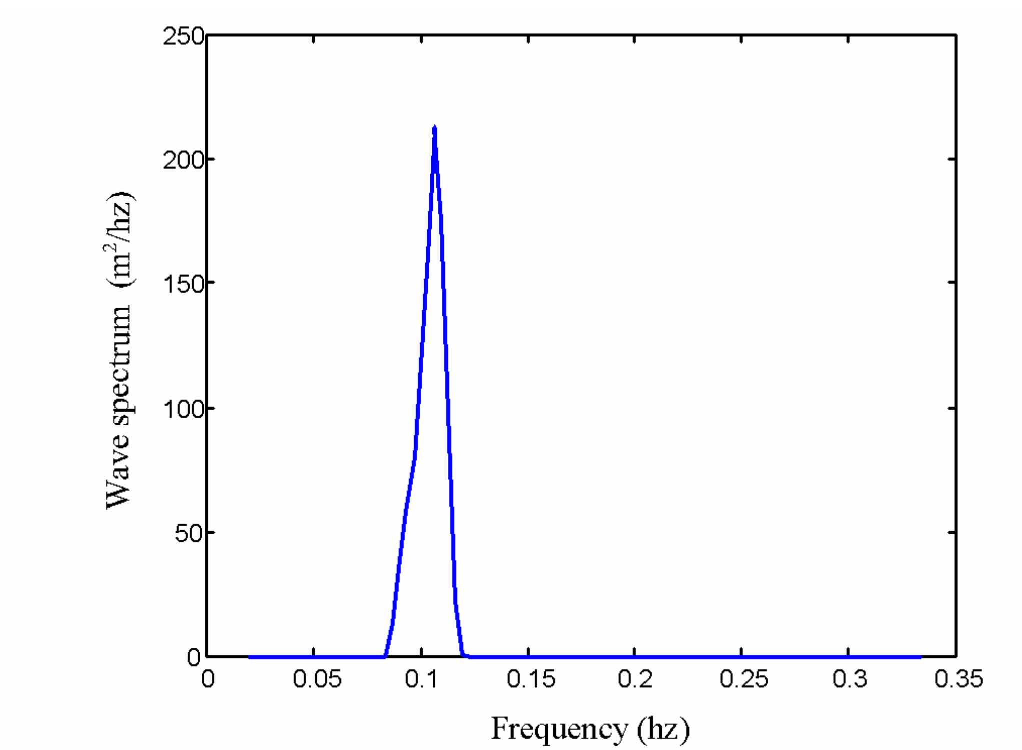

Fig. 4-10. Linear wave spectrum obtained by integrating the f - θ spectrum for the regular wave images with T = 10 s and H = 2 m.

Table 4-1. Test results for monochromatic wave trains with a given Hs = 2.83 m.

Period (s)	5	6	7	8	9	10	12	14
Angle (deg)	100	45	130	60	45	90	130	135
H_s (m)	1.12	3.02	2.42	2.94	2.35	2.84	2.71	3.02
Error (%)	-60	6.7	-14.5	3.9	-17	0.4	-4.2	6.7

The wavelength of 5 s, deepwater waves is 39 m. Thus, the 9.9 m, *i.e.*, $(7^2 + 7^2)^{1/2}$, spatial resolution and 1.66667 s temporal resolution may not be satisfactory. By reducing the spatial resolution, *e.g.*, changing Δx and Δy to 5 m, but maintaining Δt = 1.66667 s, the calculated H_s improves to 1.94 m, but the directional ambiguity problem remains because of the large Δt (Fig. 4-11a). When temporal resolution is increased by using a smaller Δt (1.25 s), the directional ambiguity problem disappears (Fig. 4-11b). This is a clear indication that the antenna should have a high rate of rotation if the expected wave period is small at a radar observation site. Also the results for short period waves improve with higher the temporal resolution.

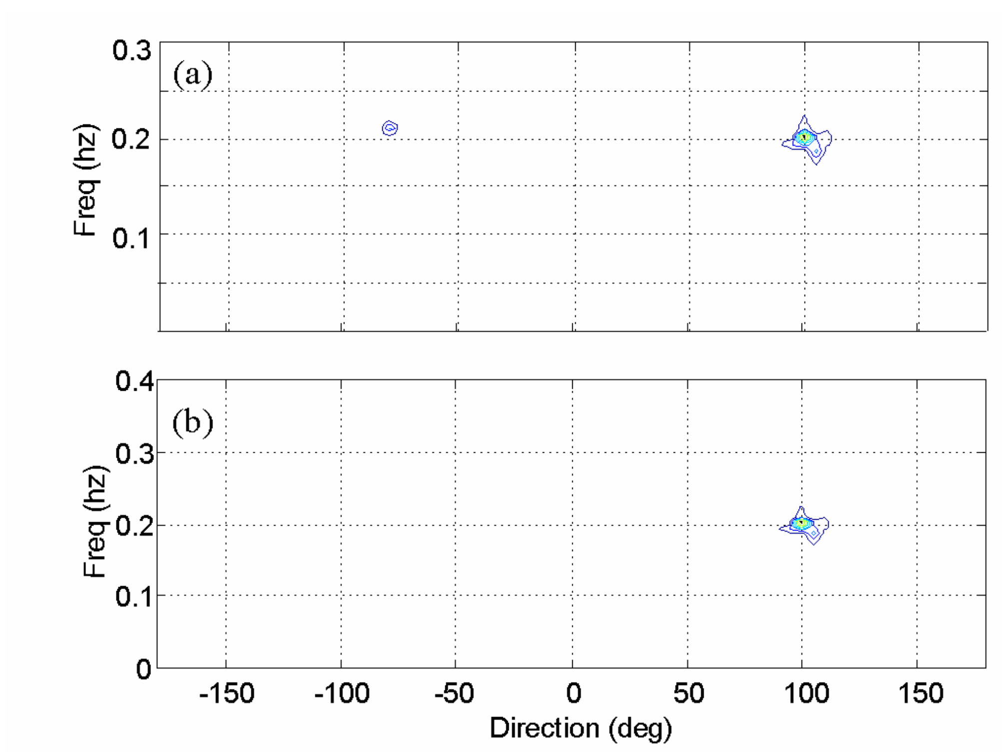

Fig. 4-11. Directional spectrum obtained from analysis of the regular wave images with T = 5 s, H = 2.83 m, direction = 100 deg. and a finer spatial resolution, x = y = 5 m. (a) Directional ambiguity problem remains for short period waves with a large Δt = 1.6667 s. (b) When reducing Δt = 1.25 s, the direction ambiguity problem disappears.

4.3. A Given Random Wave Field

It would be beneficial to verify the program developed in the previous section with images of a clearly known, random sea. This is not a simple task, however, and a month-long attempt to generate this kind of images was not successful, and thus, abandoned at an early stage. Fortunately, a software package DIrectional WAves SPectrum (DIWASP) developed at the Center for Water Research, University of Western Australia (Johnson, 2005) became available and was used successfully to generate this data. An example of the DIWASP generated images for random sea is available on the VIMS web site (http://www.vims.edu/physical/projects/diwasp/) as a depiction of the nature of a random sea.

The 64 consecutive random sea images used for verifying the 3-D FFT program given in the previous section specified a significant wave height of 2.83 m, a frequency at the peak energy of 0.1 Hz, moved toward the positive y direction (Fig. 4-12). In other words, the major wave direction was 90 degrees from the x –axis. Other parameters were specified as follows: directional spreading = 10^o, noise level = 25 (with a range from 0 to 100), water depth at the image site = 26 m, time interval between two consecutive images = 1.66667 s. Each image has 128 points in both the x and y directions, with a grid resolution of 8 m in both the x and y directions.

At a frequency that is close to the wave peak energy frequency, the program calculated directional spreading is probably more than 10 degrees (Fig. 4-13). This may be because of the selected noise level of 25. Nevertheless, the direction is correctly calculated as 90 degrees in the k_x - k_y plane. After transferring to the f - θ plan, it can be seen more clearly that the peak energy frequency is around 0.1 Hz, with a main direction of 90^o (Fig. 4-14a). This time, the energy was spread over a much large domain, caused by the nature of random sea. The given directional wave spectrum that was used to generate the wave images is also displayed (Fig. 4-14b). A much smoother contour plot for the given directional spectrum is evident. The line spectrum (Fig. 4-15) also shows the results correctly and the significant wave height calculated from the program (H_s = 2.81 m) has a negligible error of 0.7%.

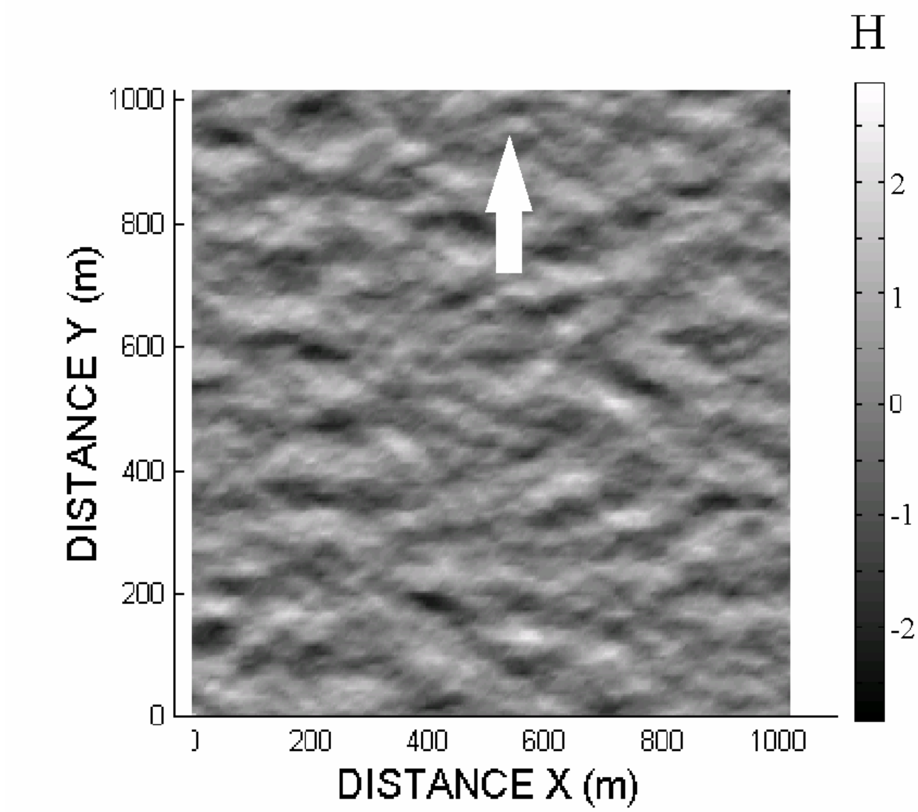

Fig. 4-12. First image of a series of random wave fields generated by using DIWASP package with peak wave frequency f_p = 0.1 Hz, H_s = 2.83 m, traveling in the positive y-axis direction.

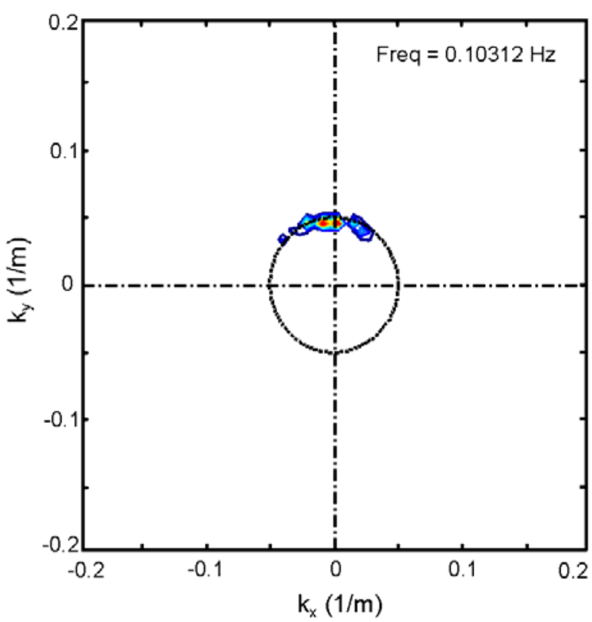

Fig. 4-13. Results from 3-D FFT in k_x - k_y plane to showing the directional spreading at a frequency band close to the given peak energy frequency for the random sea generated by using DIWASP.

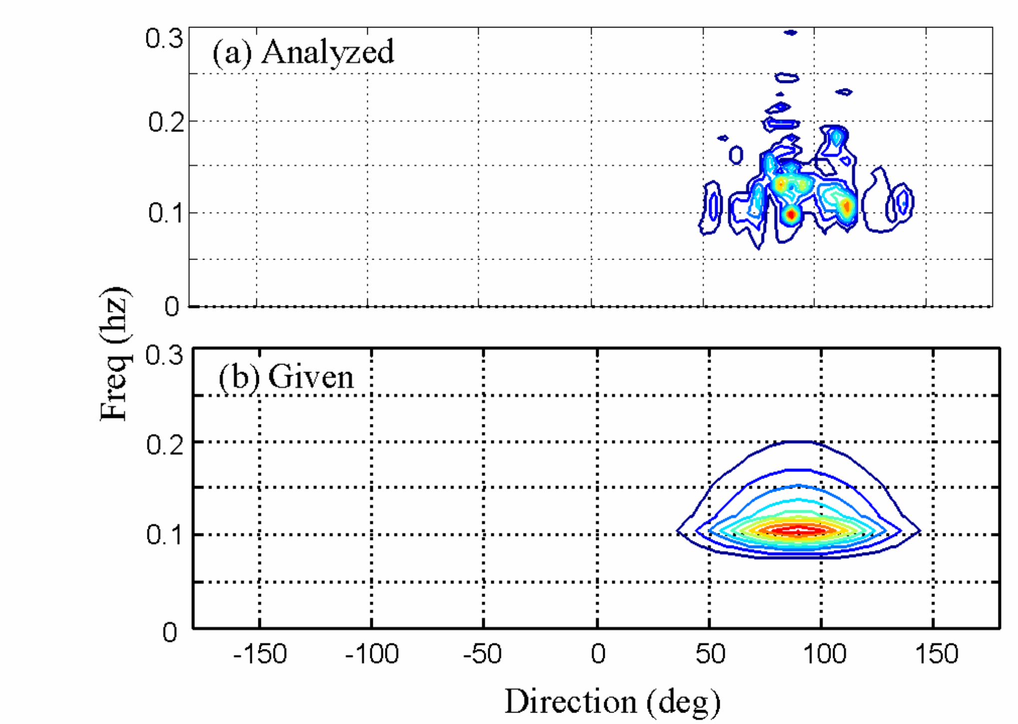

Fig. 4-14. Comparison of directional wave spectra. (a) Analyzed from the random sea images generated by using DIWASP, (b) from the given input spectrum.

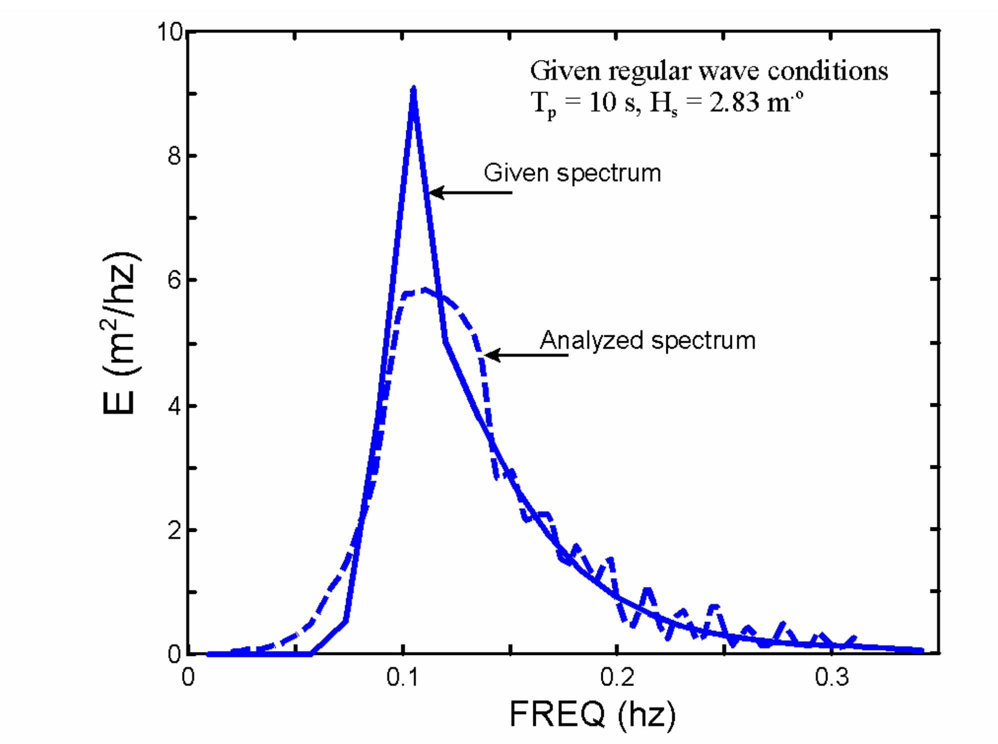

Fig. 4-15. Comparison of the analyzed and given line spectra for the random waves images.

Chapter 5. Data Processing of the Radar Images

The data analysis tool presented in the previous chapter uses data generated on a horizontal plane without any distortion. Radar images, however, are obtained from a side view with distortion. For this reason, there are a few steps that need to be taken before the wave analysis can proceed. These steps are (1) reducing the signal distortion caused by differing distance, (2) judging the sea severity, (3) selecting a small rectangular sub-domain, (4) interpreting signals for the sub-domain, and (4) analyzing the wave directional spectrum. Following the material presented in this chapter, one should have no difficulty understanding the computer codes (in Matlab®) for data analysis that are given in Appendix III.

5.1. Minimize Signal Distortion

Since the detected radar return signal strength, S, is inversely proportional to the distance from the subject to the radar antenna, r, according to $S = f(r^{-3})$, the recorded signals for the entire radar observation domain will be different even the sea severity is the same for the entire domain. For example, the signal strength varies significantly from 0 to 1000 for the raw image (Fig. 5-1a). The numbers used here are integers recorded from the high speed ADC. There is no need to transfer these integer numbers to floating numbers for voltage because they do not represent true wave heights. Nevertheless, there is a significant range to these.

Since the attenuation of radar signal strength is proportion to r^{-3}, an intuitive approach to reducing the signal difference would be taking the one-third power on the signal. This will substantially reduce the signal difference caused by distance. For example, Fig. 5-1b has a much smaller range (from 0 to 11). Note that as yet there is no theoretical proof for this approach and a relative difference still exists in the signal. Nevertheless, the difference in signal strength caused by distance is reduced significantly. It appears to the naked eye does not have a great effect if the wave period is short (with a short wavelength); but it can seen more clearly when the wave period is large, *e.g.*, on Feb. 18, 2004, 08:00 (Fig. 5-2).

This process is particular helpful when the sea severity is low. For example, at 10:00, Feb. 19, 2004, the raw radar image (Fig. 5-3a) just barely shows the swells. After taking the one-third power on the raw signals, the swells are clearly shown (Fig. 5-3b). Notice, however, if the sea is calm, then this approach cannot help much. For example, the raw radar image of a calm sea on March 2, 2004, 21:00 (Fig. 5-4a) hardly shows any wave clearly, and the processed image (Fig. 5-4b) also does not show a clear wave pattern.

The above information indicates that there is a threshold for using the x-band radar for wave observation. As discussed in Chapter 2, a minimum wind of 3 m/s is required. Here another index, average radar signal strength (S_a), discussed below, is also useful.

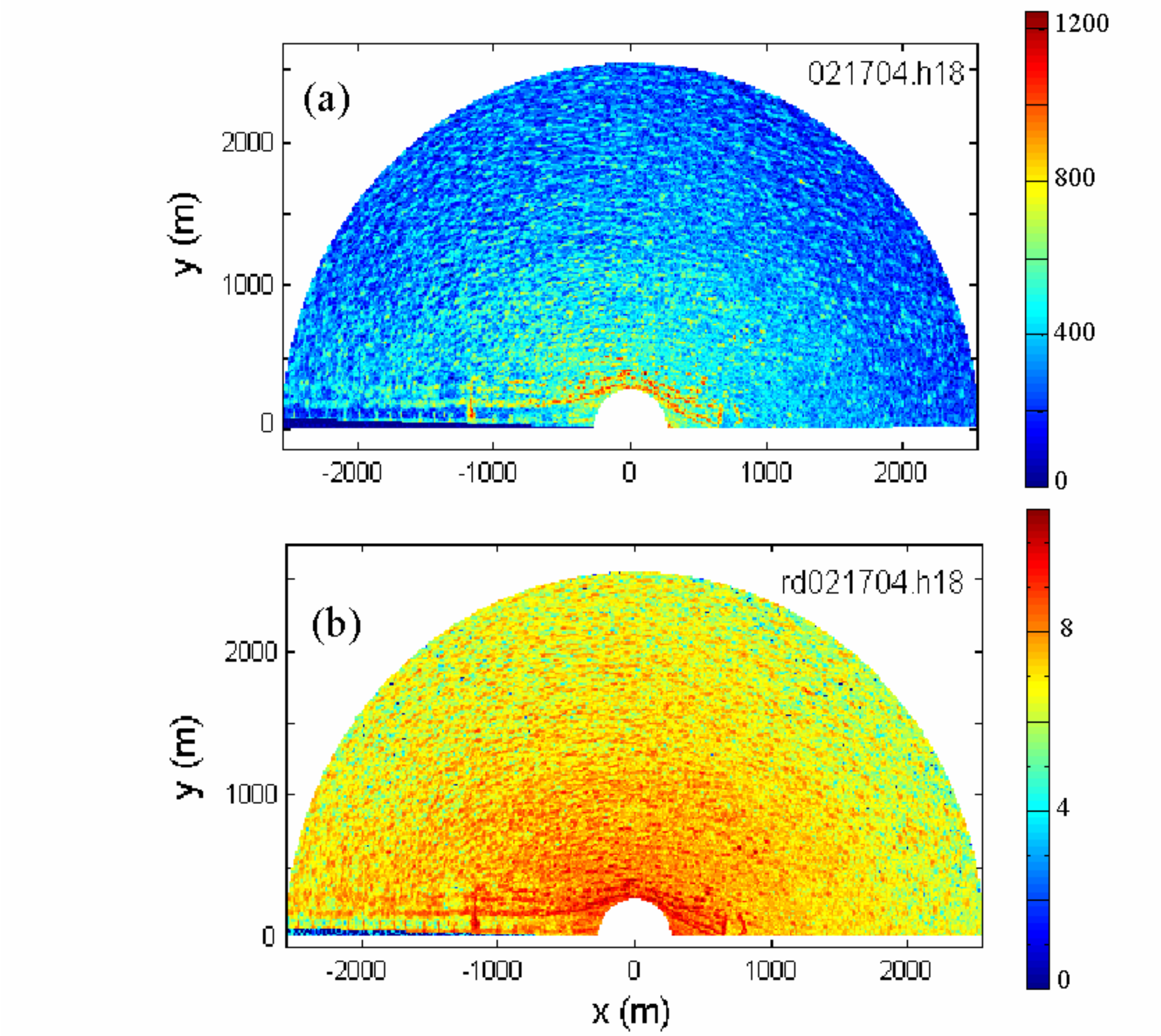

Fig. 5-1. A radar image with a relatively severe sea (Sa = 410) obtained at Virginia Beach at 18:00, Feb. 17, 2004. (a) Image from raw data, (b) image after a processing to reduce the distance effect.

5.2. Average Radar Signal Strength, S_a

Average Radar Signal Strength, S_a, can be obtained relatively simply. After taking the radar images, a simple summation of all the signals on all the radar track lines can be obtained. This process does not have to use all the images, just one or two would be enough because there is little change between images. It was found that the first three images yielded a negligible difference in S_a.

The values of S_a for the four cases mentioned in the previous section are also given in the figure captions. It can be seen that a minimum S_a value of 120 to 150 is necessary to see a wave field. A summary of S_a value for the survey period in February and March of 2004 is presented in Fig. 5-5. This figure indicates that a minimum sea severity about 120 is necessary to perform the rest analysis. In future operation, if S_a does not meet this minimum

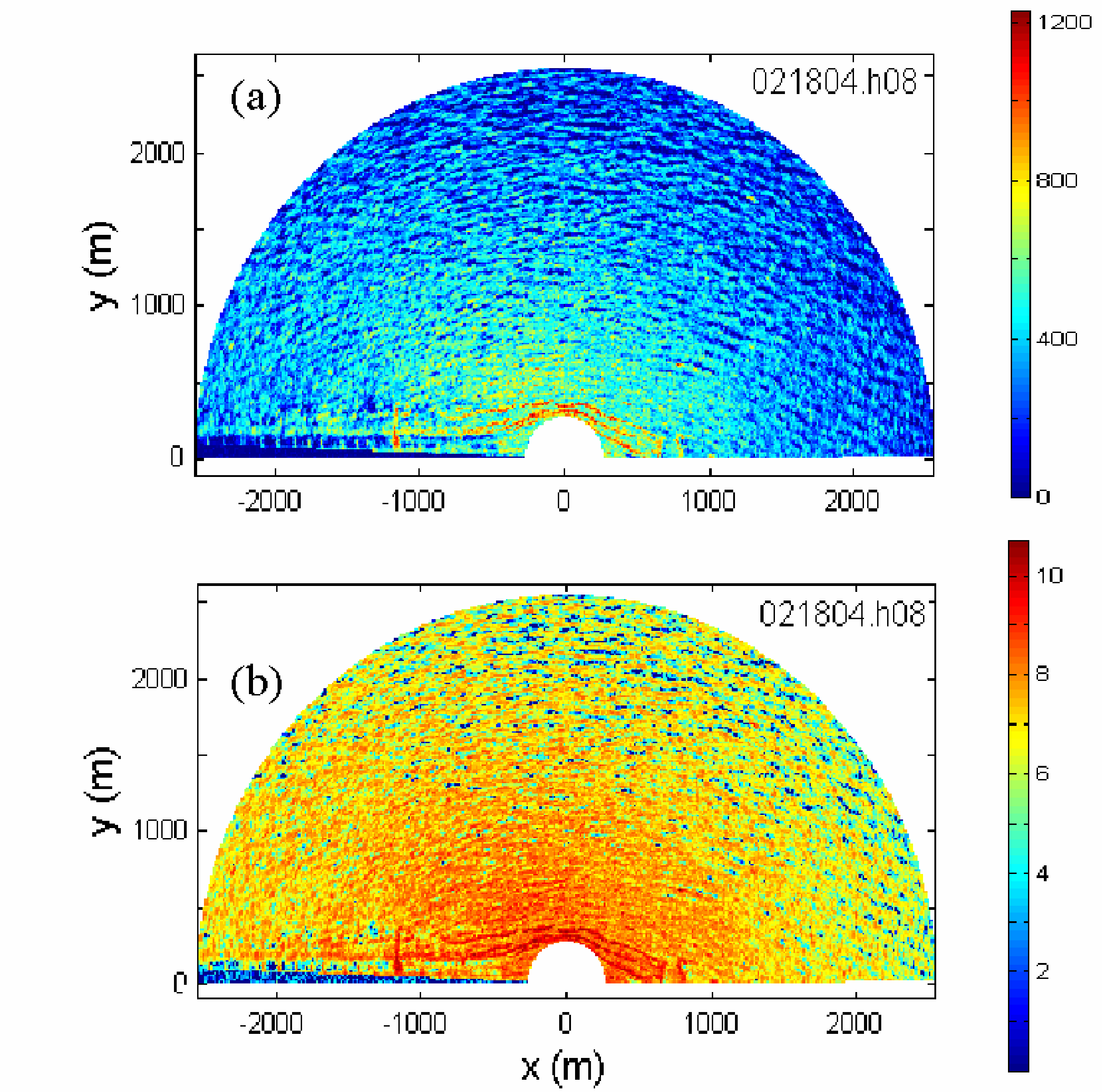

Fig. 5-2. A radar image with a relatively severe sea (Sa = 404) obtained at Virginia Beach on 08:00, Feb. 18, 2004. (a) Image from raw data, (b) image after processing to reduce the distance effect.

(or a later revised value), then a calm sea may be assumed, and the system can shut down immediately to save the battery.

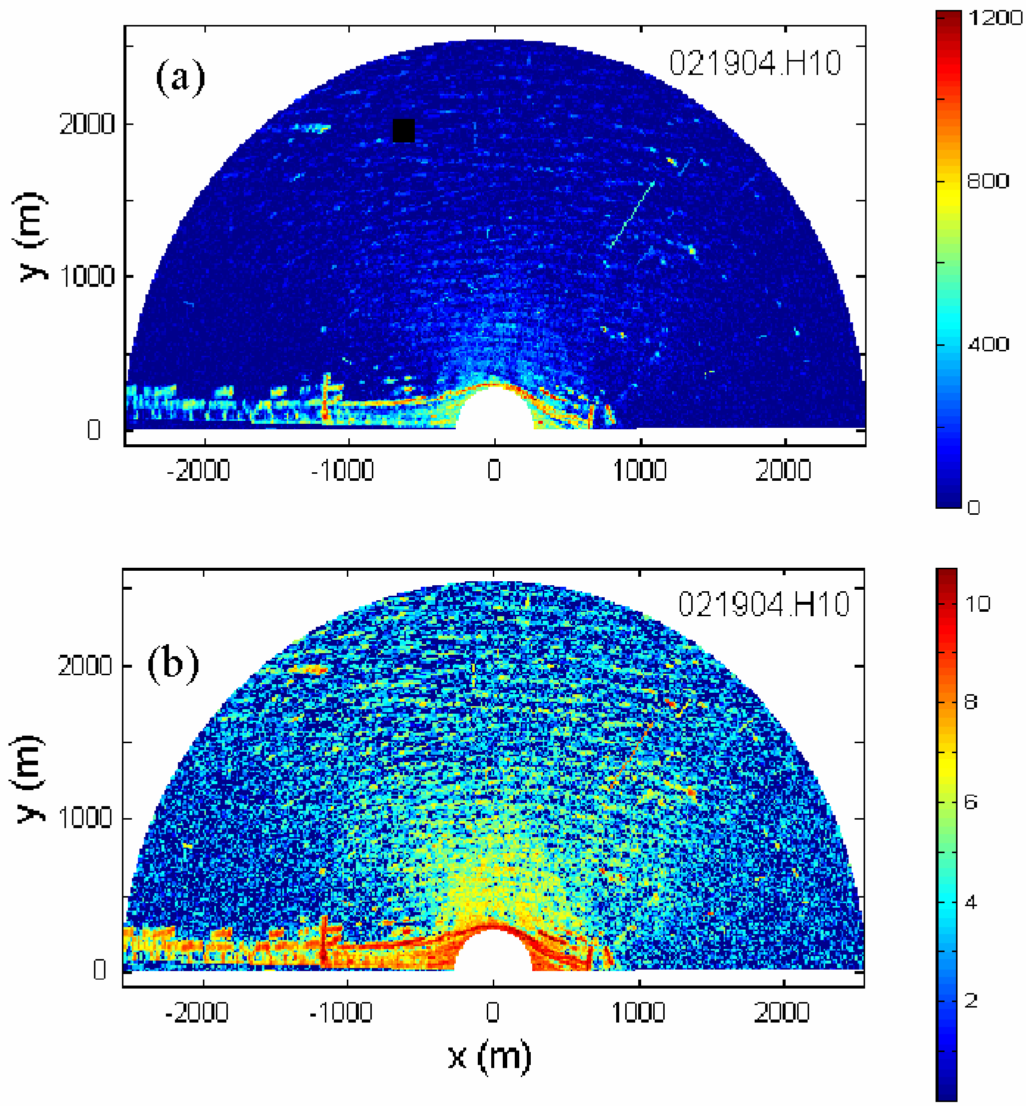

Fig. 5-3. A radar image with a relatively calm sea (Sa = 120) obtained at Virginia Beach at 10:00, Feb. 19, 2004. (a) Image from raw data, (b) image after a process to reduce distance effect.

5.3. Interpreting Radar Image for a Smaller Rectangular Domain

The next process is related to requirements of FFTN, the standard algorithm for 3-D Fast Fourier Transform. Data used by FFTN must be in a rectangular domain with evenly spaced Δx and Δy. The selection of this rectangular domain size and the size of Δx and Δy also need to be clarified. Because of the nature of radar scanning, radar data are presented in polar coordinates; this is why all the radar images presented so far have a semi-circle shape. Converting the raw data with polar coordinates and uneven spatial resolution to a data set with rectangular coordinates and an even spatial resolution is necessary for using FFTN.

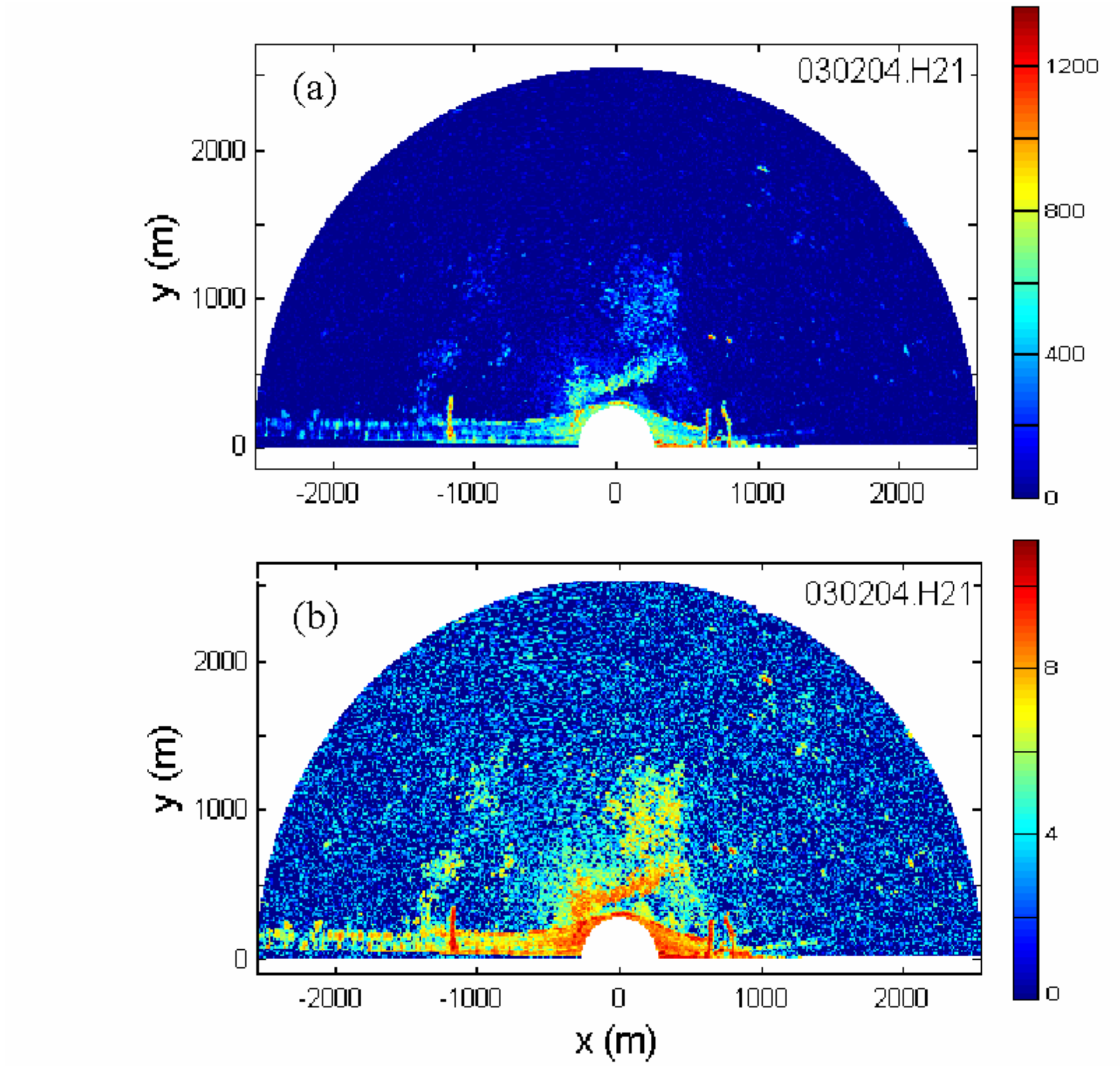

Fig. 5-4. A radar image with a relatively calm sea (Sa = 105) obtained at Virginia Beach at 21:00, Mar. 2, 2004. (a) Image from raw data, (b) image after a process to reduce distance effect.

The size of the rectangular sub-domain depends on the resolution of radar image, the raw radar image size, and the suitability of a "stationary process" within the selected sub-domain. The last condition is a basic assumption for using FFTN; it means the wave characteristics (*e.g.*, wave period, wave height, etc.) should be the same, or nearly so, for the entire sub-domain. In general, this assumption is not a problem for deepwater waves because water depth plays no role in wave transformation, and within a radius of 2.5 to 5 km, this assumption holds quite well. For coastal waves, wave characteristics change when approaching the coast.

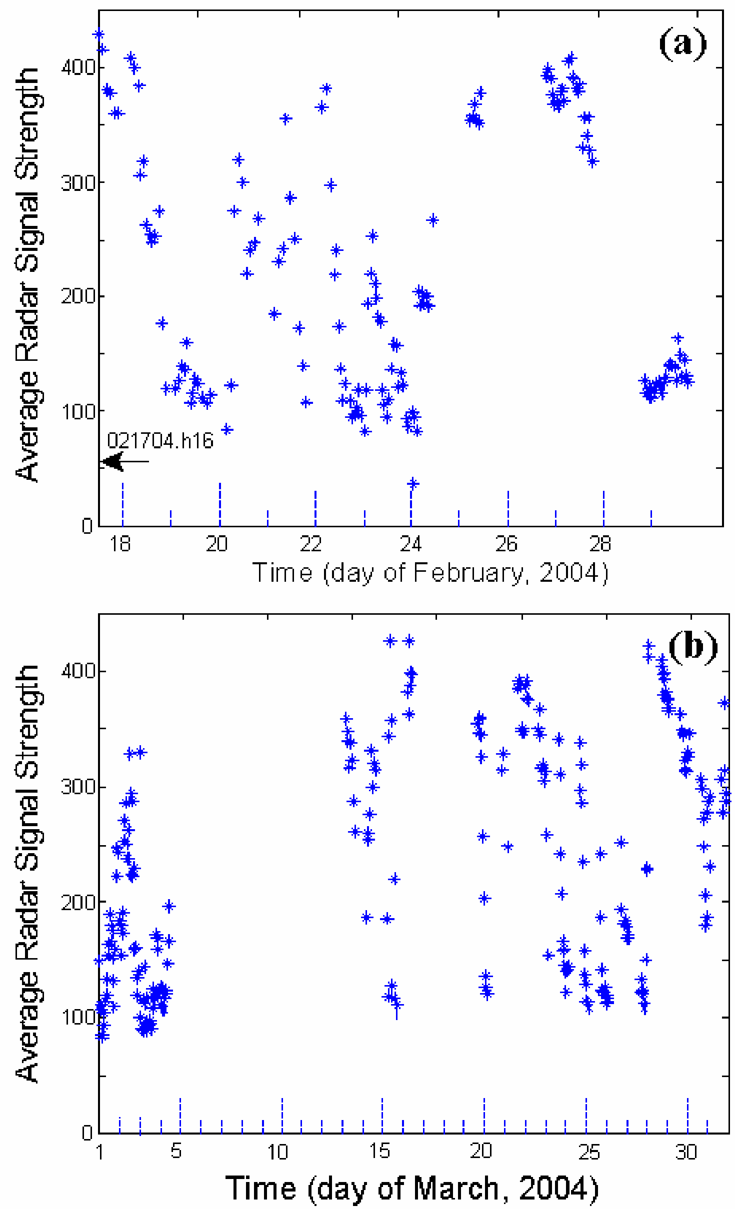

Fig. 5-5. Average radar signal strength during (a) February 2004 and (b) March 2004.

This places a major limitation on the size of the sub-domain. Considering the image distortion caused by the side lobe effect for the near field, the image within a distance of 500 m from the radar center shall not be used, unless corrections can be made. In order to assurance the image is not distorted, selection of a sub-domain that is 600 m from the radar would be advantageous. Because of using a rectangular sub-domain, another limitation on the maximum distance would simply means the maximum distance is about 200 m less than the maximum radar sensing radius.

If using 128 x 128 points for a rectangular sub-domain at 600 m away from the radar center, and considering rectangular image resolutions of 3, 5 and 8 m, the sizes of the sub-domains would be 384 x 384 m, 640 x 640 m, and 1024 x 1024 m, respectively. Two factors (*i.e.*, minimum wave period and maximum wave period) should be considered when selecting the size. For a possible range of wave period from 5 to 14 seconds, the range of deepwater wavelength would be from 37.5 and 306 m. In coastal areas, say with a water depth of 8 meters, the wavelength would be from 35 m to 102 m. For this reason, grid resolutions of 3, 5 or 8 m all are fine because at least 4 points represent a wave. The possible sizes of the three sub-domains are all having at least 3.7 waves in the sub-domain, and thus, also reasonable.

The image of a rectangular sub-domain would be obtained from interpreting the raw radar image. Locations of these unevenly spaced raw data are displayed on the left half of Fig. 5-6, and the grid locations of an evenly spaced rectangular sub-domain are on the right half of Fig. 5-6. An example of the first three interpreted rectangular wave images are given in Fig. 5-7 for the smallest sub-domain. The coordinates of the three sub-domains also are shown.

5.4. FFT Analysis on Radar Images

Using the techniques given in the previous chapter, the analyzed directional wave spectrum is given in Fig. 5-8a. This dominant wave propagation direction (-80 ^{o}, 4th quadrant) can be translated as waves coming from100^{o} (2nd quadrant), counted from the positive x direction. With the selection of x-axis orientation (Fig. 3-5), this direction can be translated as waves that come from the ENE (23^{o} = 10^{o} + 13^{o}). The line spectrum (Fig. 5-8b) indicates a peak wave period of 5.3 s. When using a grid size of 5 x 5 m, the directional spectrum has more

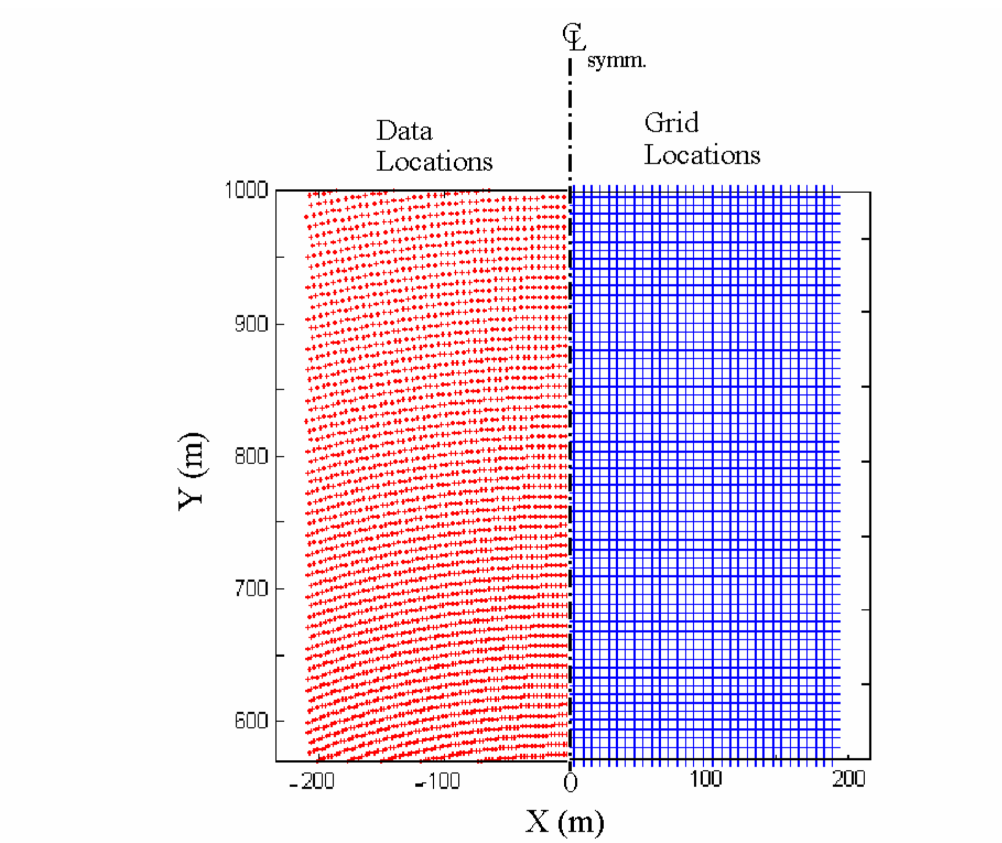

Fig. 5-6. Location map showing the measured image location (*)(left) and the interpreted location (+)(right) for wave analysis.

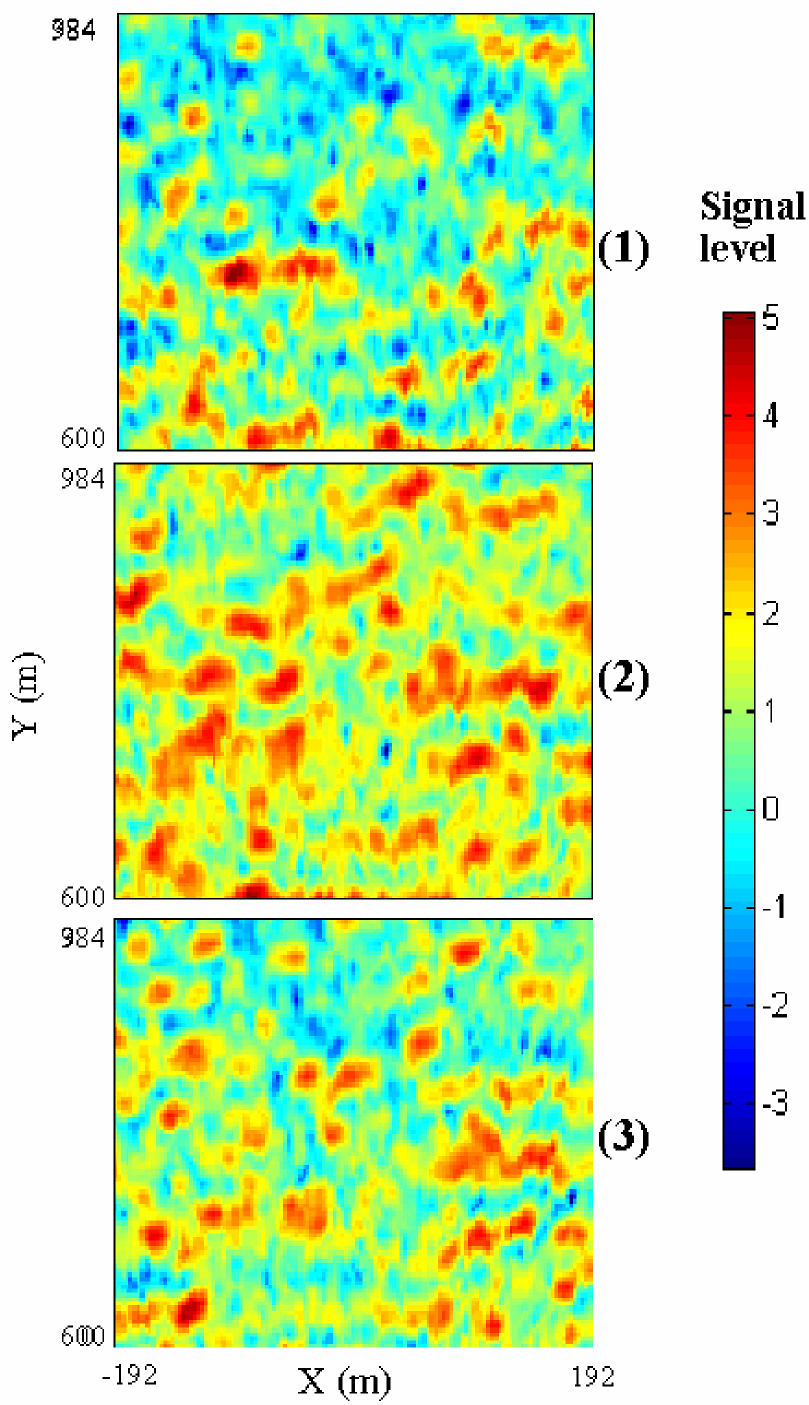

Fig. 5-7. First three rectangular radar images from 18:00, Feb. 17, 2004 for wave analysis. With x = y = 3 m, t = 1.66667s, domain size = 384 x 384 m.

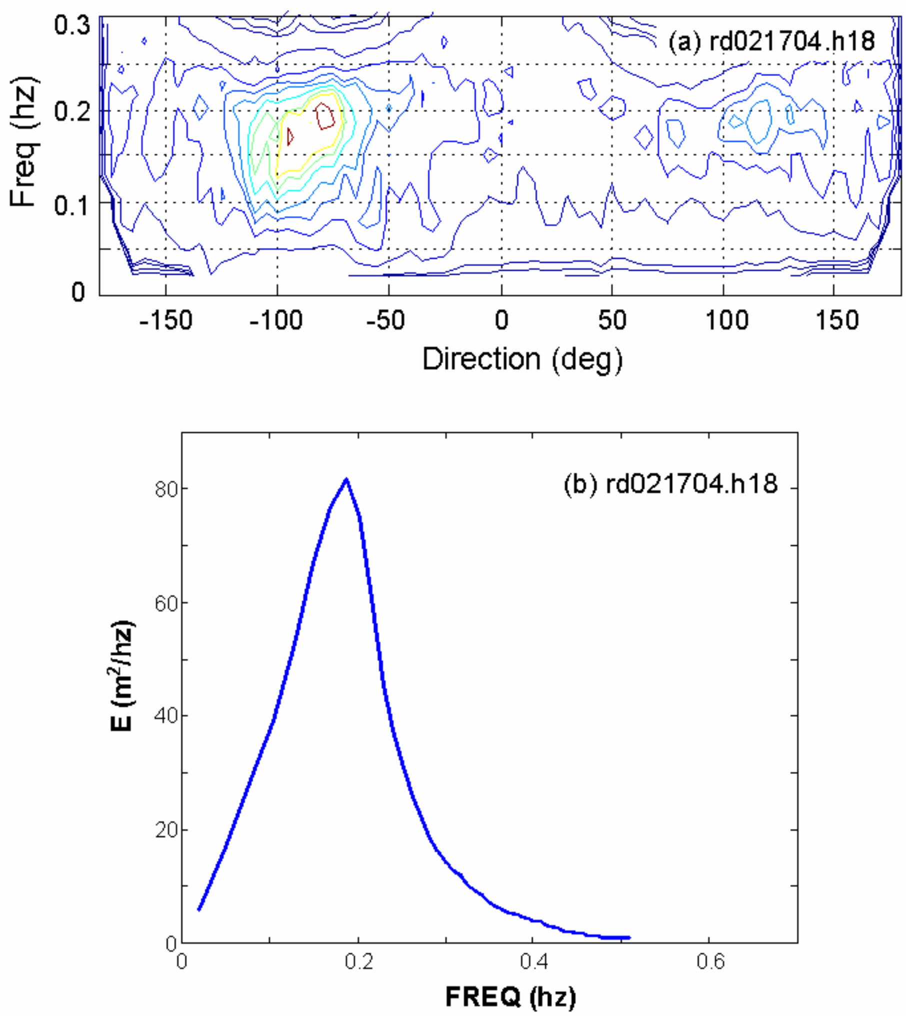

Fig. 5-8. Results of analysis of radar images from 18:00, Feb. 17, 2004 with x = y = 3 m, t = 1.66667s, domain size = 384 x 384 m. (a) Directional spectrum, (b) line spectrum. The presented direction is for the direction of wave propagation.

concentrated energy contours (Fig. 5-9a), and the line spectrum indicates a slightly different peak wave period, 5.5 s (Fig. 5-9b). When using the largest grid (1024 x 1024 m), the directional spectrum and the line spectrum (Fig. 5-10) are all almost the same as those obtained from the middle-size grid (640 x 640 m). Considering the radar image resolution at 600 m from the radar center, raw image resolution is less than 5 m, the middle grid size is selected for later analysis.

For a moderate sea (significant wave height, $H_{s,}$ of about 2 m at offshore National Buoy Data Center station CHLV2, see Chapter 6), the radar images obtained at 10:00, Feb. 19, 2004 still clearly show a large wavelength (Fig. 5-11), and the analysis results (Fig. 5-12) using the middle resolution grid (*i.e.*, 5 x 5 m) also show a clear dominant wave at 0.1 Hz that is moving toward 95^o. This direction corresponds to the shore normal direction (off only by 5^o), which is 8^o counter clockwise from E. Actually, this wave field represents a combination of 10 s swells and some wind waves (frequency 0.19 Hz) that all come from the east, if the 8^o error is neglected.

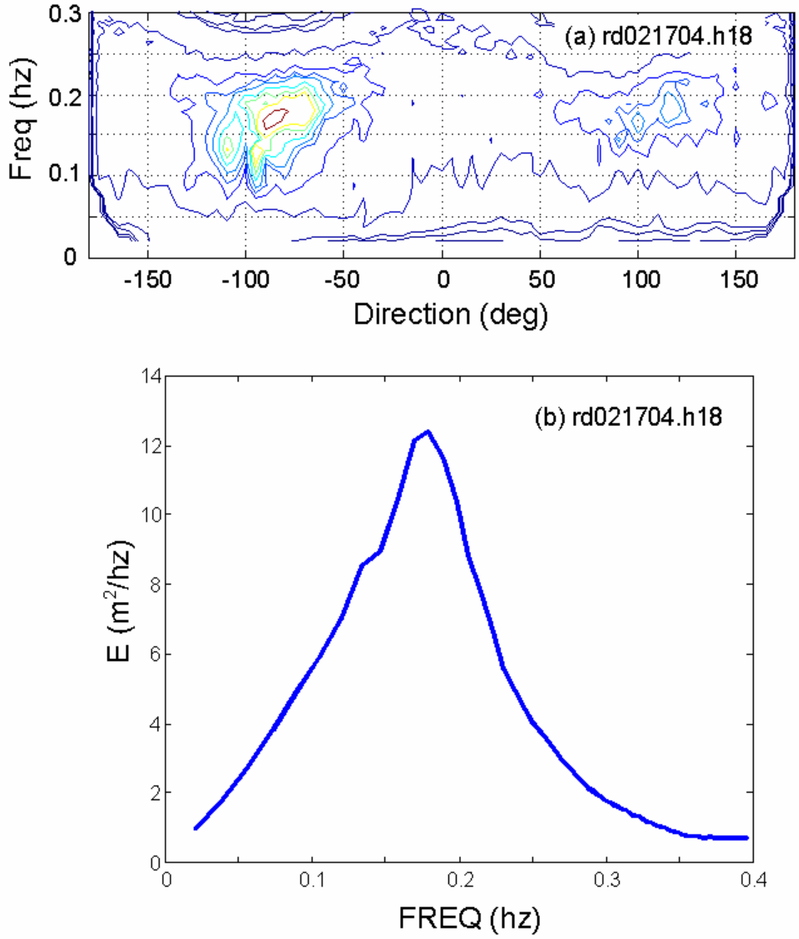

Fig. 5-9. Results of analysis of radar images from 18:00, Feb. 17, 2004 with x = y = 5 m, t = 1.66667s, domain size = 640 x 640 m. (a) Directional spectrum, (b) line spectrum.

For the calm sea radar images obtained at 21:00 March 2, 2004 ($H_s \approx 0.5$ m at Station CHLV2, see Chapter 6), the first three interpreted rectangular images (Fig. 5-13) do not show a clear wave field, and the analytical results (Fig. 5-14) using the middle resolution grid (*i.e.*, 5 x 5 m) also do not show a clear dominant wave. The energy is practically spreading in all frequencies and all directions. Although the line spectrum still shows a peak wave period of 4.8 s, this information may be meaningless because of the wide spreading of energy in all directions.

With a significant wave height of about 1 m at the offshore station CHLV2 on 00:00 Feb. 21, 2004, the radar images (Fig. 5-15) just barely show the wave pattern, and the analyzed directional spectrum (Fig. 5-16) shows the equally important long period waves (0.1 hz) going toward -100^o and short period (0.2 Hz) waves going toward 40^o. The line spectrum indicates more energy at the 0.2 Hz frequency band, but actually the wave energy at that frequency band comes from two major directions, 40 and -130^o.

The above three paragraphs indicate that a significant wave height, H_s, about 1 m at the offshore station CHLV2 would be the minimum for radar to pick up meaningful images. Further discussion will be given in next chapter.

Note that the energy level given in all the spectrum plots are meaningless because the signals used are not water surface elevation. The numbers in the signal are just integers that representing the signal strength. For this reason, the analysis so far can only reveal the wave directional distributions not the significant wave height. The value of Signal to Noise Ratio (SNR) was suggested (Young *et al.*, 1985) for interpreting the significant wave height, and, thus, requires calibration. That will be given in next chapter.

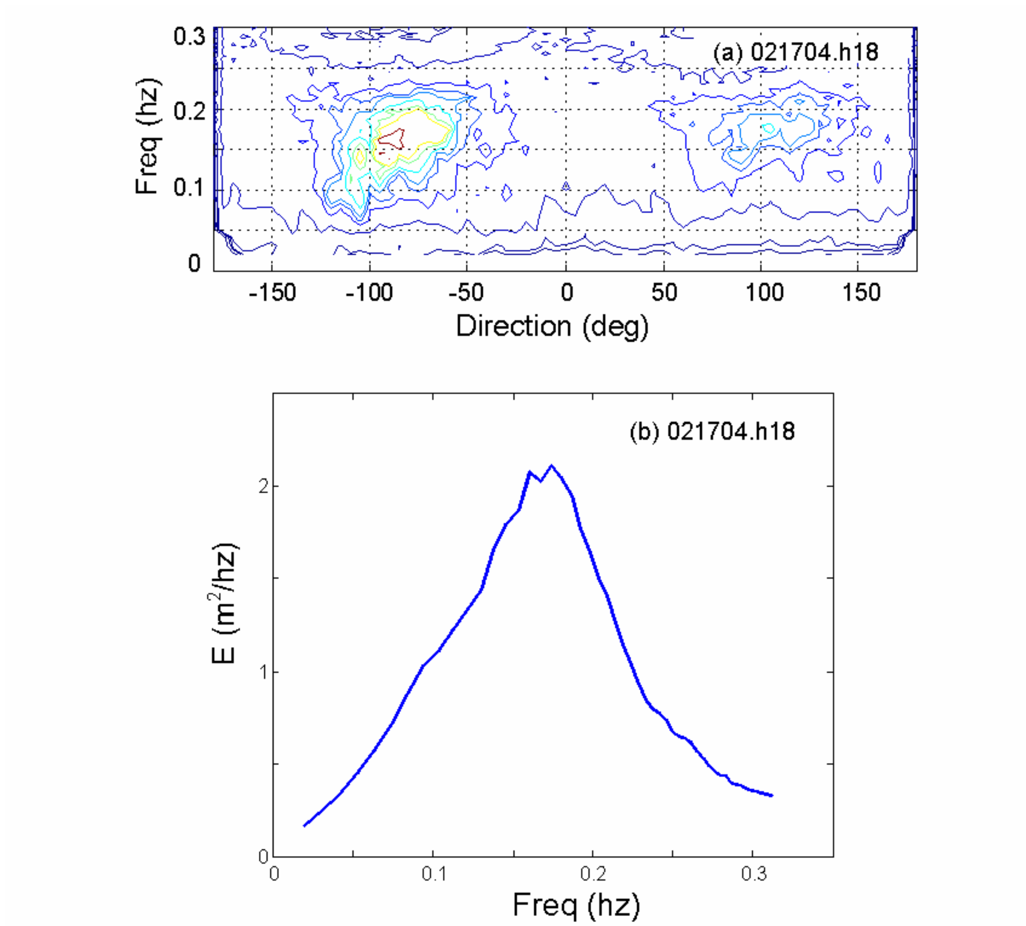

Fig. 5-10. Results from radar images analysis of 18:00, Feb. 17, 2004 with x = y = 8 m, t = 1.66667s, domain size =1024 x 1204 m. (a) Directional spectrum, (b) line spectrum.

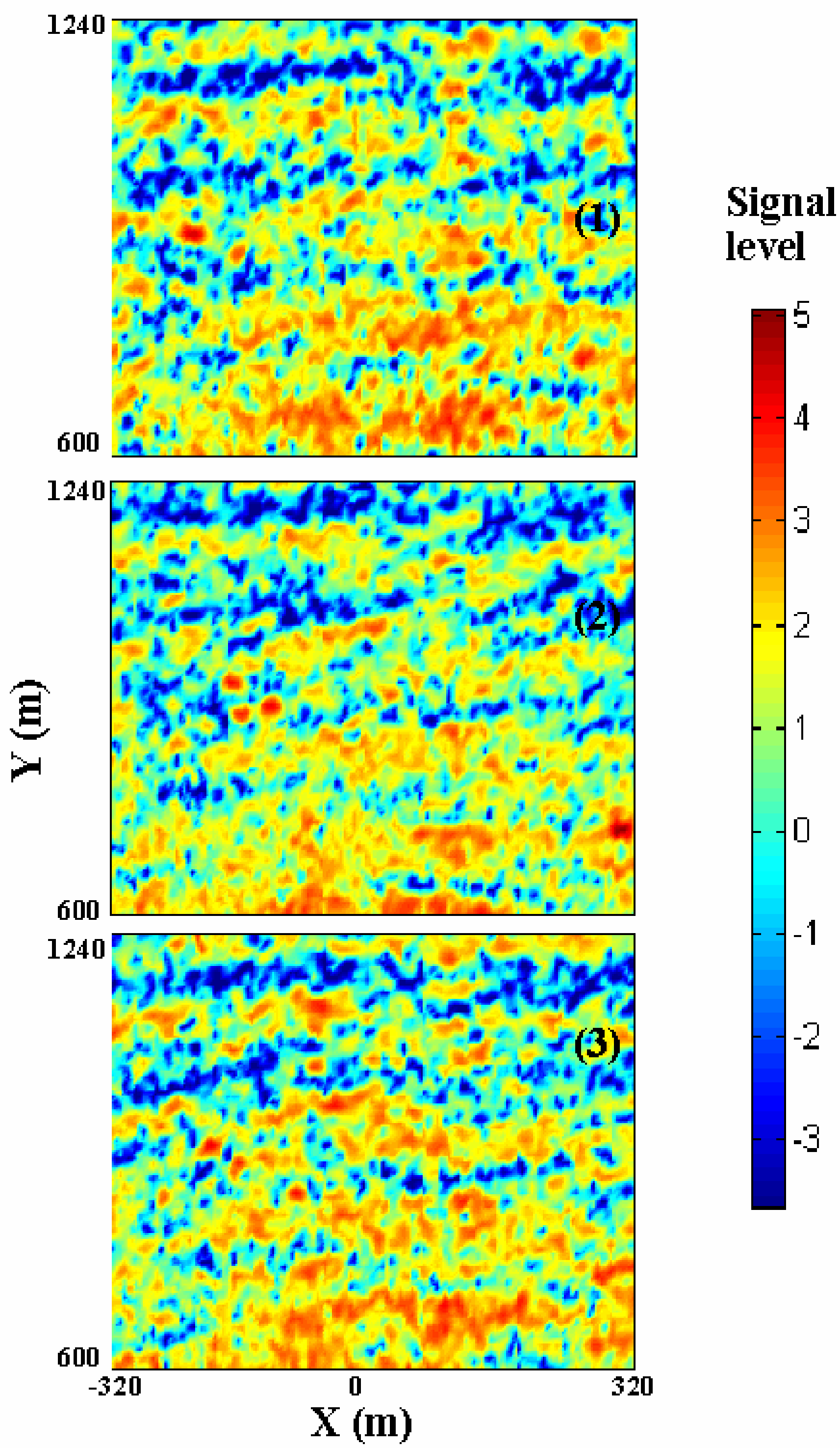

Fig. 5-11. First three rectangular radar images from 10:00, Feb. 19, 2004 for wave analysis. With x =y =5 m, t =1.66667s, domain size = 640 x 640 m.

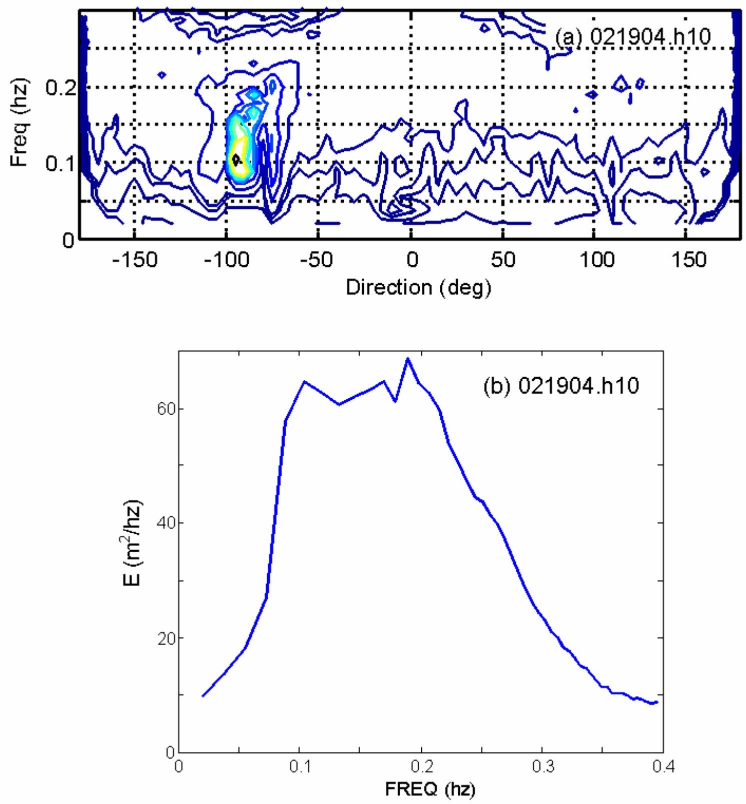

Fig. 5-12. Results from radar images analysis from 10:00, Feb. 19, 2004 with x = y =5 m, t = 1.66667s, domain size = 640 x 640 m. (a) Directional spectrum, (b) line spectrum.

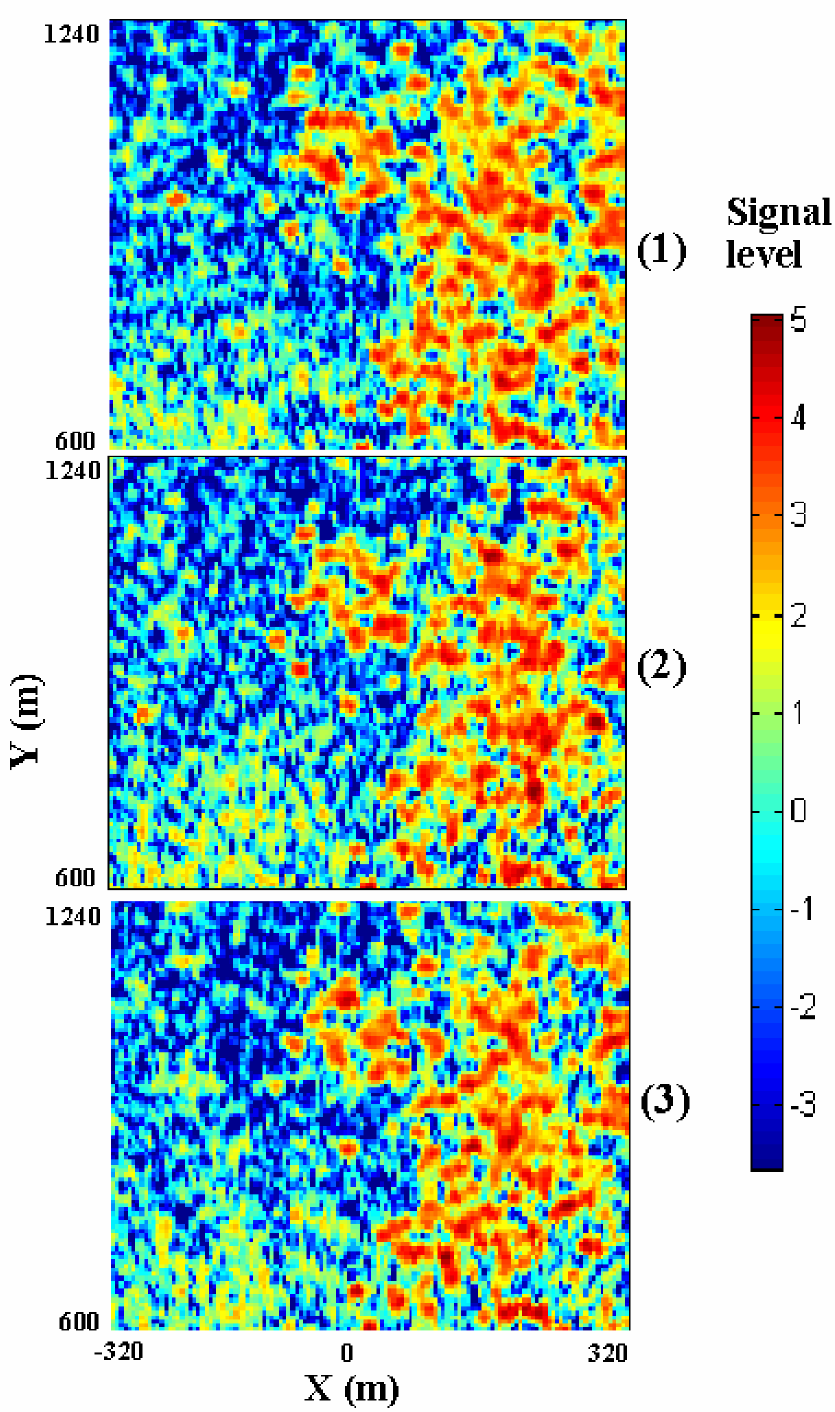

Fig. 5-13. First three rectangular radar images from 21:00, Mar. 2, 2004 for wave analysis. With x =y = 5 m, t = 1.66667s, domain size = 640 x 640 m.

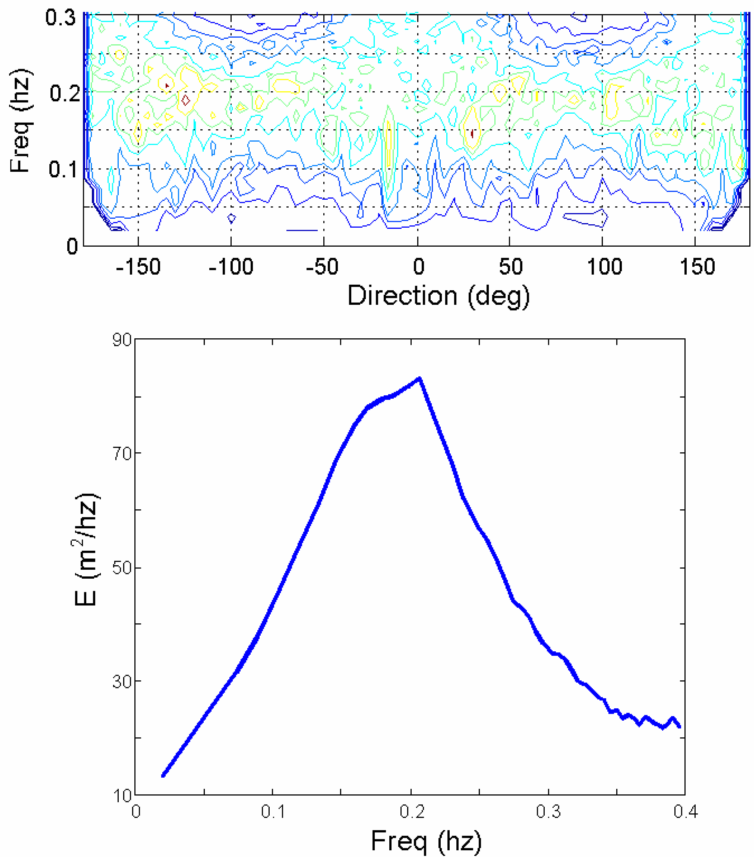

Fig. 5-14. Results from radar images analysis from 21:00, Mar. 2, 2004 with x = y = 5 m, t = 1.66667s, domain size = 640 x 640 m. (a) Directional spectrum, and (b) line spectrum.

5.5. The Average Radar Image

When using a X-band radar for wave measurements, there are side products that can be used for other purposes. For example, each radar wave analysis requires 64 images to resolve the ambiguity on wave propagation direction, but the average of all images during the measurement interval may be used for measuring the bathymetry (Leu, 1998) and others. Here an example is given that shows the image of rip current. During a relatively severe sea, the alongshore current created by oblique wave breaking will find a way to return to the ocean. This alongshore current also can be deflected by a shore-normal jetty. For example, the shore-normal jetty at the Virginia Beach, located at x = -1150 m (Fig. 5-17), causes the south-flowing alongshore current to bend and return to ocean. This shore-normal current may dig a trench that parallels the jetty. Because of the relatively deeper water in the trench, waves will not break there, and thus, it can be clearly seen by the average radar images (Fig. 5-17a). When the sea severity is low (Fig. 5-17b), the alongshore current is also weak, and thus, the trench is not clearly depicted. For another relatively severe sea on 21:00 March 19, 2004, the trench again is clearly seen (Fig. 5-18). This time, there is another large signal (x from -1000 to 1000 and y from1000 m to 1200 m). However, more study is necessary to understand its importance.

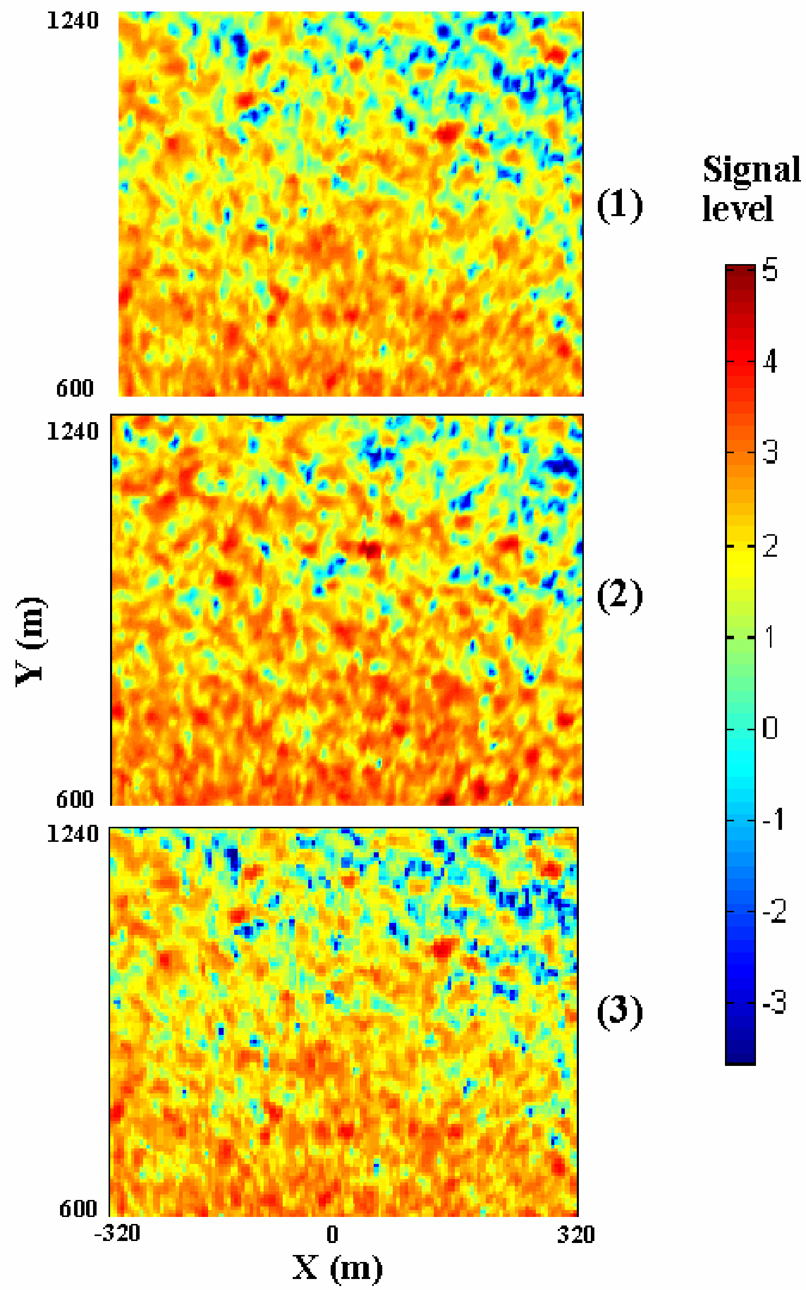

Fig. 5-15. First three interpreted rectangular wave images from 00:00, Feb. 21, 2004 for wave analysis.

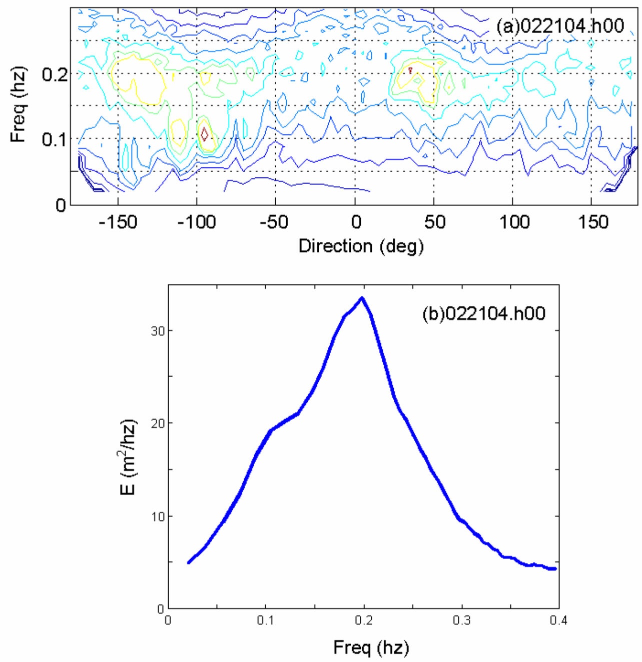

Fig. 5-16. Radar measurement results of 00:00, Feb. 21, 2004, (a) Directional wave spectrum, and (b) Line spectrum.

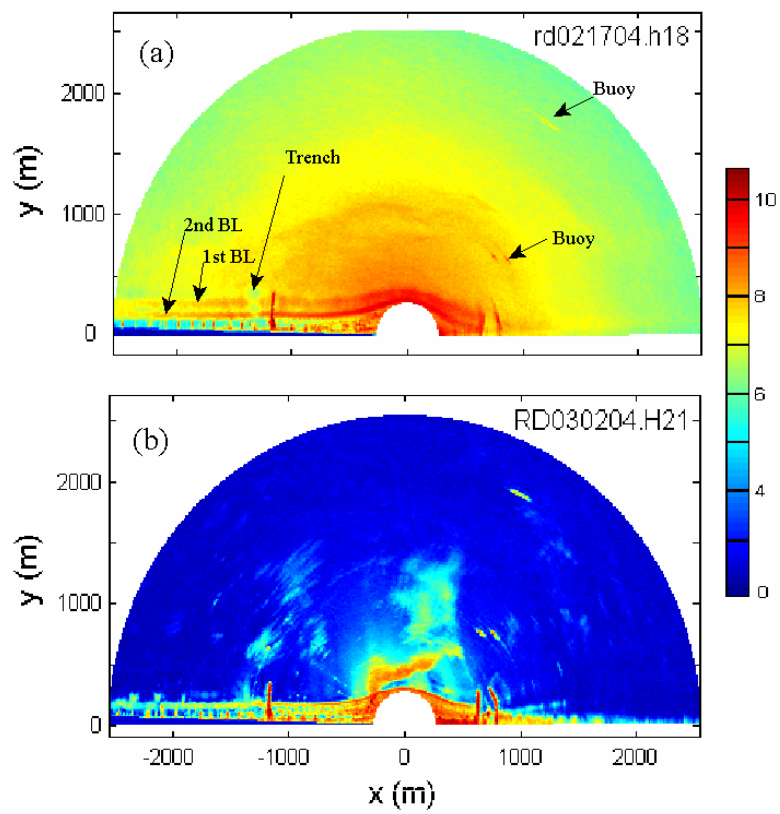

Fig. 5-17. Averaged radar images from Virginia Beach. (a) For a relatively severe sea on 18:00, Feb. 17, 2004 showing two lines of breaking waves on the left side, and (b) a relatively calm sea on 21:00, March 2, 2004. The buoys sets offshore of Rudee Inlet are much clearer in the calm sea.

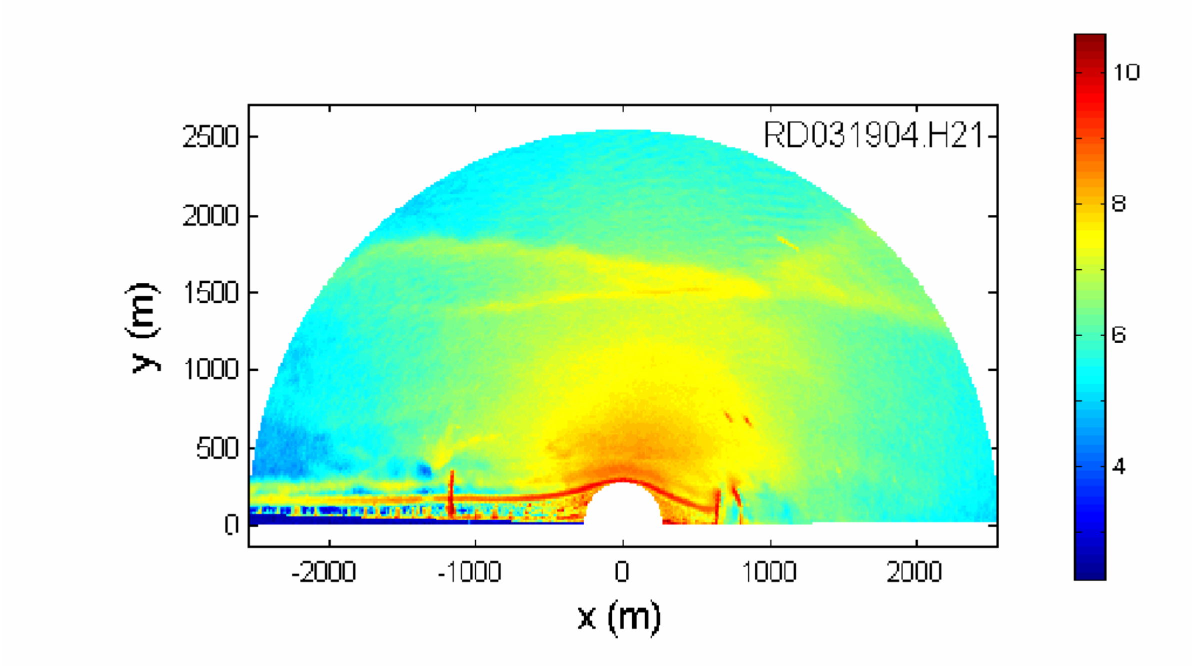

Fig. 5-18. Averaged radar images at Virginia Beach from 21:00, March 19, 2004 showing signals that are not yet understood. Two lines of breaking waves (left) and a trench are clearly seen

Chapter 6. Calibration of X-band Radar Wave Measurements

A star wave gauge for directional wave spectrum measurements was launched at a site offshore of the Virginia Beach during the Spring of 2005. The objective of this deployment was to provide ground truth of wave characteristics for converting the Signal Noise Ratio (SNR) obtained from analyzing X-band radar images to the significant wave height, H_s.

The correlation between wave heights measured at a NOAA station CHLV2, located about 25 km offshore of Virginia Beach, and U. S. Army Engineer Research and Development Center (ERDC) wave station VA001 immediately offshore of Rudee Inlet also was made for calibrating the radar measured SNR.

6.1. Star Wave Gauge

The star wave gauge was deployed at 36°50.116667'N, 75°57.8666'W, off the City of Virginia Beach, Virginia, with a mean water depth of 8.2 m. The distance between the wave gauge and the X-band radar was approximately 570 m (Fig. 6-1).

A star wave gauge has three pressure gauges mounted on the tips of a tripod base, 0.66 m above the seabed (Fig. 6-2). Diver observation determined the orientation of the tripod after deployment. Each pressure transducer was connected to the data logger with an underwater cable. The pressure transducers were model PDCR130 manufactured by Druck, Inc.. Two different ranges (15 psig and 30 psig) were used because of the availability. These transducers have an accuracy of ±0.1% of their maximum reading, thus, with an accuracy of 1.03 cm and 2.06 cm, respectively.

A micro-controller (Onset Computer, model TFX-11) in the data logger house controlled the power supply to the transducers and a datalogger, carried out the Analog to Digital Conversions (ADC) of all pressure signals and other auxiliary signals, and sent the digitized data to the datalogger (manufactured by Persistor, model CommLogger-BBR) for storage. All the above functions were executed by running a BASIC program in the micro-controller. The analogy pressure signals were digitized at a rate of 2 Hz for 2048 points. This yeilds a measurement duration of about 17 minutes every hour

Hourly water wave conditions were collected from March 16 to April 12, 2005. Unfortunately, only data for the first 20 days were able to be used. Data for the last seven days were corrupted for unknown reasons, probably a malfunctioning battery.

6.2. Data Analysis

A MATLAB® program package for DIrectional WAve SPectra (DIWASP) developed by the Center for Water Research, University of Western Australia (Johnson, 2005) was used for the wave spectrum analysis. In this software package, five different estimation methods can be selected, depending on the quality or speed of estimates that is required (for details, see DIWASP *ver*. 1.1). In this study, the Extended Maximum Entropy Method (EMEP; Hashimoto

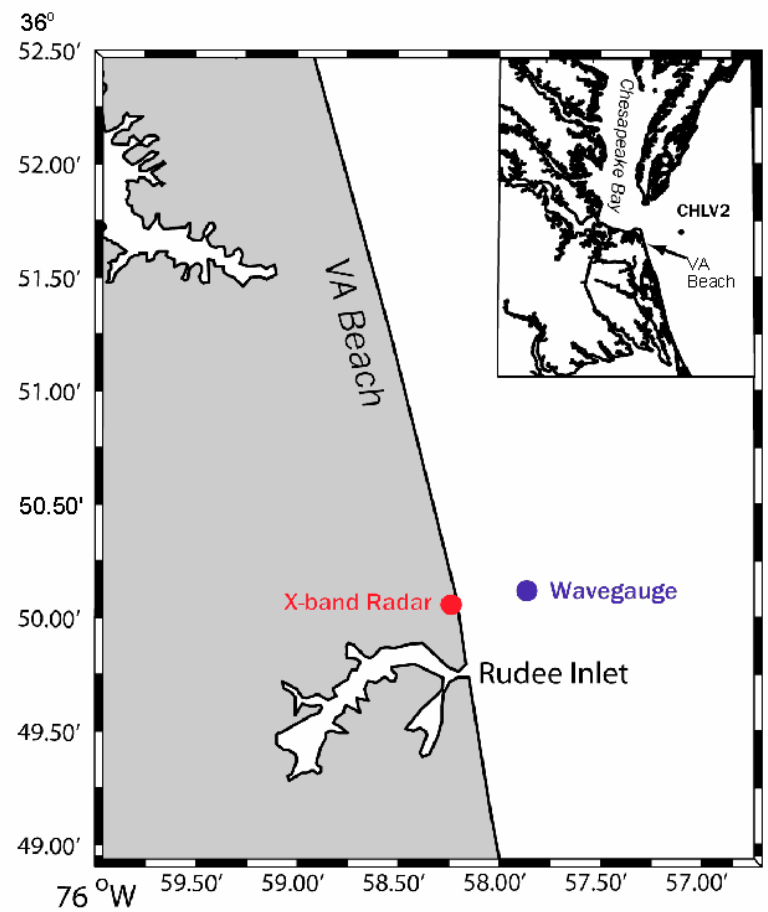

Fig. 6-1. Location map for the X-band radar, the star wave gauge tripod, and the NOAA Station CHLV2. Distance between the radar and the tripod is approximately 570 m.

et al., 1993) was selected because it is a good all-round method that accounts for errors in the data and has a tolerable computation time, compared with other methods.

In the post processing, the center of tripod was arbitrary assigned as the origin with the x-axis representing the cross-shore direction with positive toward the offshore. The y-axis represents the along shore with positive to north (Fig. 6-2). Wave spectral densities (in unit of m^2 Hz^{-1}) for the frequency band (0.01 - 0.5 Hz) with a band resolution of 0.01 Hz were estimated. Directional resolution of 2° was selected as an optimized value considering the tradeoff between the resolution and calculation time. Through the wave spectral analysis with the layout described above, the significant wave height, peak period, direction of peak period, and dominant wave direction can be derived.

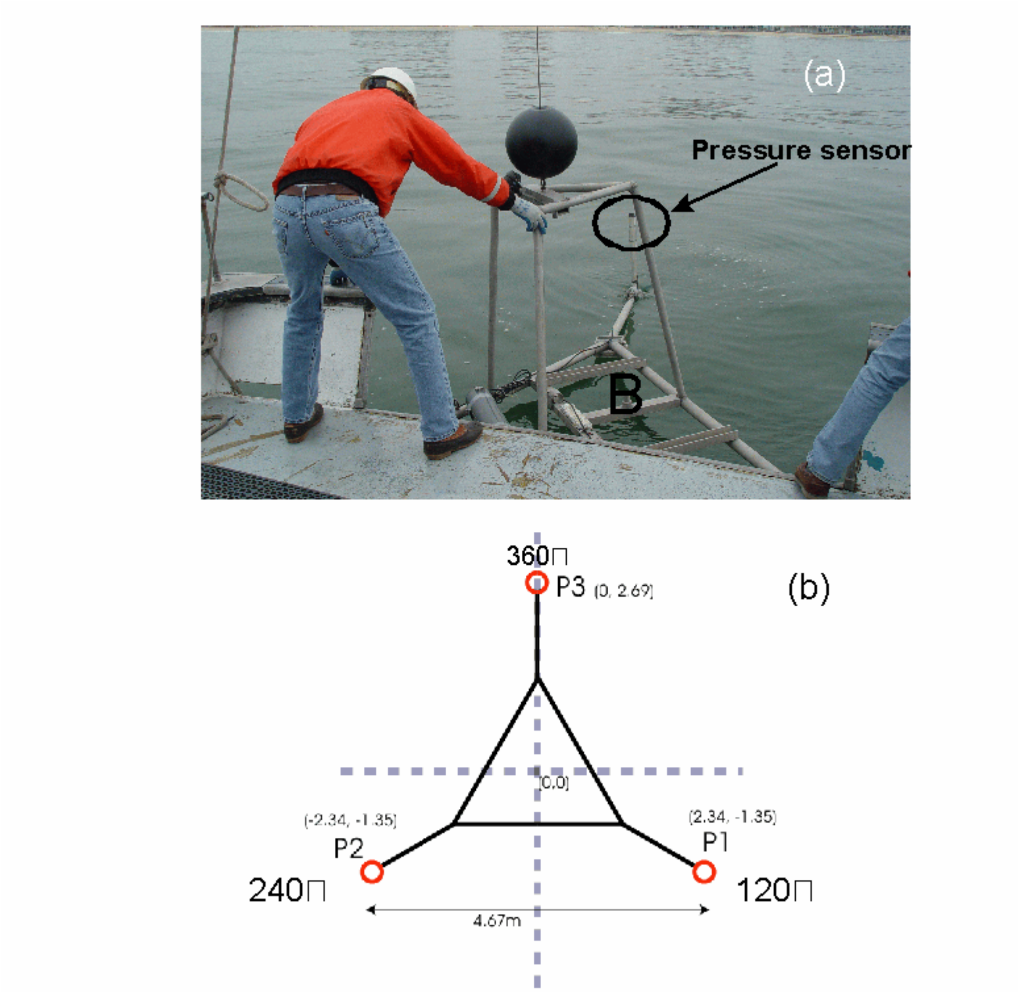

Fig. 6-2. The star wave gauge. (a) On the moment of deployment; (b) coordinates for wave spectral analysis. P1, P2 and P3 represent the location of pressure sensors. The center of tripod was selected as the origin. Each sensor was located 0.66 m above the seabed.

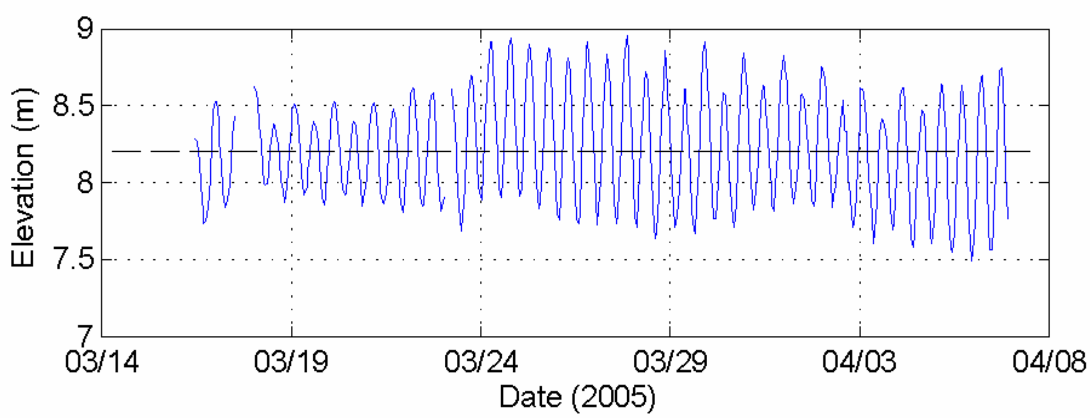

Fig. 6-3. Time-averaged water surface elevation. The mean water depth is 8.2 m.

6.3. Measurement Results

Figure 6-3 displays the change of mean-water elevation (time-average of each burst period) during the wave measurement period. These data may represent the change of tidal elevation. At two points, unfortunately, data were missing due to a bad sector on the Compact Flash memory.

The wave analytical results (significant wave height, H_s, period of peak wave energy, T_p, and the direction of the peak wave period, D_p, Dominant wave direction, D_d) from the star wave gauge records are shown in Fig. 6-4. Significant wave height was calculated as 4 times the zero-th moment of the line spectrum (*e.g.*, Fig. 6-6b). The peak period corresponds to the highest point in the line spectrum and the direction of the peak period is the main direction of the peak period. Dominant direction is defined as the direction with the highest energy integrated over all frequencies.

During the measurement period, H_s varied from 0.24 to 1.44 m with a mean of 0.68 m. The highest H_s occurred at 10:00, March 28. There were four time spans when H_s was greater than 1 m (see the arrows in Fig. 6-4a and Table 6-1). T_p was within the range of 3.2-16.7 s with a mean of 9.3 sec. Longer period waves with periods of 12.5-16.7 s occurred between 16:00 March 21 and 00:00, March 23. D_p and D_d information indicate that waves were mainly from the ENE and varied between 70° and 90° (Figs. 6-4c, 6-4d, and 6-5).

Directional wave spectra were provided at four selected times (H_s >1 m, see Table 6-1 and Figs. 6-6 to 6-9). The upper panels in Figs. 6-6 to 6-9 represent the directional distribution of wave energy. The lower panels in these figures show the distribution of spectral densities for each frequency. Note that the direction in these figures is the wave propagation direction (DIWASP *ver*. 1.1), which is exactly 180 degrees from the direction from which the waves come.

The directional spectrum on 1:00, March 18, 2005 showed three major wave groups (Fig. 6-6). The largest wave group (with a dominant frequency about 0.175 Hz) came from the NE and the two minor wave groups (with dominant frequencies of 0.1 Hz and 0.27 Hz) came from the E and NNE. This phenomenon may represent a developing sea with a very dynamic wind field because the wave periods for all the three groups were not large. This phenomenon was also seen on the wide line spectrum (Fig. 6-6b).

The directional wave spectrum at another time (16:00, March 23, 2005, Fig. 6-7) showed a completely different sea condition. There was only one long-period, dominant wave component, which represented a nearly perfect swell indicated by the narrow band line spectrum

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At 10:00, March 28, 2005, the sea condition represented another developing sea. This time, however, the change in wind speed and direction probably are limited. Waves mainly come from the East, and had a large directional spread (Fig. 6-8).

The last directional wave spectrum diagram (16:00, April 2, 2005, Fig. 6-9) may represent a nearly developed sea. The wave energy was relatively concentrated in the frequencies between 0.09 and 0.14 Hz, with a small tail at 0.2 Hz.

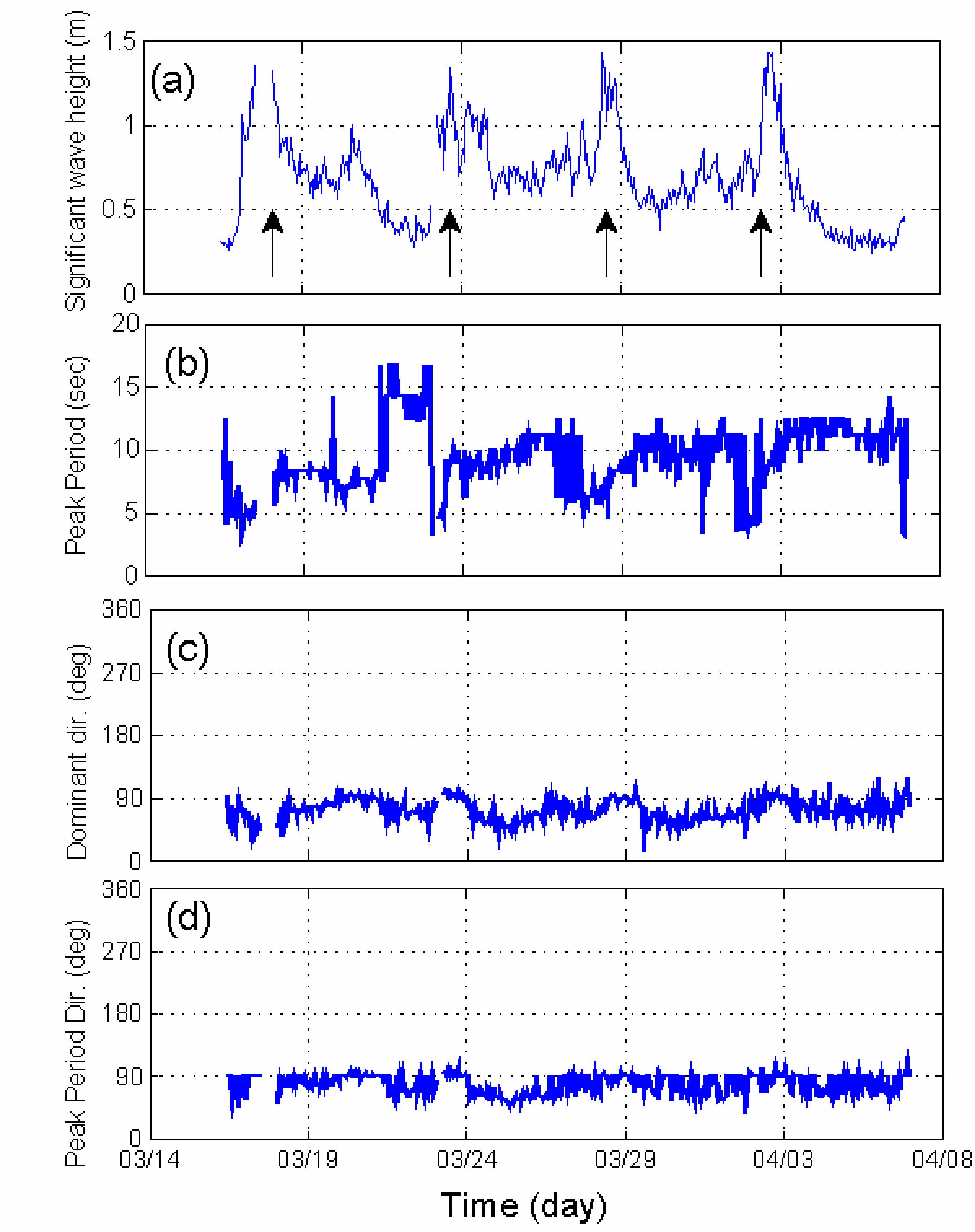

Fig. 6-4. Time series records from the wave gauge: (a) significant wave height (Hs), the arrows indicate when a detailed spectrum analysis is given in Fig. 5.6, (b) peak wave period; (c) dominant wave direction; (d) direction of the peak period.

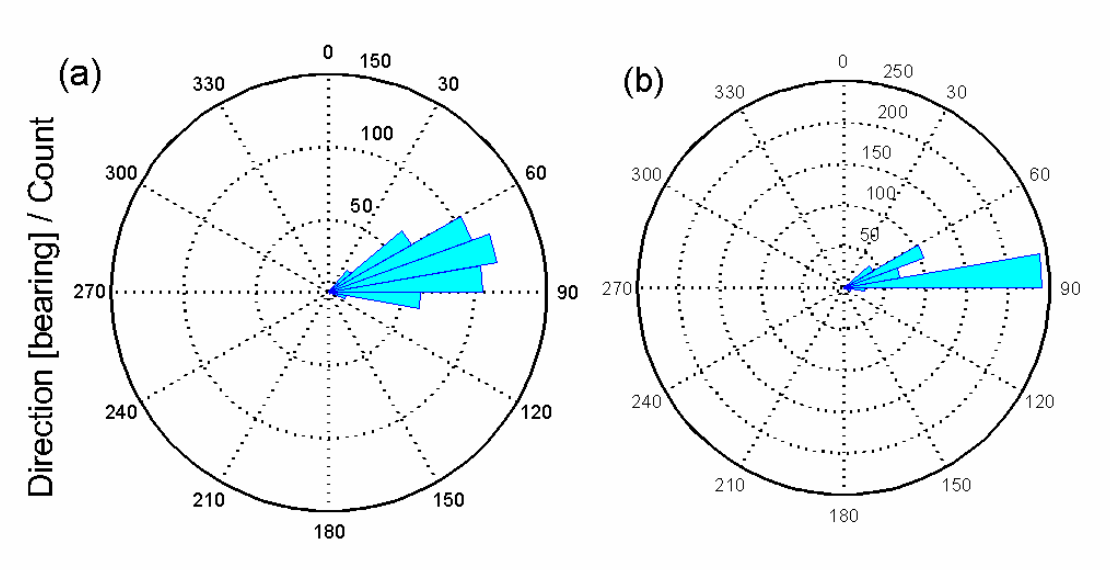

Fig. 6-5. Wave roses for the period from 11:00, March 16 to 22:00, April 6, 2005. (a) Direction of wave period, at the peak energy, and (b) dominant wave direction.

Table 6-1. Maximum significant wave height and wave peak period estimated from the wave gauge tripod.

Date	Time	H_s (m)	T_p (sec)
03/18/05	01:00	1.32	8.33
03/23/05	16:00	1.35	9.09
03/28/05	10:00	1.43	7.14
04/02/05	16:00	1.44	8.33

6.4. Wave Data from CHLV2 and VA001

In addition to the wave measurements specifically made for this project, wave data were obtained from two wave-stations in the vicinity of Virginia Beach. One is NOAA station CHLV2 (see Fig. 6-1). The other is an ERDC station VA001 located offshore from the Rudee inlet at a water depth about 8 m. Station VA001 is immediately adjacent to the radar station, and, thus, would be valuable for calibration. Unfortunately, Station VA001 was in continuous operation only from 1992 to 1997, and completely ceased operation after 2001. Although the wave record at Station ChLV2 is not comprehensive either, there are wave records for most of the year 2004. Also there are records from both station for a period in1996 and 1997, so it is possible to develop the correlation of wave heights at these two stations. The results (Fig. 6-10) indicate that the significant wave heights, H_s, at Sta. CHLV2 can be converted to the H_s at Sta. VA001, which, in turn, can be used for calibrating the radar measured SNR to H_s. Thus, there are extra data (Fig. 6-11) for the calibration.

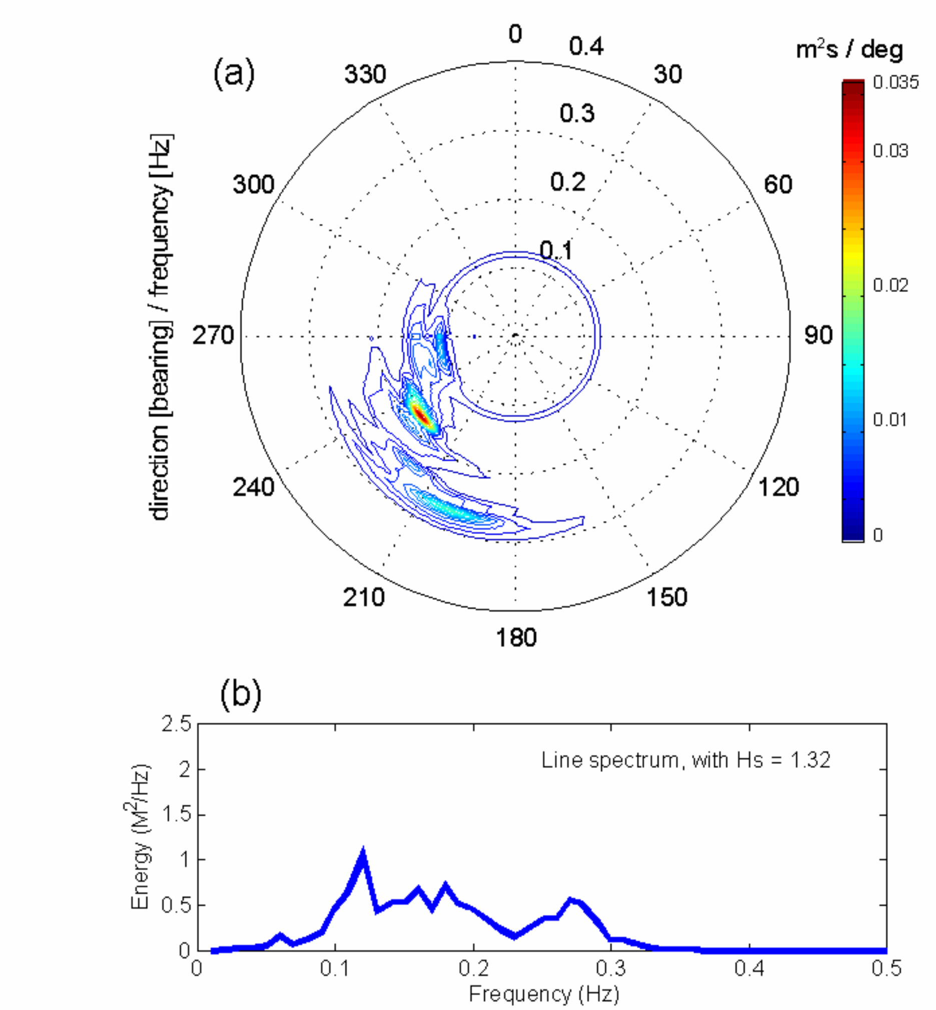

Fig. 6-6. Wave conditions at 1:00, March 18, 2005. (a) Directional spectrum, (b) line spectrum.

6.5. Signal Noise Ratio (SNR) from Radar Images

In general, SNR is a parameter for judging the quality of an electronic device in performing a particular function. For example, the higher the SNR of an amplifier, the better the quality of this amplifier. There two different definitions of the SNR for converting the radar measured SNR to H_s. The first definition of SNR was given by Young *et al.* (1985) as "the ratio of the energy at the spectral peak to the background energy level well away from the dispersion shell." The second definition is specified by Borge *et al.* (1999) as

$$SNR = \int_{\Omega} F(k_x, k_y, f).dk_x dk_y df \,/ \int_{b} F(k_x, k_y, f).dk_x dk_y df \qquad (6\text{-}1)$$

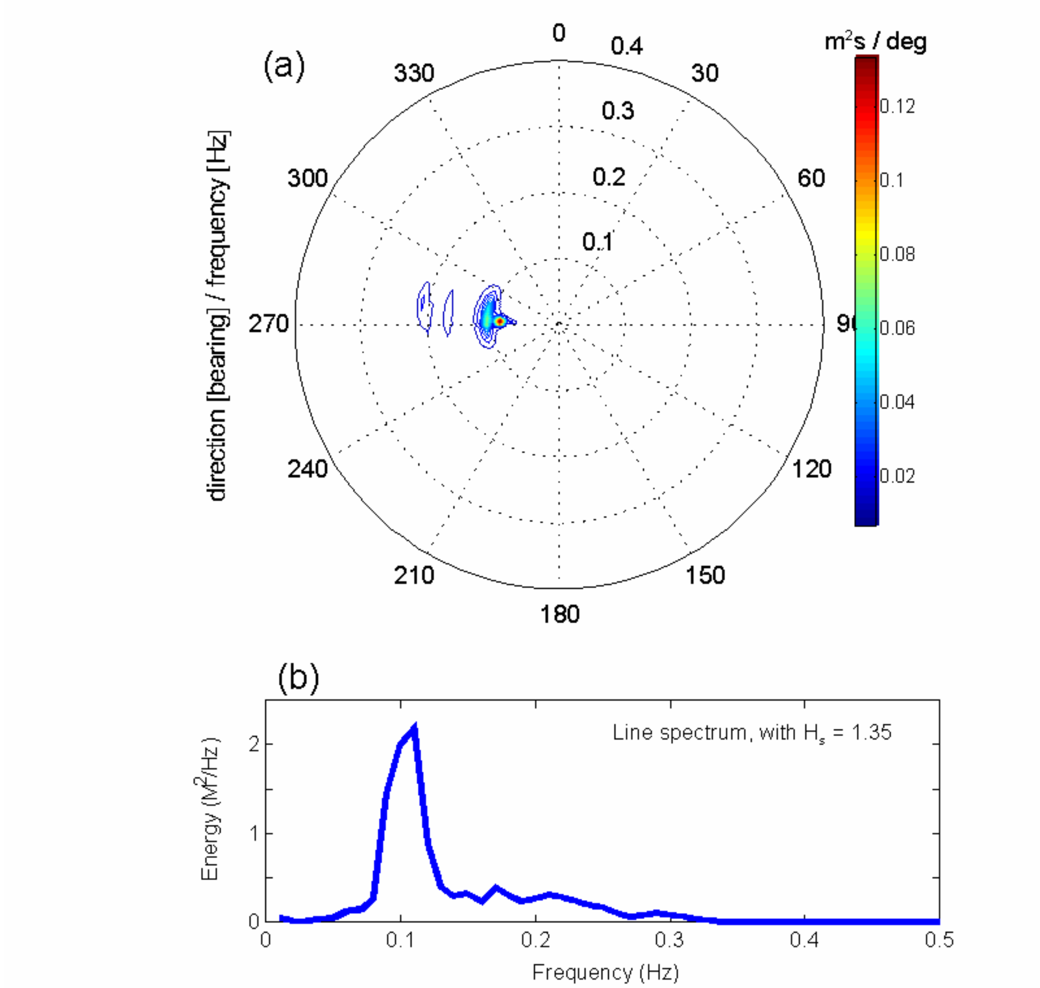

Fig. 6-7. Wave conditions at 16:00, March 23, 2005. (a) Directional spectrum, (b) line spectrum.

where the integration domain Ω represents a selected finite thickness of the dispersion shell (discussed in next section), and the other integration domain, b, stands for the background. These two different SNRs will be compared for their use in assessing the conversion of SNR to H_s.

The "dispersion shell" is an imaginary shell in the 3-D display of the dispersion relation $\sigma^2 = gk \tanh(kh)$ with k_x and k_y on the horizontal plane and σ (= $2\pi/f$) on the vertical axis. In a 2-D plot, the shell will be collapsed on the $k_x - k_y$ plane and form infinite number of circles with different radius but the same center at $k_x = k_y = 0$. An example of selected collapsed shells is given in Fig. 6-12. If one plots the dispersion shell in 3-D format, then the amount of energy would be in the 4th dimension. This makes the plot of 3-D energy display impossible. If one cuts the dispersion shell for each frequency band, then a finite number of 2-D plots (Fig. 6-13) can be developed to represent the energy for each band. Or the energy for all frequency bands can be plotted together as that displayed in Fig. 6-12.

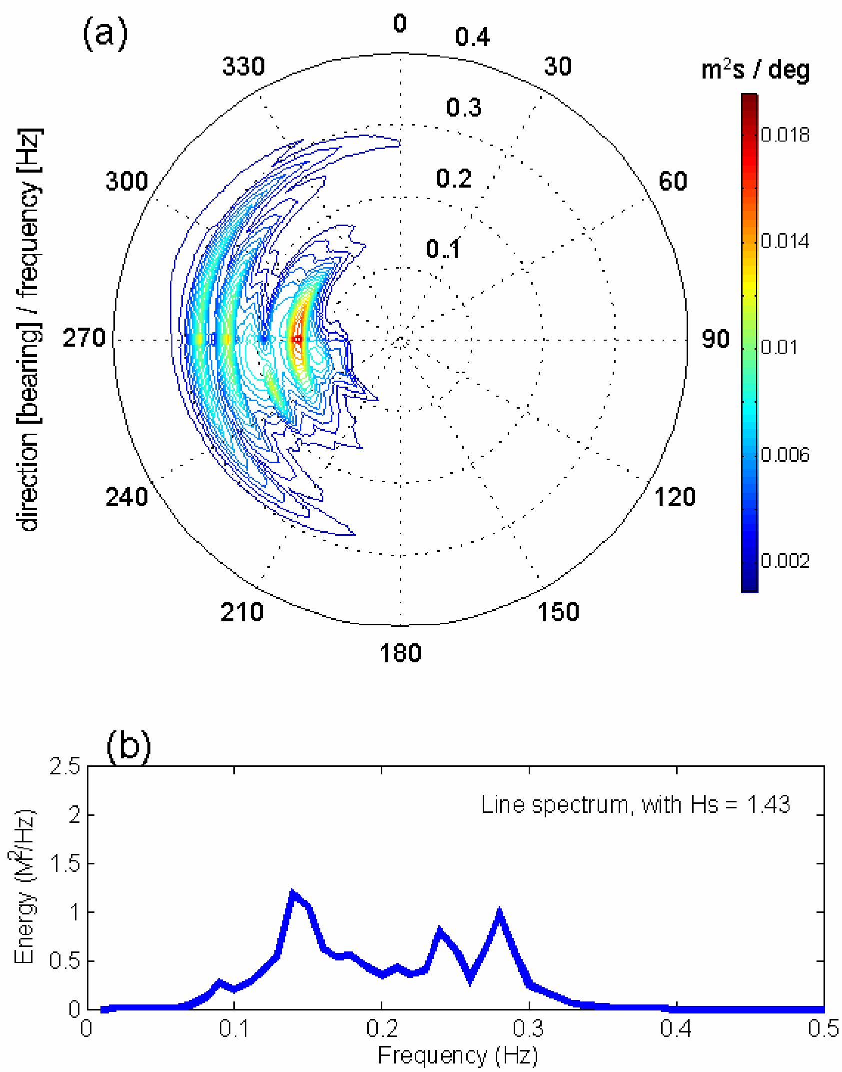

Fig. 6-8. Wave conditions at 10:00, March 28, 2005. (a) Directional spectrum, (b) line spectrum.

Using the definition given by Young *et al.*, (1985), the SNR can be calculated relatively easily. This is because the energy at the spectral peak can be found by a single Matlab command, e_{max} = max(max(max(e))), where e is a 3-D wave spectrum energy distribution matrix. However, there is no specific rule for determining what is "well away from the dispersion shell." In this study, the average energy on a circular belt (similar to the circle displayed in Fig. 6-13b with a belt width of about 0.03 m^{-1}) but at the lowest frequency band (*i.e.*, f = 0.00937 Hz) was used as the noise level.

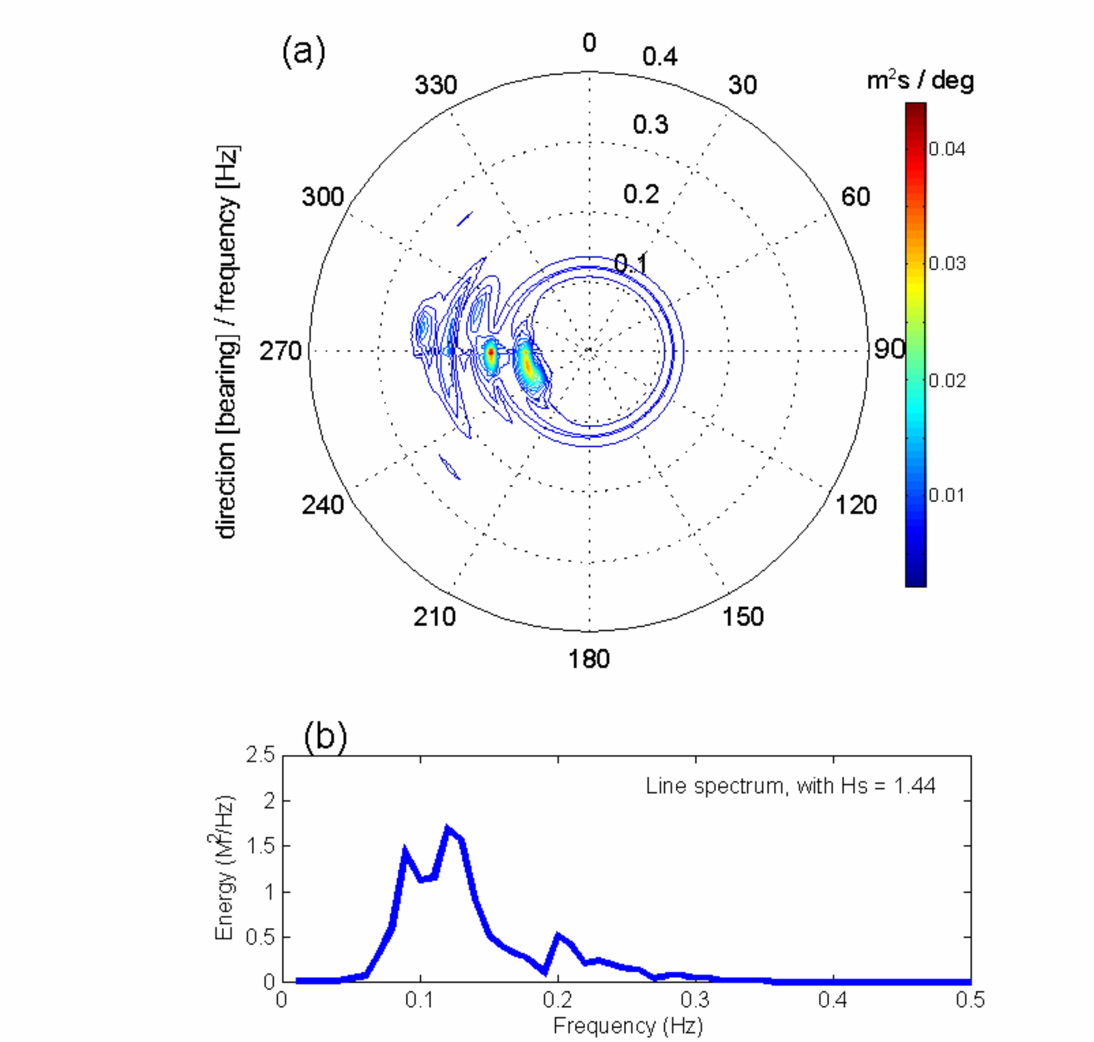

Fig. 6-9. Wave conditions at 16:00, April 2, 2005. (a) Directional spectrum, (b) line spectrum.

Following the work of Alpers and Hasselmann (1982), the suggested relationship between H_s, and SNR was given as (Borge *et al.*, 1999):

$$H_s = A + B\sqrt{SNR} \quad (6\text{-}2)$$

where A and B are two calibration constants. Results of the effort to find A and B are given next.

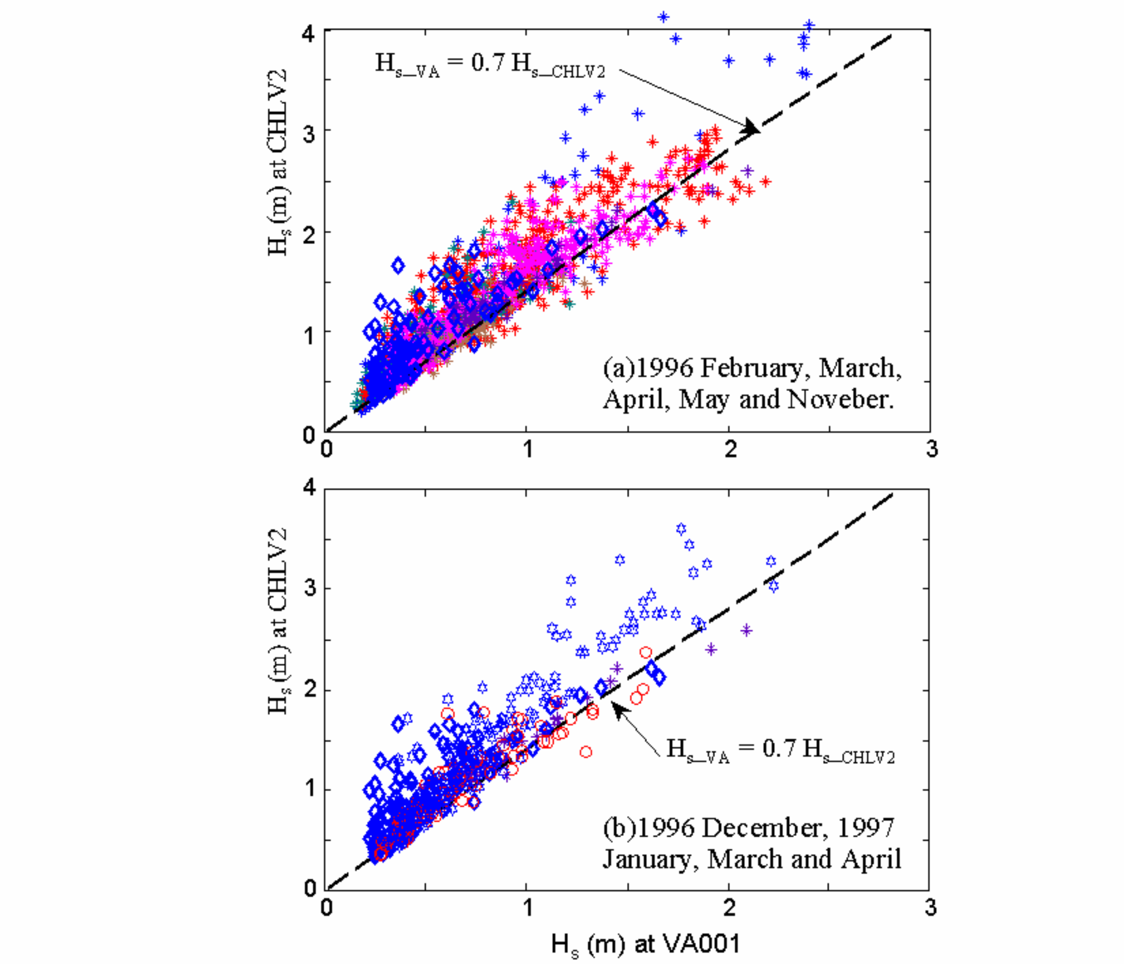

Fig. 6-10. Relationship between the significant wave heights at Stas. CHLV2 and VA001.

6.6. Results

The first definition of SNR (Young *et al.*, 1985) does not show any correlation between H_s and SNR (Fig. 6-14). The reasons of this are not clear. It is possible that the definition of SNR given Young *et al.* (1985) may just be a parameter for judging the quality of radar image and cannot be used to convert to H_s. More study is needed to further address this issue. When using the second definition, although the data are somewhat scattered, the trend is clear (Fig. 6-15).

Despite the effort to conduct ground truth measurements on wave height, the radar measurements after December 2004 were not good because of interference on PCI bus caused by the PCI graphic interface card and the Gage ADC card. For this reason, data measured from the star wave gauge are not used. More of this phenomenon will be presented in the discussion section. Nevertheless, the process for using a marine X-band radar for wave measurements is completed.

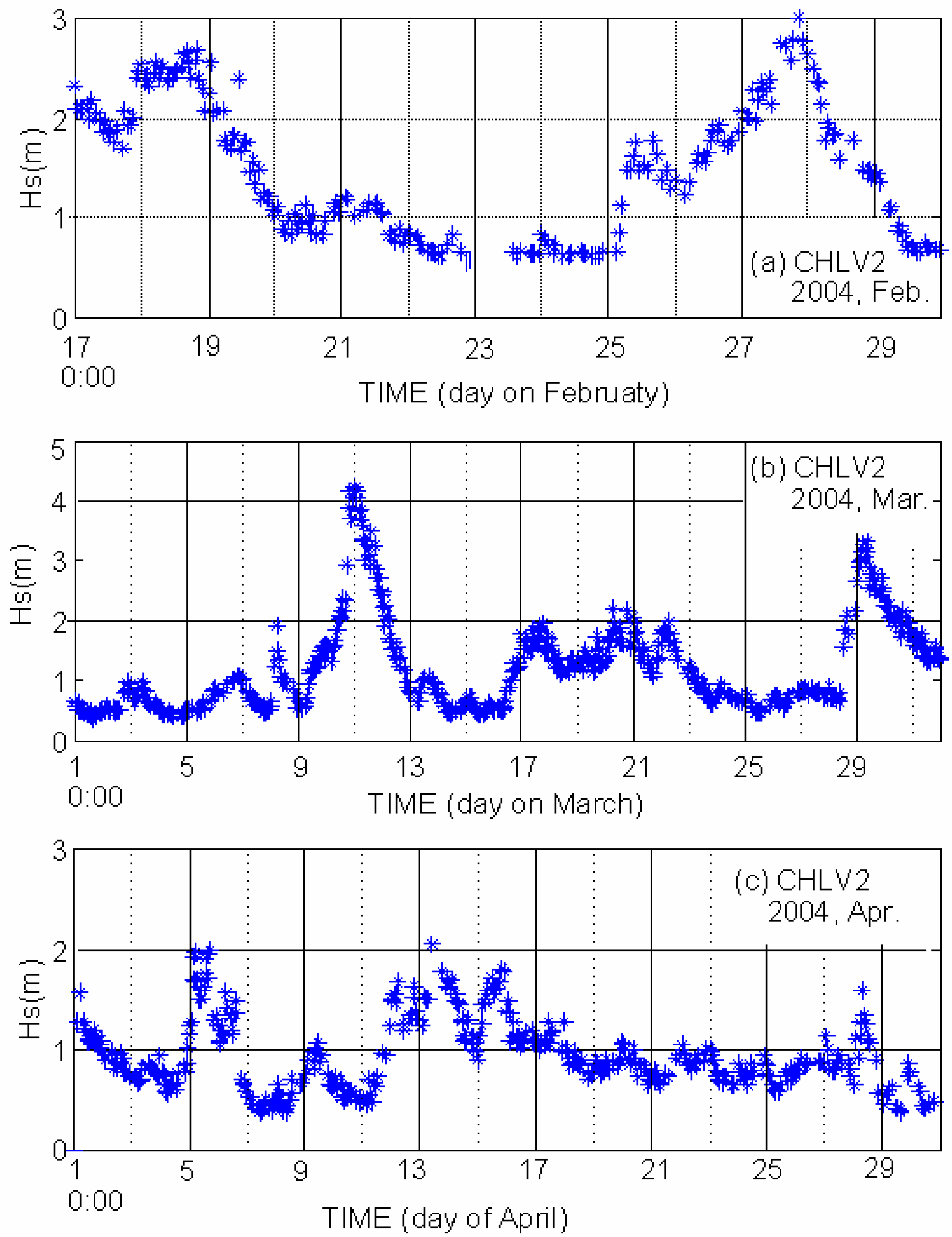

Fig. 6-11. Records of significant wave height at CHLV2. (a) February, (b) March, (c) April, (d) November, and (e) December 2004.

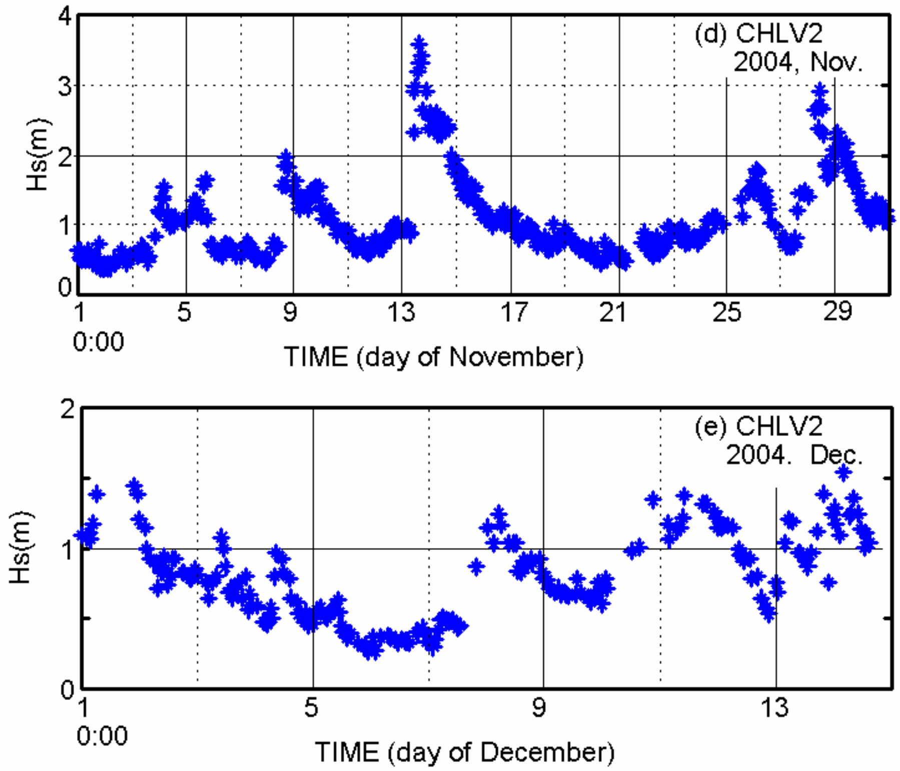

Fig. 6-11. (Continue).

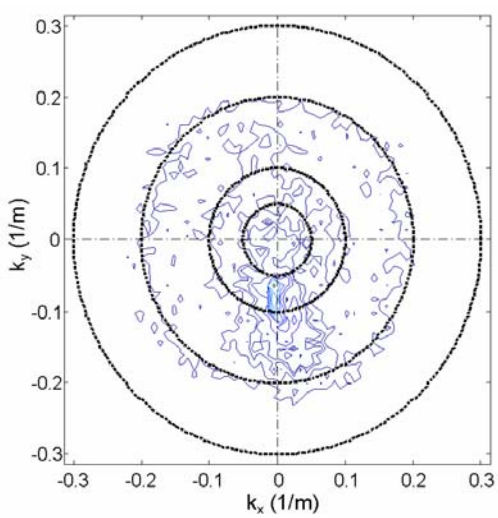

Fig. 6-12. Examples showing a collapsed "dispersion shell" in a 2-D plot. Each dashed circle represents the dispersion relationship between wave frequency and wave number. The energy distribution given here is for 10:00, Feb. 19, 2004.

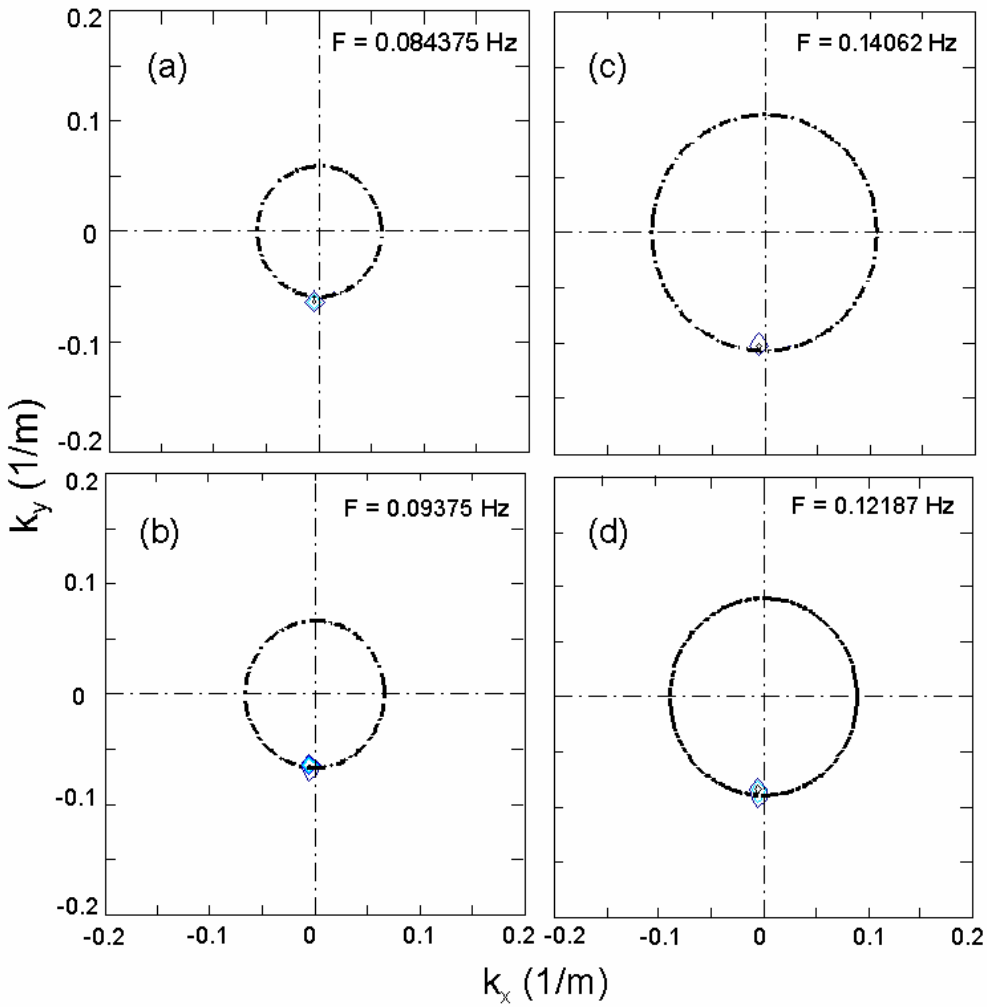

Fig. 6-13. Examples showing a fraction of the “dispersion shell” with energy within that frequency band for radar wave image from 10:00, Feb. 19, 2004.

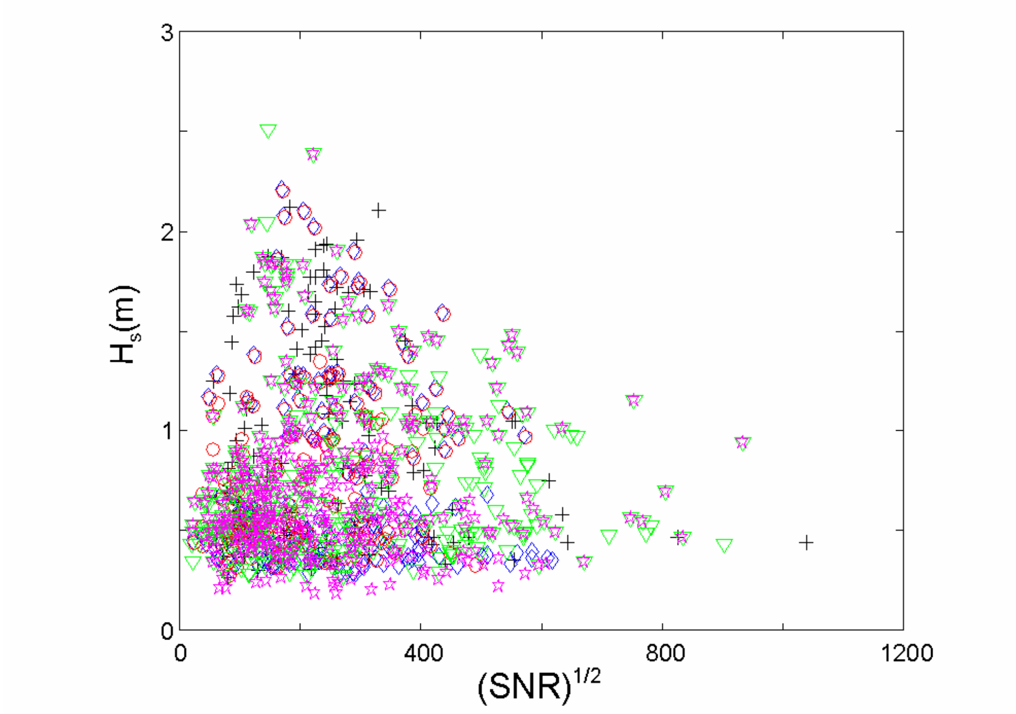

Fig. 6-14. Example showing that there is no correlation between the significant wave height and the SNR defined by Young *et al*. (1985).

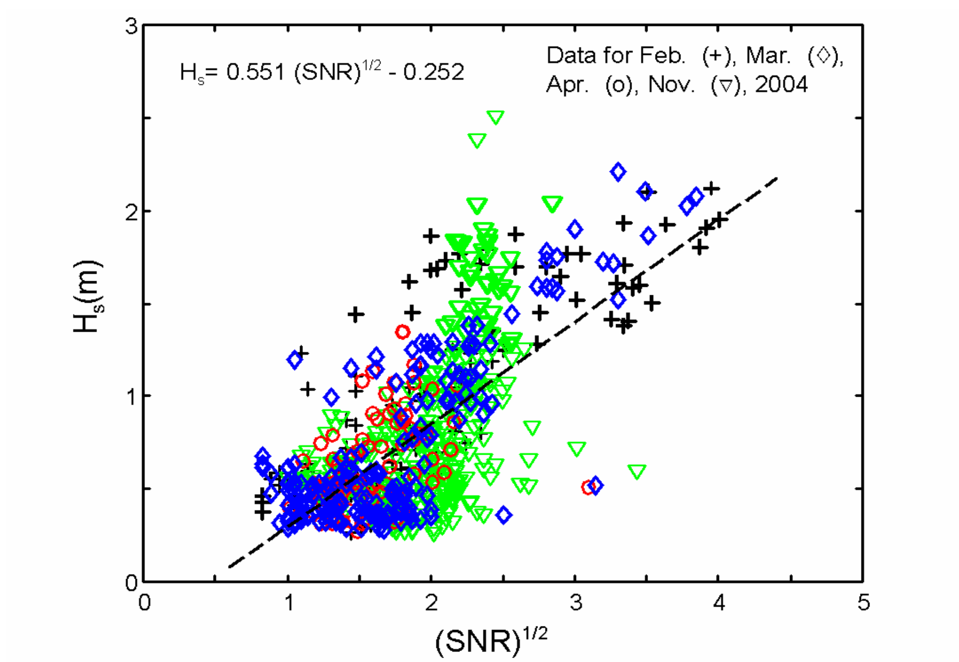

Fig. 6-15. The relationship between significant wave height, H_s and the second definition of SNR. Wave height data are from CHLV2.

Chapter 7. Remote Operation of the Radar System

Remote access to and control of the radar wave observation system would provide several benefits. The radar site can be far away from the data center and timely access to the observations is important and improves the efficiency of the analytical process. The two main options for remote operations are (1) by Local Area Network (LAN) and (2) by modem. This chapter describes how these might be implemented. It should be noted that a broadband connection (LAN) would be better but is not necessary if only the measurement results, such as directional spectrum and line spectrum, are required to be passed back to the data center.

7.1. General Requirements

In order to remotely operate a personal computer (PC), either WakeOnLan (WOL) or a WakeOnModem (WOM) capability is necessary. This means an ATX power supply with standby power for the motherboard is required. In general, this is not a concern as most currently available PCs have this capability. The motherboard (ASUS, A7V8X) used in this project has both options: WOM and WOL.

When two computers are connected by LAN or modem, they are in a client-host relationship. The computer that controls the radar system is the host computer. The host waits for a connection from a client (a computer in the data center) and then provides the requested services. A client connects to the host and instructs the host how to carry out a specific task.

7.2. Remote Control and Access by LAN

Remote access over a LAN and using WOL is the preferred option as it is the simpler and faster option. In order to use WOL, however, the set up of BIOS on Power Management must enable the WOL and a fixed IP address and Subnet Mask address must be assigned to the host computer. The research center's LAN administrator would provide these addresses.

The operational principle of WOL is as follows. Even if the host PC has been shut down (but still connected to power), the Network Interface Card (NIC) still gets power from the PC's ATX standby power supply. Software burned in a chip on the NIC constantly checks for internet calls to its Media Access Control (MAC) address. If the system detects 16 repeated calls, the NIC will send a "power-on" signal to the motherboard, activating the power supply and booting the system. An internet call can be sent from any PC by using the "WaveOnLanGui.exe" software which is available at http://gsd.di.uminho.pt/jpo/software/wakeonlan. This software is included in the attached CD. When using "WaveOnLanGui.exe", one needs to know the host PC's MAC address as well as the host PC's IP address and the Subnet Mask address (Fig. 7-1). Note that the addresses given in Fig. 7-1 are no longer valid.

In order to obtain the MAC address, it is necessary to run the Windows® program "ipconfig.exe" available in Windows® 2000 operation system. This program usually is found in the subdirectory "system32." When running this program, one needs to type "ipconfig/ all" under the DOS prompt. The 12-digit physical address in the results (Fig. 7-2) is the MAC address. IP and Subnet Mask address are also included in the results.

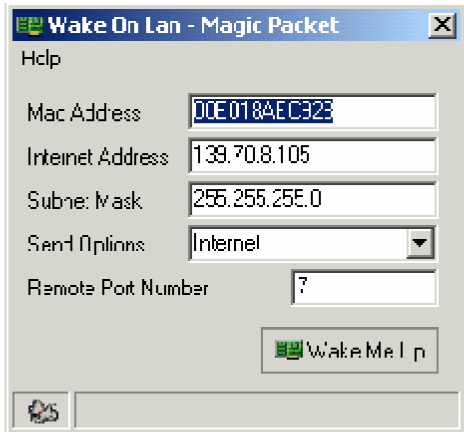

Fig. 7-1. The window generated when running the program WaveOnLanGui for WOL.

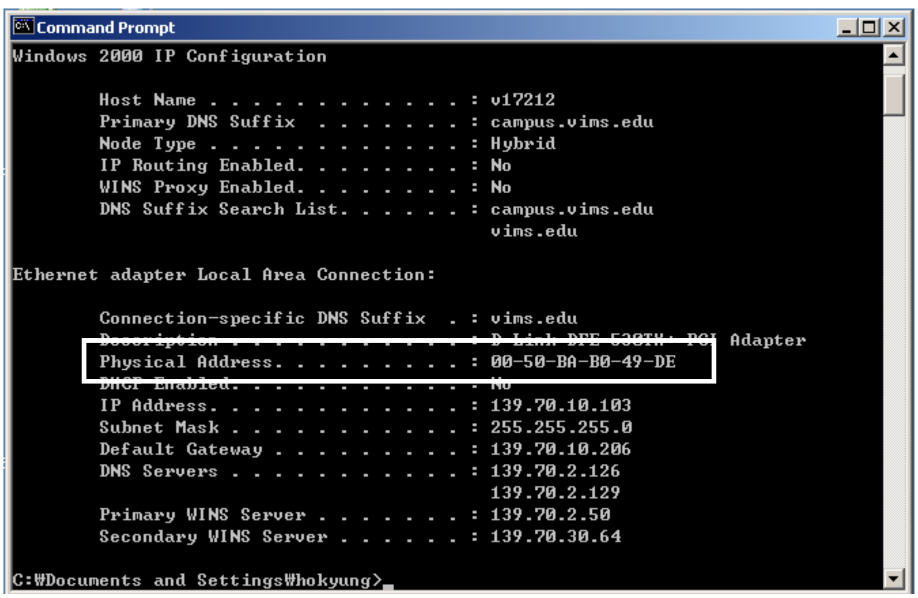

Fig. 7-2. An example of the window for the command prompt showing the MAC address which is the same as the 12-digit physical address. Each individual NIC has its own MAC different from other NICs.

A potential problem of using LAN is that for security reasons the firewall may prevent the computers from communicating. If the host to be connected is outside of the firewall of LAN, a user might have problems. If this happens, the LAN system administrator must be consulted for a solution.

7.3. Remote Access by Modem

Considering the limited network resources at isolated radar sites, WOM using an analog telephone line or a wireless telephone connection might be the choice for remote operation. Wireless systems were not reviewed as part of this project, but most of the details of WOM have been addressed with the regular, wired modem.

A dedicated phone number and a modem are required at both the remote host PC and the client computer. One modem dials and connects to the other. Similar to WOL, WOM switches the computer from the power-off mode when receiving a phone call. This requires that the host computer has been powered off properly (see next paragraph). Figure 7-3 shows the device connections for WOM with an external or an internal modem. Both types can be used for WOM, but an external modem requires another power supply. In this study, an external modem from US Robotics (Model: Sportster) was tested and proved satisfactory. Note that a wireless modem functions like an external modem the only difference being the service provided by the phone company. It is evident that in the future a wireless connection via Personal Communication System (PCS) would provide more convenient access.

For the motherboard (ASUS, A7V8X) used in this project, WOM works only under the “soft-off” mode accessed by pressing the power-off switch for about 4 seconds. This “soft-off” requirement may vary among motherboards provided by different venders. One needs to consult the user’s manual or the motherboard vender to determine the proper setting. Despite of the relatively slow communication speed, the modem-to-modem connection does not have the problem of crossing a security firewall.

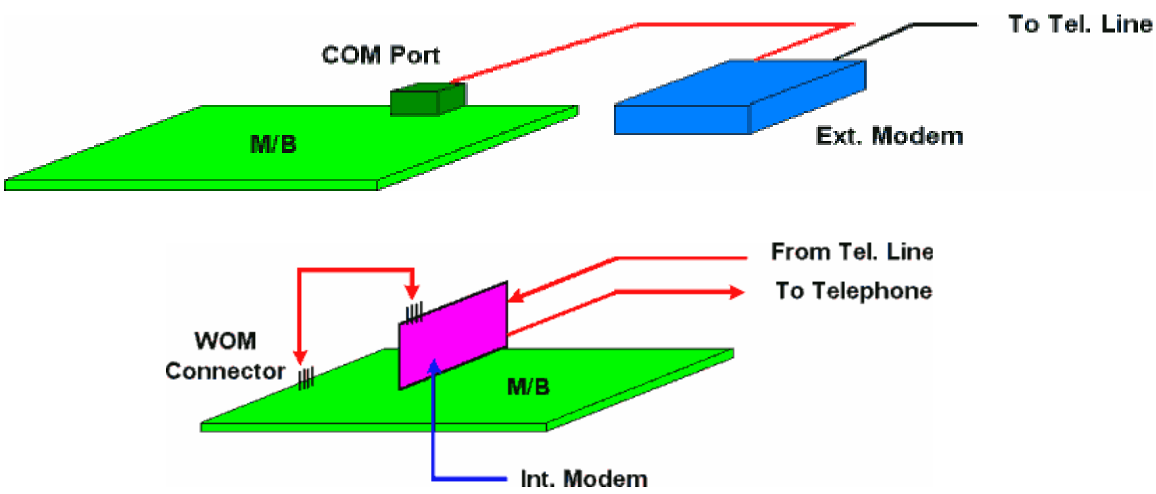

Fig. 7-3. The device connection diagram for WOM using either external or internal modems.

7.4. Software for Remote Control

PcAnywhere™ from Symantec was chosen for remote control between the host and client. This software provides a secure remote access for various types of connections, LAN and modem. Details of pcAnywhere commands can be found in the user's manual. There were no problems transferring files and folders and with remote control by either LAN or modem. Additionally, through the use of a password, the host computer can be protected from unauthorized access. Access to the computer resource can be restricted by setting the access rights options for each caller. The "Windows® XP Professional" operating system has a built-in function called "Remote Desktop" that is similar to pcAnywhere™, however, was not tested in this project. For details see http://www.microsoft.com/windowsxp/using/mobility/getstarted/remoteintro.mspx.

Chapter 8. Discussion and Conclusions

This section presents a discussion of possible hardware improvements, the limitations of X-band radar as a method of measuring waves, and other items that were not previously addressed. The section includes consideration of X-band radar as a tool for verifying numerical wave models along with a set of concluding thoughts.

1. Improvements Needed

During the course of working through the details of the X-band radar wave observation system, the major difficulties encountered were understanding of hardware limitations and the verifying the analytical results. Although most of the hardware requirements and reasons for them are given in Chapter 2, a few additional items need to be considered.

8.1.1. Stability of Antenna Speed: This is a rather critical factor for ensuring the accuracy of the system. In theory, successive radar scans should yield images with each pixel having exactly the same physical location. In other words, the location of any pixel in one image should be the same as the location of the corresponding pixel in the other images. Marine radars, however, may not meet this requirement because there is no usual need to examine consecutive images. When using radar to get consecutive radar images for 3-D FFT, however, this requirement is important. A high-precision gear motor and sufficient power supply are needed to meet this requirement.

8.1.2. Minimize Hardware Interference: As noted previously, the interference between the PCI graphic card and the PCI ADC device interrupted the ADC process and produced useless images at later stage. This problem occurred after November 2004, but the fatal interference on the radar image (Fig. 8-1) was not recognized until the data analysis process was completed. The square sub-domain retrieved from the previous figure shows the problem more clearly. The occasional missing radar line images (the blue lines in Fig. 8-2) produce a strong signal gradient in the x-direction. Thus, the resulting wave propagation direction, after taking FFT, is always parallel to the x-axis, either between 170^o to 180^o, or between -10^o to 10^o.

This problem was finally identified as the interference on PCI bus and solved by changing the PCI graphic card to an AGP card. It did, however, take months to identify this problem. Actually, it was the home-made digital radar trigger signal generator that helped shift our attention from software bugs to hardware interference. Before the generator was used, there is no firm answer on exactly how many trigger pulses would be generated from the radar for a half-circle radar image. Thus, it was not clear what caused the mis-counting problem. After switching to the generator, it finally became obvious that something else was wrong, and that lead to the identification of interference on the PCI bus. This experience prompts the following suggestions.

In a PC's BIOS setup, there are options for turning off devices. It is recommended that all the unnecessary devices, *e.g.*, video, audio, USB, parallel, serial ports, and keyboard, should be off and all unnecessary hardware should be removed.

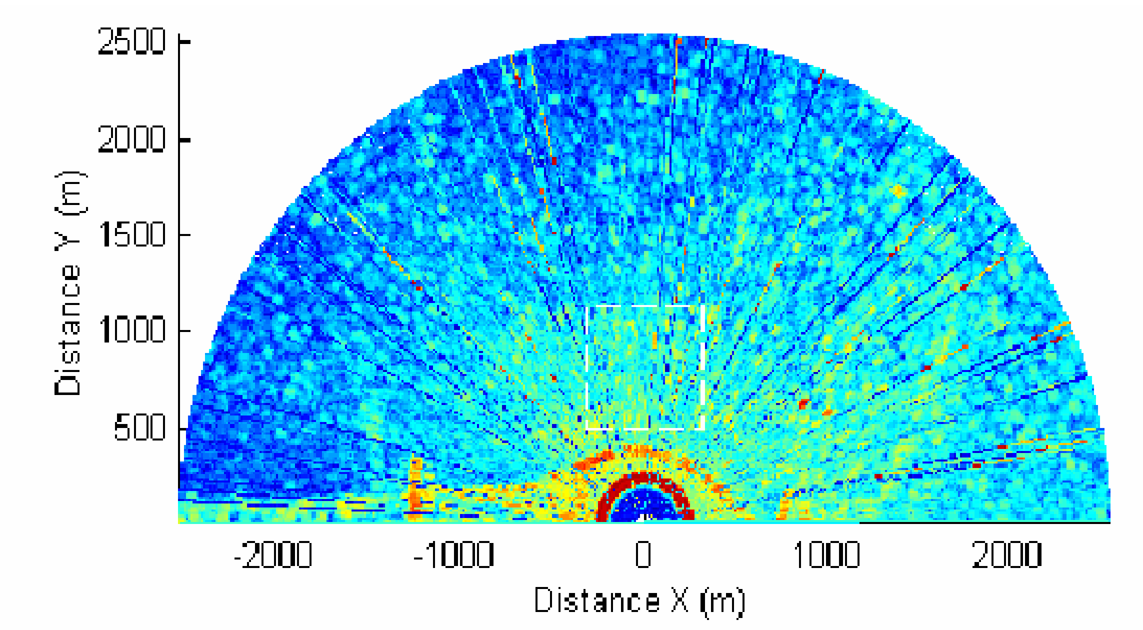

Fig. 8-1. A raw radar image showing the incorrect setting of the radar measurement range and the occasional missing line image.

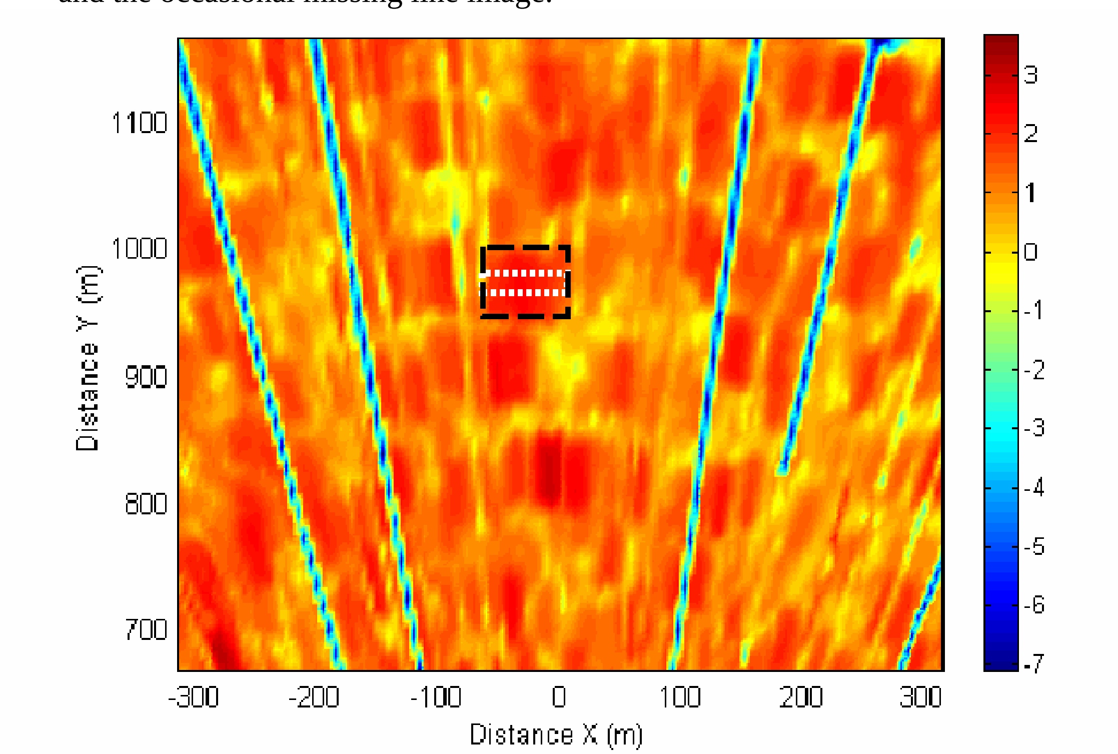

Fig. 8-2. The Incorrect setting on radar measurement range changes the image size from that in the thin white dotted box to that in a much thicker black dashed box. The occasional issing line images (the blue lines) produce a strong signal after FFT and with the result that waves always travel in a direction parallel to the x axis.

8.1.3. Select the Minimum Radar Operation Range: As mentioned in Chapter 2.6, the burst duration should be short so as to reduce echo image distortion in the radial direction. When operating the radar manually, however, a large operating domain often is selected in order to see a more complete picture. One has to remember to reset this to the minimum domain, *e.g.*, 500 m. If this is not done, the radar image will be smeared as shown in Fig. 8-2. In the center of this figure, if using the short range, then the wave face image shall be thin, as shown by the white dashed box. When using a large operation range, the image is thick, as shown by the black dashed box. The problem is an error in operation and this documentation should prevent its occurrence in the future.

2. Limitations

The antenna rotating speed of marine X-band radars is a major limitation as the maximum speed determines the temporal resolution. Because the Nyquist frequency is about 0.3 Hz (F_{nq} = $1/2\Delta t$, and Δt = 1.6667 s), any signal that is greater than 0.25 Hz cannot be trusted. The analysis Chapter 4 using a clearly know signals also demonstrates that a directional ambiguity problem remains when the frequency is close to the Nyquist frequency.

The spatial resolution of radar images limits the selection of a sub-domain, which should not be too far away from the antenna. A reasonable radius distance would be between 0.6 and 2.5 km, if the antenna elevation is sufficiently high. If the antenna elevation is low (*e.g.*, less than 10 m), then the radius distance would be reduced significantly (*e.g.*, 0.2 to 0.5 km). This limitation, however, may be utilized for different projects.

In this project, the radar was installed on the roof of a tall hotel building, and thus, the foundation was stable. If it is necessary to mount the antenna on a slender tower, the movement of radar during high wind might cause more image distortion. If that is the operating condition, more attention should be paid to the structure of the foundation.

The currently available method of data analysis is limited to 3-D FFT. Previous experience on wave data analysis on other types of wave measurement techniques suggests that a better approach might be possible. For example, the extended maximum entropy method (Hashimoto *et al.*, 1993) showed much better results for the wave buoy measurements. The need of other data analysis techniques for radar images, however, has to be justified first because of the very different input data. For example, radar images have information from many different locations (*i.e.*, 128 x 128 points in spatial domain, and 64 points in time domain). Traditional wave data analysis techniques are heavily dependent on information from time domain (*i.e.*, 4096 points), but only have 3 points in the spatial domain (with a total of 12,288 points of input data). For this reason, the traditional techniques developed for wave measurement may not necessarily be superior to the 3D FFT approach used in this study. Actually, the results presented in Chapter 4 demonstrated that 3-D FFT can produce very accurate results for directional distribution. This is mainly due to the large size of the input dataset (1,048,576 = 128 x 128 x 64 points). The number of input data used for buoy data analysis, on the other hand, is only around 1percent of that for radar image analysis.

Another limitation of this technique may occur if the bathymetry at the radar measurement site is too complex to avoid the assumption that the wave field is “stationary.” For example, if wave the diffraction or refraction process is strong, then the traditional FFT procedures cannot be used. In that case, wavelet analysis should be used (Doong *et al.*, 2001; 2003). The other option to overcome this difficulty is to reduce the size of the selected sub-domain (*e.g.*, from 128 x 128 points to 64 x 64 points) and increase the number of images for FFT (*e.g.*, from 64 images to 128 images). Although this option has not verified, it is based on the understanding that wave diffraction and refraction is a local effect and a smaller sub-domain should have a smaller impact caused by a local effect.

3. Other Features.

Given the resources and specific focus of this project, only the details of the wave measurement portion of a X-band radar wave observation system have been studied. It is documented, however, that tidal current fields and the bathymetry can be measured by this remote sensing technique (Bell, 1999; Prandle *et al.*, 2000; Kobayashi *et al.*, 2001; Gangeskar, 2002; Lee *et al.*, 2005; Wu *et al.*, 2005). Ruessink *et al.* (2002) used marine X-band radar in studies of the dynamics of nearshore bar-crest locations. McNinch (personal communication) is developing study of sand bar movement using a small (6 kw) radar. The above statements demonstrate that there is a great potential for this remote sensing technique.

Additionally, it is worth noting that a small (6 kw) marine X-band radar could also be used for measuring waves, with a limitation of a small range, around 200 to 500 m from the radar. The principal of this application is identical to that of the radar used in this study, and the only limitation is the range. Because it is much easier to increase the antenna speed for small radars, the accuracy of FFT can be improved. This is particularly useful for offshore wave measurement where the bathymetry has little influence on waves.

8.4. A Tool to Verify Numerical Model Results

In our previous numerical studies on wave transformation near coastal areas, it was not uncommon to see a strong gradient of wave condition along the coast. Because it is hard to deploy a sufficient number of traditional wave gauges to capture the gradient, it is hard to field verify the model results. With the X-band radar wave observation system, however, image analysis on different shore-parallel sub-domains are possible, and thus, can be used for the purpose of model verification.

Before the this application can be implemented, however, the question on different radar scatter reflection, caused by different radar beam incident angles, should be addressed. Because the radar wave signals are weaker if the incident beam is not normal to the wave crest lines, it is understood that the radar measured echo signals would be different even the wave condition are the same. The possible relationships among radar measurement results, wave propagation direction, and radar beam direction should be investigated. These subjects would be the target for next phase study.

8.5. Conclusions

1. Using marine X-band radar for wave measurements and other scientific purposes is a promising remote sensing technique. This is because of the versatility of the systems and the advances of personal computer and high-speed ADC devices.
2. For the X-band radar set up used in this study, there is a limitation on temporal (< 2 Hz) and spatial resolution (> 8 m).
3. For offshore uses of this technique, a small (6 kw) X-band radar might be the best choice.
4. Experience on calibrating the X-band radar installed at Virginia Beach indicates that it is impossible to get a perfect correlation between the Signal Noise Ratio (SNR) and the significant wave height. More comprehensive calibrations are necessary to clarify the reason(s) of a scatter correlation between these two parameters.
5. Other wave analysis techniques for use with radar image analysis should be verified with mathematically generated wave fields.

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Project Report

Beach Nourishment Monitoring Protocol
and
Assessment of the Subaerial and Nearshore Region of Sandbridge, Virginia

Submitted

to

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Chapter 4

Beach Nourishment Monitoring Protocol
and
Assessment of the Subaerial and Nearshore Region of Sandbridge, Virginia

1. Introduction

Beach nourishment has become a standard practice for mitigating coastal erosion problems and for resolving often contentions resource management issues. The use of sand and gravel resources from the Outer Continental Shelf (OCS) for nourishment projects has grown rapidly and is predicted to increase as comparable upland resources are depleted or become less accessible. Numerical wave modeling has shown that excavation of OCS shoals can modify the local wave transformations and, consequently, the sediment transport regime and pathways (Maa and Hobbs 1998; Basco *et al.* 1999; Bender and Dean 2003; Kelley *et al.* 2004). These potentially large scale system changes may cause unanticipated morphological changes in the subaerial beach and nearshore region (Bender and Dean 2003). In anticipation of increased demand for nourishment material from the OCS, the Minerals Management Service (MMS) commissioned development of a suite of protocols for monitoring and managing marine mining sites and adjacent areas impacted directly of indirectly by the mining activities (Michel *et al.* 2001; Nairn *et al.* 2004).

In 1999, MMS commenced a research effort to develop, field test, and evaluate a suite of monitoring protocols with the possibility of eventually implementing a standard policy for future sand-mining efforts in federal waters. Since 2002, the Virginia Institute of Marine Science (VIMS) has worked on a multi-phase effort to evaluate the efficacy of the protocols in capturing changes to the southeastern coastal area of Virginia resulting from sand mining on Sandbridge Shoal and beach nourishment along Sandbridge and Dam Neck. The program includes testing a methodology to document shoreline and nearshore change due to beach fill and mining. The field effort focused mapping the three dimensional subaerial beach and adjacent nearshore area. The subaerial beach was documented using real-time kinematic GPS equipment deployed on an all-terrain vehicle. These quasi-periodic topographic surveys, coupled with a swath bathymetry survey, chirp seismic, and periodic two dimensional offshore beach profile surveys, were used to create a detailed picture of beach and nearshore morphology. Another component of the program called for review and integration of available historic data. The analysis focused on beach profile data collected between 1980 and 1999 along Sandbridge Beach. These data were used to document the variability of recent and historic shoreline and nearshore change and to provide a baseline for morphologic change comparisons. Also it was beneficial to place the Virginia experience in context of existing monitoring programs that were established in the areas where the OCS is being or is anticipated to be mined. The combination of field testing results and information gained from existing monitoring programs was used to specify minimum monitoring requirements.

2. OCS Mining, Nourishment, & Monitoring: Finding Common Ground

2.1. Background

Many issues need to be addressed when developing a systematic monitoring protocol. Foremost, it is essential to frame any protocol in context of the range of shoreline and nearshore types and conditions in which nourishment and mining are being conducted. Since regional coastal zones differ in morphology, geologic setting, hydrodynamic climate, and human impact, a universal definition or standard of a beach and or nearshore environment not only is impractical but is impossible. The range of morphologic character and hydrodynamic regimes necessitates utilization of an adaptive suite of monitoring and management approaches. Monitoring protocols, including those aimed at evaluating the effect of mining borrow sites on adjacent beaches, must be planned and implemented within the framework of local and, if possible, regional conditions. In order to address larger scale processes, programs should, however, be designed and implemented around commonalities so that projects within regions or with similar conditions can be compared and used to enhance performance and mitigate adverse impacts of mining and nourishment. Most importantly, the design of the monitoring program should reflect how the data will be used to support decision making.

A sound understanding of the beach and nearshore system is necessary for the evaluation and mitigation of possible adverse, short-term and long-term changes resulting from modifications to the original system. Since physical responses to dredging at borrow sites and placement of the dredged material on the subaerial beach are not well understood, it is a difficult and uncertain task. Changes owing to dredging may affect offshore shoal stability, regional sediment transport regimes and pathways, wave energy, and nearshore and subaerial beach stability. Borrow areas, nourished beaches, and the adjacent nearshore continually respond to external system forcing, including storms and seasonal changes, which in turn interact with antecedent, underlying geology.

Different approaches are being taken in different areas to evaluate the performance and impacts of beach nourishment projects. Monitoring is often cited as too limited and of insufficient duration to effectively quantify project performance or project-related impacts (Seymour *et al.* 1996). The scope and extent of monitoring efforts are a function of the availability of funding. It has been argued that extensive monitoring programs should be required for all beach nourishment projects and should be factored into the cost of such projects. Of course, proponents do not offer a solution for finding the funds necessary to implement expansive programs.

Advocates for monitoring argue the need for a mechanism to track changes and/or unanticipated effects (such as erosional hot spots), assess project performance, and provide a basis for design refinements and corrective action (Seymour *et al.* 1996). Physical monitoring typically is limited to tracking sand within and away from the target area. Seymour (1996) identified a range of problems with this brand of systematic monitoring; often cited problems include inappropriate cost sharing, insufficient monitoring protocol design, data analysis, and incorporation of data into exercisable management strategies and policy. It is clear that the objective and endpoint of a monitoring program must be clearly outlined from the onset of the project; however, provisions for adapting and modifying monitoring procedures and guidelines must also be provided. An effective monitoring regime must provide data with which to answer questions pertinent to the project and area of interest and also to justify the nourishment activity.

The scale of monitoring generally is related to the scale of the project or the scale of anticipated effect. Small-scale monitoring may only be necessary for a smaller project. Conversely, for larger-scale projects, more comprehensive monitoring and a longer duration may be warranted. Projects with potential significant impact may warrant extensive, long-term monitoring. Moreover, monitoring can provide necessary information for subsequent mining and nourishments; it is difficult to evaluate performance and impact without commensurate data. Data obtained from effective monitoring projects may indicate that subsequent monitoring is not necessary locally or even regionally. Every monitoring protocol needs to be reviewed with a regular frequency in the context of resultant data and modified to reflect management needs and system conditions.

The best compromise will strike a balance between information needed and gained about the system and the cost for the acquisition of that information. In finding common ground, the monitoring scheme also must account for the rights of states and local entities. In a more practical sense, there must be an appropriate scale, resolution, and frequency of monitoring that balance the concerns facing each site.

2.2 Common Variables

2.2.1. Monitoring

The essential components of the monitoring scheme include the spatial coverage and density, survey frequency, surveying procedures, required accuracy and precision, and application of data to scientific and decision models (Table 1). For example, spacing of two-dimensional profiles can be problematic if local spatial changes (deposition and erosion) are complex and highly variable. The exact specification should reflect an adaptive management approach and vary with the objectives and needs of the project, setting, project budget, and evolution and performance.

The recommended protocol (Michel *et al.* 2001) advocates the use of line models to track morphologic change. Such line models typically operate on the movement of a representative shoreline. This outlines the importance of clear delineation of the shoreline through time (National Research Council 2004). Pajak and Leatherman (2002) and Leatherman (2003) emphasize the variability of indicators employed for shoreline change mapping and list the standard proxies employed including beach scarp, high water line, mean and low high water, berm crest, vegetation line, dune toe, dune crest, and bluff edge. It is important to recognize that a common reference feature must be selected and used consistently within the project and balanced with adjacent and overlapping efforts.

Table 1
Essential Components of Beach Topographic and Nearshore Bathymetric Surveying

Spatial Coverage:	
	Longshore Extent
	Cross-shore Extent
Spatial Density:	
	2D vs 3D
	Cross-shore Profile Spacing
	Point Spacing
	Longshore Profiles
Survey Frequency:	
	Seasonal
	Event
Methodology / Technology	
Resolution and Accuracy	
Projection	
Data Analysis / Application	

2.2.2. Technologies

Changes in shoreline behavior due to nourishment, offshore mining, and/or natural causation typically are documented by periodic beach topographic and nearshore bathymetric surveys. Historically, accurate but time consuming ground-based surveys of cross-shore profiles have been conducted to analyze long-term erosion trends and beach nourishment performance (Morton *et al.* 1993). At a minimum, such surveys provide two-dimensional elevation data along shore normal lines of the subaerial and subaqueous beach extending from the foredune toe, sea wall, or a specified baseline into the water, typically wading depth or a depth assumed to approximate the depth of closure (Weggel 1995; Gorman *et al.* 1998). More recently, 3D kinematic GPS surveys have been used to provide accurate and rapid delineation of shoreline positions and detailed topographic variability over much larger areas of the subaerial beach (Ruggiero *et al.* 2000; List *et al.* 2002). These beach surveys are easily coupled with nearshore bathymetric surveys made with single, swath or multibeam echosounding. In the last few years, airborne scanning laser systems also have also been used to survey extensive areas or reaches of shoreline and, when possible, the nearshore (Stockdon *et al.* 2002).

2.2.3. Numerical Modeling

Unexpected changes in the shoreline planform have been attributed to mining offshore borrow pits where the changes in offshore bathymetry modify the local wave refraction, diffraction, reflection, and dissipation (Bender and Dean 2003). In addition to wave transformation, sediment transport dynamics also may be affected by bathymetric anomalies and/or physical/hydrodynamic coupling. Numerical models permit for moderately flexible representation of nearshore dynamics and shoreline response to the change in wave field and can be used to study the evolution of nourished beaches. Though they draft protocols (Michel *et al.* 2001) included a recommendation concerning numerical modeling, it was not tested as part of this evaluation and will not be discussed further.

3. The Virginia Experience

3.1. Introduction

The Virginia Institute of Marine Science (VIMS) designed and implemented a multi-phase, field program to study various aspects of Virginia's southeastern coast in the vicinity of the Sandbridge Shoal complex based on the proposed MMS monitoring protocols. This included field testing a methodology for documenting shoreline change and assessing beach impacts at Sandbridge, Virginia due to mining at the offshore borrow site and to monitor the movement of sand on the beach.

Field testing incorporated real-time kinematic (RTK) GPS and an all-terrain vehicle to map reference features along the beach. These beach topographic surveys, coupled with a suite of cross-shore beach profiles collected by Waterway Surveys & Engineering, Ltd., provided a more detailed picture of nearshore and beach morphology. A suite of digital shorelines was developed from historic aerial photographs and analyzed to determine regional shoreline change rates. Another suite of digital shorelines was also developed from the RTK-GPS data and the beach profile data. The new high-resolution beach topography, beach profile, and shoreline position data were integrated with existing beach profile data. Nearshore geophysical surveys, including interferometric, swath bathymetry, side scan sonar, and chirp seismic were conducted and used to evaluate the effectiveness of traditional methods of profiling the beach and nearshore.

3.2. Study Area

The southeastern Virginia coast extends from Cape Henry at the mouth of the Chesapeake Bay to False Cape and the North Carolina state line (Figure 1). The focus of this work, Sandbridge Beach, is found within this larger shore cell. Sandbridge consists of approximately 7.7 km of shoreline along the Atlantic Coast, south of the U.S. Naval Fleet Anti-Air Warfare Training Center at Dam Neck and north of Back Bay National Wildlife Refuge. The shoreline between Cape Henry and False Cape is a barrier beach and dune system. From Rudee Inlet south to the northern segment of Sandbridge, the beach abuts the mainland, whereas the southern half of Sandbridge south to False Cape is separated from the mainland by backbarrier lagoons, North and Back Bays.

Figure 1: Location of the Sandbridge Beach, Virginia study area.

Approximately eighty percent of the oceanfront in Sandbridge is private property (Basco *et al.* 1997). In the late seventies and early eighties, homeowners began bulkheading private property to protect it. Similarly, bulldozing of the beach to pile sand in front of threatened structures was routine practice (Figure 2) (Hobbs *et al.* 1999). Beginning in 1988, the residents of Sandbridge began an extensive bulkheading effort to inhibit dune erosion (Figure 2). Between 1988 and 1990, bulkheads were constructed along over 3,900 m of shoreline. By 1995, over 4,700 m of shoreline at Sandbridge had been protected (Basco *et al.* 1997). Since then, many of the bulkheads have failed, have been removed, and/or have been rebuilt. More recent anthropogenic impact to Virginia's southeast coast has been extensive beach nourishment. In 1996, approximately 600,000 m^3 of sand mined from Sandbridge Shoal was pumped onto Dam Neck, immediately north of Sandbridge. During the summer of 1998, Sandbridge beach was nourished with approximately 840,000 m^3 of sand also taken from Sandbridge Shoal. Most recently, during the winter and spring (January - May) of 2003, Sandbridge beach was again nourished using approximately 1,500,000 m^3 of Sandbridge Shoal derived sand (Figure 3). Dam Neck was nourished again between January and April 2004, with 535,000 m^3 dredged from Sandbridge Shoal.

Historic shoreline recession rates at Sandbridge range from 1.1 m y^{-1} at the northern end to 3.5 m y^{-1} at the southern end (Everts *et al.* 1983). The long-term pattern shows significant recession in the vicinity of south Sandbridge. The maximum long-term erosion rate of 3.5 m y^{-1} corresponds to high-average-breaking-wave height described by Wright *et al.* (1987) and Maa and Hobbs (1998). The distribution of the longshore component of wave energy along the southeastern Virginia coast is controlled by the nearshore bathymetry. Wright *et al.* (1987) performed a wave climate analysis using a linear wave propagation model, RCPWAVE, which computes changes in wave characteristics that result naturally from refraction, shoaling, and diffraction over nearshore topography. The results of the analysis indicated a concentration of wave energy in the area just south of Sandbridge. This corresponds to an area of greater water depth. This region also has the highest rate of shoreline recession on the southeast Virginia ocean coast and is considered an area of divergence, or a "nodal" zone, from which shore-zone sediments are transported northward toward Cape Henry and southward toward False Cape (Everts *et al.* 1983). Hobbs *et al.* (1999) found that the highest historic erosion rates (1851-1925) along the southeast Virginia coast occurred at the south end of Sandbridge at Little Island Park and at the southern portion of Back Bay National Wildlife Refuge. However between 1925 and 1980, the highest rates of erosion had shifted slightly north in Sandbridge. Shorter-term rates were variable depending on the method of calculation. However, from the City of Virginia Beach's profile data (1980-1996), the southern end of Sandbridge at Little Island Park was erosional.

Figure 2: Photographs depicting the chronic shoreline erosion and the effort of the local residents to mitigate loss of property. Descriptions from top left: 1) bulldozing to elevate foredune and dune (1985), 2) seawall construction along south central Sandbridge (1986), 3) oblique aerial photograph looking north from Little Island Park (1990), and 4) seawall failure (1994).

Seasonal variations play a large part of shore change along this stretch of coast. Hardaway *et al.* (1998) found that subaerial beach accretion occurs in the summer or fall and beach erosion occurs in the winter or spring. The summer profile has the highest berm and nearshore bars will develop during the winter indicating that sand is stored in the bar system during the winter. Twenty years of WIS data obtained from the U.S. Army Corps of Engineers website show a distinct difference in seasonal wave conditions off the southeast Virginia coast (Table 2). In fact, a decadal variation occurs within the dataset as well. Winter waves were more northerly during the 1990s than during the 1980s (Figure 4).

Table 2
Twenty Years of WIS Data Presented Seasonally

Year	Spring Hmo (m)	Spring Direction (degree TN)	Summer Hmo (m)	Summer Direction (degree TN)	Fall Hmo (m)	Fall Direction (degree TN)	Winter Hmo (m)	Winter Direction (degree TN)	Mean Hmo (m)	Mean Direction (degree TN)
1980	0.7	122	0.7	116	1.2	138	1.2	170	1.6	137
1981	0.8	122	0.9	101	1.2	166	1.1	171	1.0	142
1982	0.7	114	0.6	113	1.1	102	1.1	132	0.9	115
1983	0.8	128	0.7	107	1.2	147	1.4	137	1.0	130
1984	0.8	134	0.8	110	1.1	119	1.2	141	1.0	121
1985	0.7	132	0.8	105	1.1	143	1.1	177	0.9	139
1986	0.9	116	0.7	116	1.1	101	1.1	156	0.9	122
1987	0.9	102	0.7	101	1.0	149	1.2	145	1.0	125
1988	0.8	114	0.7	121	1.0	164	1.0	135	0.9	134
1989	0.8	133	0.9	104	1.1	164	1.1	125	1.0	132
1990	0.7	109	0.7	106	1.0	118	0.8	124	0.8	114
1991	0.7	102	0.7	105	1.0	116	1.0	121	0.8	111
1992	0.9	103	0.8	112	1.2	111	1.2	134	1.0	115
1993	0.8	116	0.8	110	1.2	122	1.3	116	1.0	116
1994	0.9	118	0.7	120	1.4	100	1.2	149	1.0	124
1995	0.8	99	1.2	101	1.2	152	1.2	149	1.1	126
1996	0.9	121	0.9	132	1.2	124	1.4	145	1.1	131
1997	0.9	123	0.7	109	1.0	134	1.1	131	0.9	124
1998	0.8	110	0.9	117	0.9	140	1.3	125	1.0	123
1999	1.0	109	1.0	118	1.2	139	1.1	164	1.1	132
Mean	**0.8**	**116**	**0.8**	**111**	**1.1**	**133**	**1.1**	**142**	**1.0**	**126**

Figure 3: Oblique aerial photography (courtesy of City of Virginia Beach) documenting the 2003 beach nourishment at Sandbridge Beach. Descriptions from top left: 1) January 2003 pre-nourishment, 2) late January 2003 nourishment, 3) April 2003 between winter 2003 and May 2003 nourishment cycles, and 4) September 2003 post-nourishment conditions shortly after Hurricane Isabel.

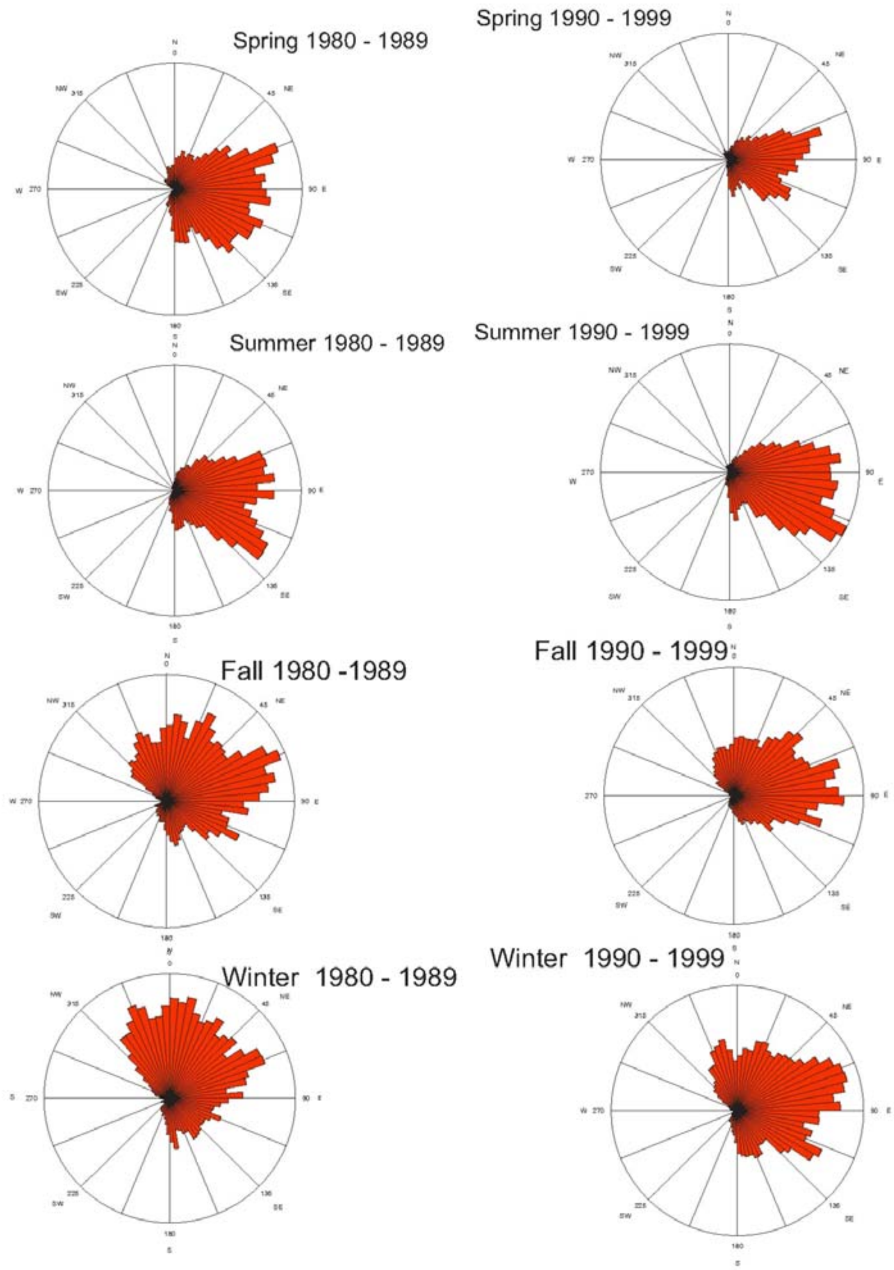

Figure 4: Seasonal WIS data from the U.S. Army Corps of Engineers. Wave roses were created from monthly means calculated by the Corps and grouped into seasonal sets and summarized on a decadal scale.

3.3. Historic Beach Profile Dataset

Survey data obtained from the City of Virginia Beach and Old Dominion University Coastal Engineering Center (ODU-CEC) (Table 3) were used to help contextualize different aspects of the protocol. Since the data were collected by several different research entities, the profile length and spacing, baseline reference, methodology, and survey frequency varied significantly (Figure 5). Some of the ODU-CEC profiles were surveyed using the same reference location as the City of Virginia Beach data. All profile data were entered into a database using the Interactive Survey Reduction Program (ISRP) (Birkemeier 2000) and checked for errors using CEDAS-BMAP. All data were referenced to the same elevation datum (NGVD 1929); however, each data set was horizontally referenced to a different baseline. Although it was possible to mosaic the beach profile data into a single database by re-referencing the data to a uniform baseline, such a project was beyond the scope of this effort. As a result, the data, which generally correspond to discrete time periods, were analyzed separately.

Table 3
Beach Profile Survey Data Analyzed in this Study

Source	No. of Surveys	Survey Dates	Survey Frequency	Surveys	Length	Spacing	Vertical Datum
City of Virginia Beach	9	1980-1994, 1996,2000	Depends on Profile	18-37	Variable	Variable	NGVD 1929
Old Dominion Univ. CEC	28	1990-1999	Monthly / Post-storm	106-111	Wading Depth	Variable	NGVD 1929

Table 4 summarizes the historic beach-profile data used to characterize the cross-shore, alongshore, and shoreline position variability in south Sandbridge Beach (near Little Island Park) from 1980 to 2000. Between 1980 and 1994, approximately 60 km (37 miles) of ocean and bay shoreline were routinely surveyed by the City of Virginia Beach Department of Public Works at 29 ocean coast locations. Prior to 1987, surveys were performed quarterly (*i.e.* spring, summer, fall, and winter), and at least two times per year, select profiles were run offshore to approximately 7 m below mean sea level (NGVD 1929). After 1987, the frequency of surveying varied significantly. While nine of the City of Virginia Beach profiles provide excellent reference for the study area, only profile 57, located in Little Island Park, is used in the subsequent analysis. ODU-CEC surveyed the Sandbridge Beach shoreline monthly from 1991 to 1999 (Basco *et al.* 1997). Elevations were interpolated for four months over the 106-month period to provide for monthly profiles. The complete dataset consists of 28 irregularly spaced profiles at seawall and dune locations. The profiles extend from the middle of Sandfiddler Road to wading depth, approximately Mean Low Water. Each profile was numbered by the distance in hundreds of feet south of the Dam Neck Sandbridge property boundary. The following analysis focuses on the profiles measured along the most southern segment of Sandbridge Beach, including Little Island Park and one kilometer

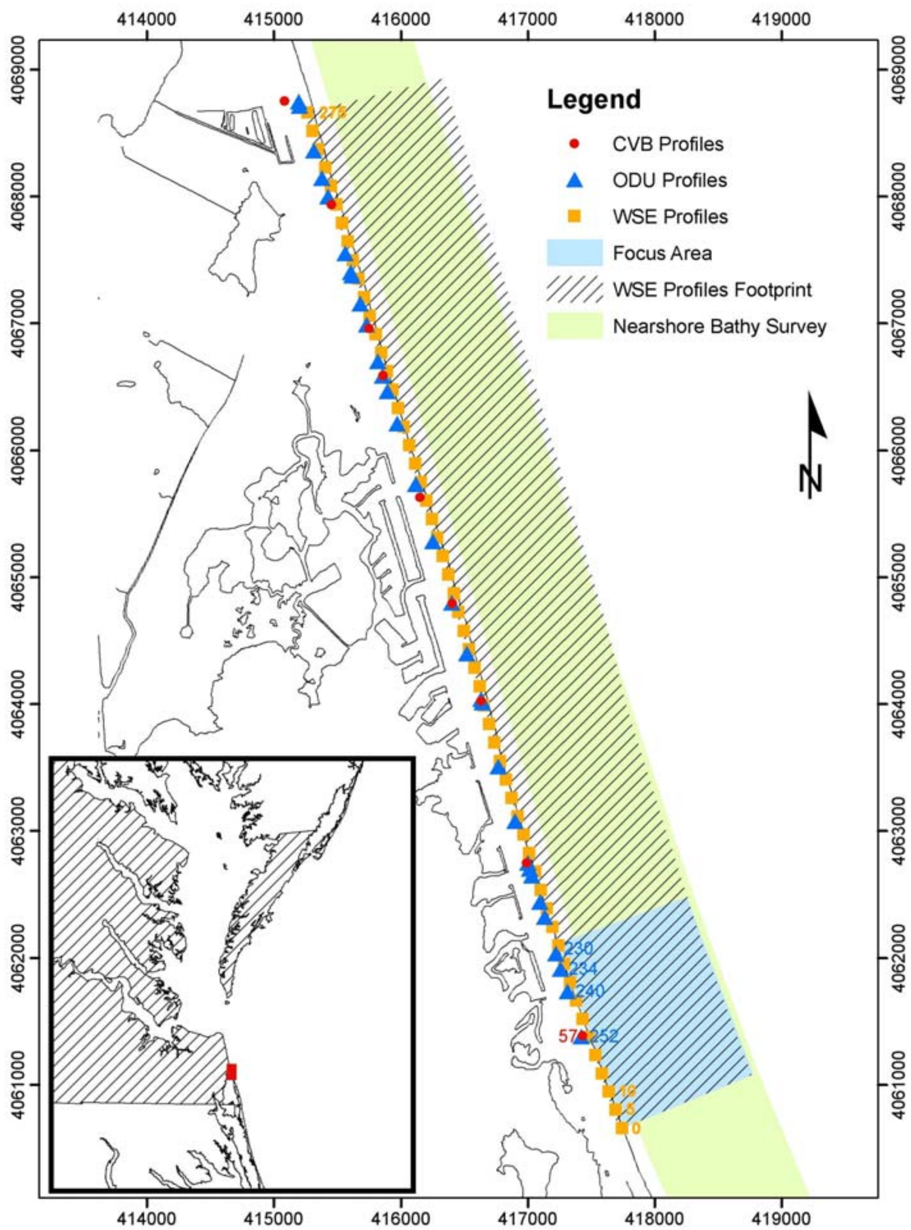

Figure 5: Location map of Sandbridge showing historic and recent beach profiles and the bathymetric survey analyzed for this report. From 1980 to 1993, the City of Virginia Beach (CVB) collected beach profiles at 9 locations. From 1991 to 1999, Old Dominion University (ODU) collected monthly beach profiles at 31 sites. Waterways Surveys and Engineering (WSE) collected beach profiles at 56 sites following the most recent nourishment (2002 to 2005). In May 2002, VIMS conducted an interferometric swath bathymetry survey and from 2002 through 2005 a series of RTK-GPS surveys of topographic reference features. Coordinates in UTM NAD 1983 (m).

immediately north of the park (Figure 5). Profiles 230, 234, and 240 are located along a stretch of residential properties, whereas profile 252 is located in Little Island Park. ODU-CEC profile 252 was surveyed using the same reference location as the City of Virginia Beach profile 57.

Table 4
Historic Beach Profile Survey Data Analyzed in this Study

Source	Profile Number	Dates	Frequency	Surveys	Datum
City of Virginia Beach	57	1980-1993	Irregular	16	NGVD 1929
Old Dominion Univ.	230,234,240,252	1990-1999	Monthly	106*	NGVD 1929

*Four surveys were linearly interpolated at each profile location.

3.3.1. Shoreline Change Method and Results

Shoreline change can be evaluated by examining the cross-shore migration of a tidal contour. At Sandbridge Beach, the 0.67 m (approximately 2 ft) contour (NGVD29) approximates the Mean High Water (MHW) datum (Basco *et al.* 1997). The MHW contour separates the subaerial beach from the subaqueous nearshore. A MathWorks MATLAB™ script was written to linearly interpolate beach profile elevations between survey points and to extract the distance between the profile's baseline and the MHW elevation intersecting the cross-shore profile. The change in position of MHW was plotted through time. Endpoint and linear regression shoreline change rates were calculated for several distinct time periods to describe the variability in decadal shoreline change. The endpoint rate calculation (EPR) only utilizes the first and last shoreline position and survey date, whereas linear regression rate calculation (LRR) utilizes all data in the specified time window. Figure 6 depicts the southern portion of Sandbridge, the 1994 high water shoreline, and the locations of specific profiles.

The analyzed profiles are presented in Figures 7 through11. Figure 7 shows the surveys taken by the City of Virginia Beach between 1980 and 1993 and describes the spatial variability of the system particularly in the shoreface and nearshore berm. Figures 8through 11 depict the yearly data taken by collected by ODU at four different profile locations as shown on Figure 6. These figures also show the spatial and temporal variability of the system, particularly when viewing the oblique three-dimensional cross-shore profile shape through time. The last of the eight panels (labeled January 1998-October 1999) includes data collected before and after the nourishment project in the summer of 1998. Eighteen surveys, measured within sixteen months after the beach nourishment, are further highlighted in Figures 12 through 15 and illustrate the variability inherent in the beach profile configuration following beach nourishment.

Since a twenty-year record for shoreline position was available for Little Island Park (spatially coincident CVB profile 57 and ODU profile 252), shoreline change rates could be determined to evaluate decadal and sub-decadal shoreline position variability in the south Sandbridge area. Figure 16 reveals the variability of the Mean High Water contour from 1980 through 1999. The decadal-scale shoreline clearly retreats landward, and seasonal recession and progradation are superimposed on the overall landward migration. Shoreline change ranges, both EPR and LRR, were determined at several time scales, including entire survey period (1980-1999), approximately ten-year intervals (1980-1990; 1991-1998), and pre-nourishment (1980-1998) and post-nourishment intervals (1998-1999) (Table 5).

The shoreline retreat at Little Island Park is relatively constant when considering decadal time scales. The erosion rate from 1980 through 1990 (10 year period) is comparable to that from 1991 through 1999. The twenty-year erosion rates are misleading since the rates reflect the artificially inflated shoreline conditions after beach nourishment in spring 1998. Likewise, end point rates are misleading in that the change rates can show some bias associated with seasonality. The significant increase in erosion rates reflected in the sixteen months post nourishment reflect equilibration, or net offshore movement of sand from the subaerial to subaqueous portions of the nourished profile.

Table 5
Shoreline Change Rates for Specified Time Windows at Little Island Park, Located at the Southern Boundary of Sandbridge Beach

Window	No. of Surveys	Method	Rate (m/yr)	r^2
10/1980-12/1990 [Decadal]	28	EPR	-1.89	N/A
		LRR	-1.85	0.57
10/1980-4/1998 [Pre-Nourishment]	127	EPR	-1.32	N/A
		LRR	-1.47	0.61
10/1980-10/1999 [Entire Period]	144	EPR	-0.80	N/A
		LRR	0.85	0.27
1/1991-10/1999 [Decadal]	99	EPR	-1.91	N/A
		LRR	-1.22	0.20
5/1998-10/1999 [Post-Nourishment]	17	EPR	-13.43	N/A
		LRR	-6.70	0.50

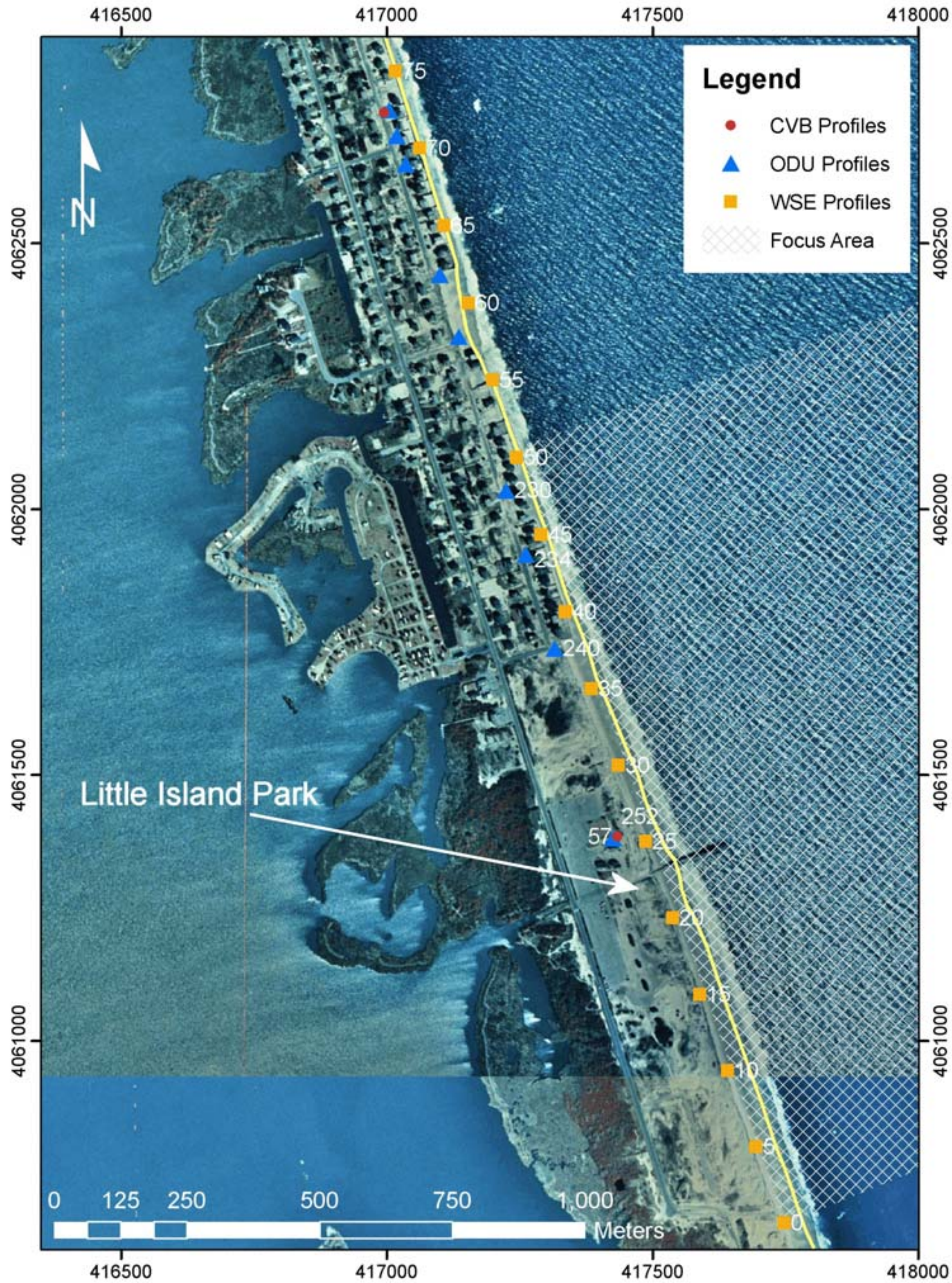

Figure 6: Plan view of the southern portion of Sandbridge Beach, Virginia. The 1994 high water shoreline is delineated in yellow. The 1994 base imagery was acquired by the USGS National Orthophotography Program. Analyses of historic beach profiles focused in the area north of Little Island Park. A comparison of bathymetric models derived using hydrographic and nearshore profiles was completed in the focus area. Coordinates in UTM NAD 1983 (m).

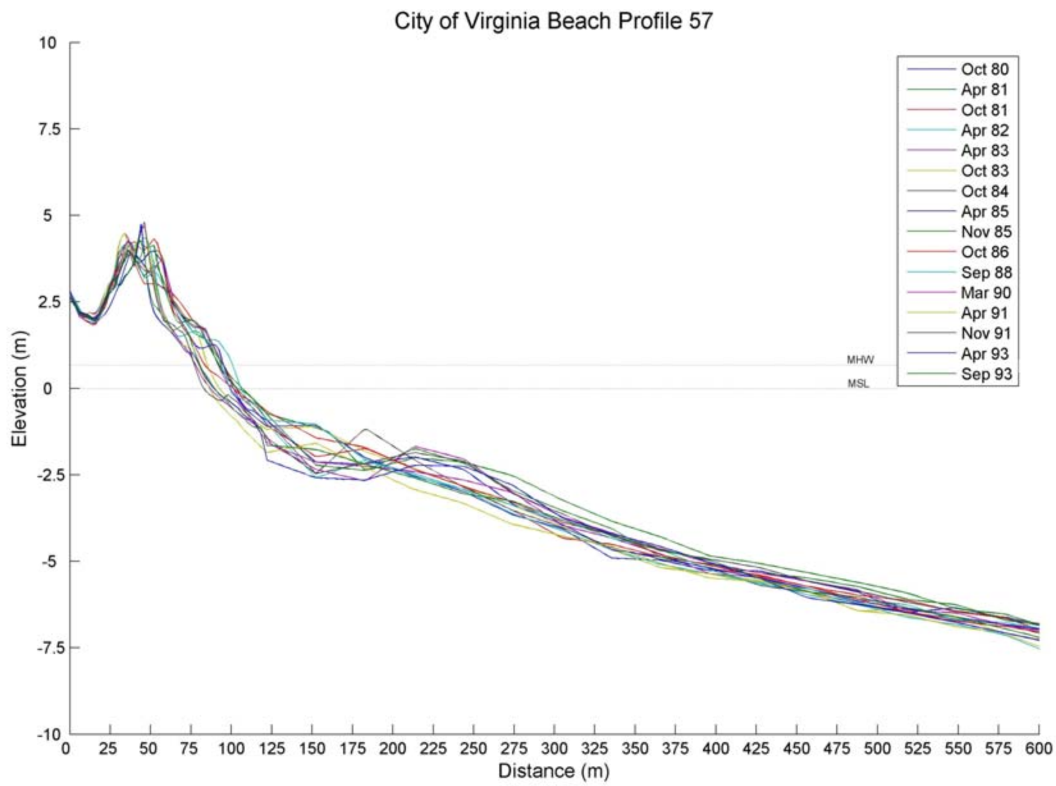

Figure 7: City of Virginia Beach long profiles surveyed between 1980 and 1993 at location 57 in Little Island Park (see Figures 5 and 6 for location). Most of the variability is associated with the shoreface and the position and height of the nearshore berm. Vertical datum is NGVD 1929.

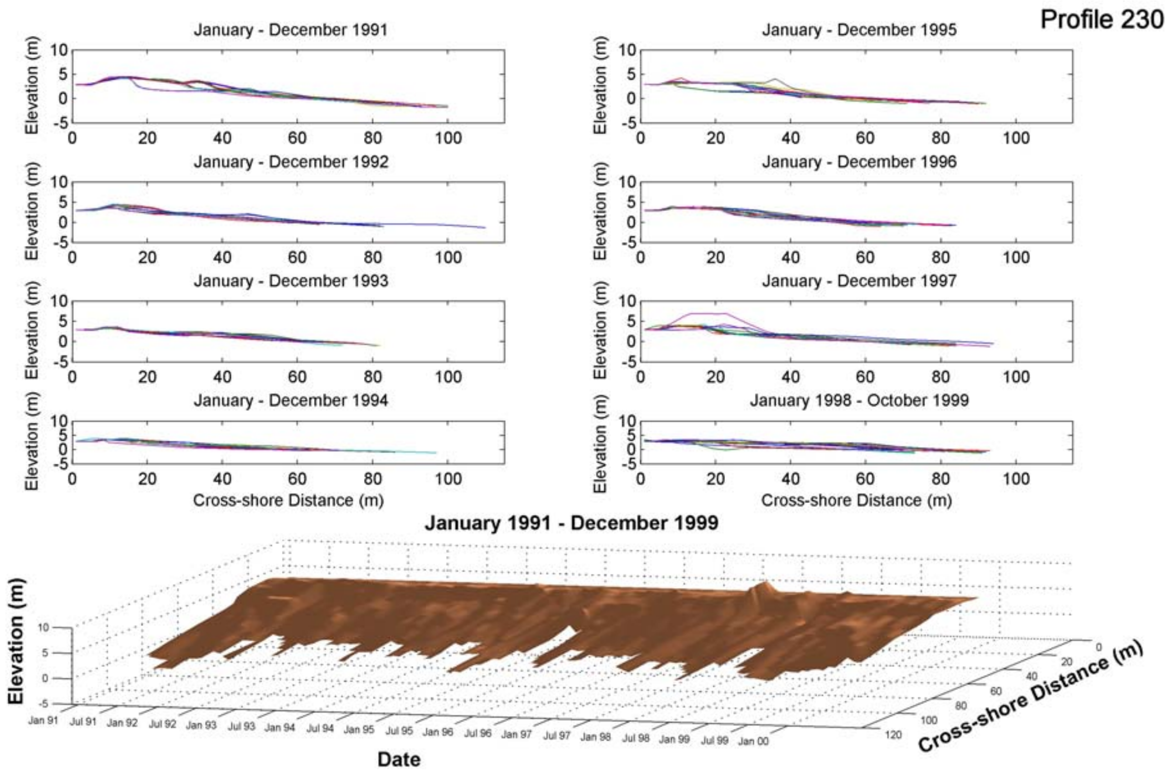

Figure 8: ODU, wading-depth, beach profiles surveyed monthly from 1991 through 1999 at location 230 (see Figure 5 and 6 for location). The figure is divided into nine panels; the first eight panels display profile subsets, each labeled with a specified time interval. The eighth panel (second column, fourth row) displays all profiles surveyed within six months before or sixteen months after beach nourishment. Panel nine is an oblique, three-dimensional visualization of the profile configuration through time, where the left side of the image represents the profile at time 1. Vertical datum is NGVD 1929.

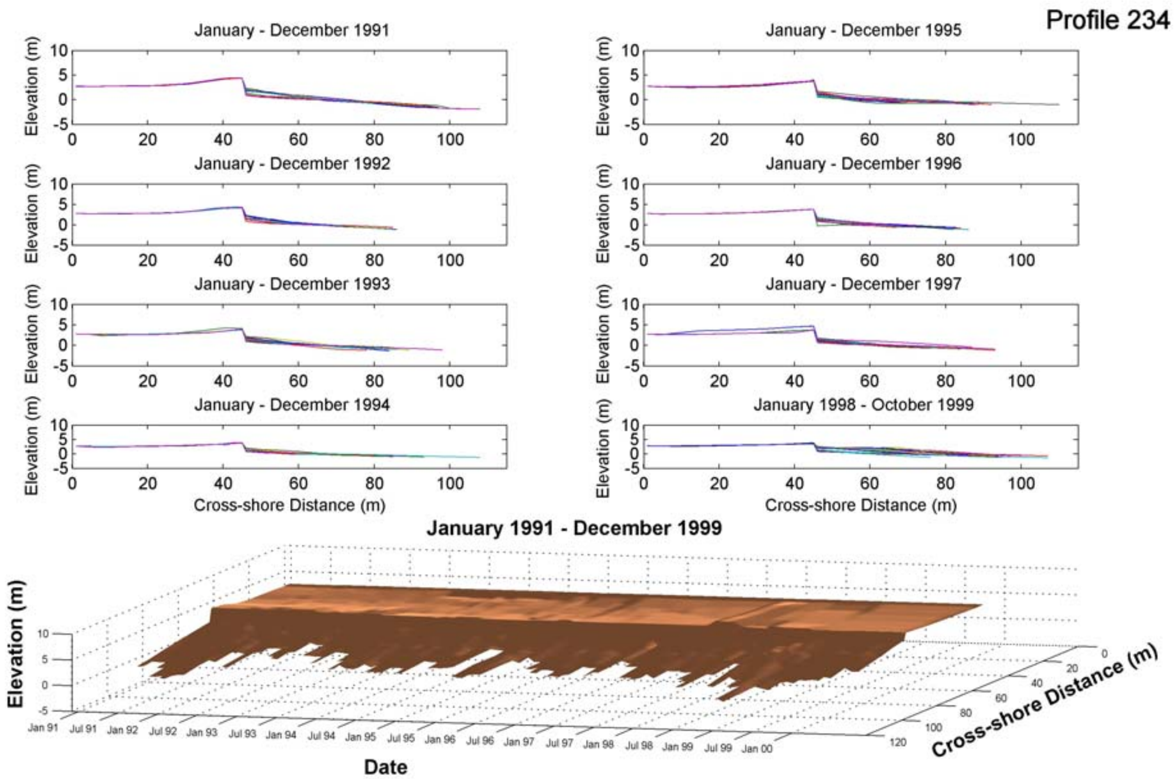

Figure 9: ODU, wading-depth, beach profiles surveyed monthly from1991 through 1999 at location 234 (see Figures 5 and 6 for location). The figure is divided into nine panels; the first eight panels display profile subsets, each labeled with a specified time interval. The eighth panel (second column, fourth row) shows all profiles surveyed within six months before or sixteen months after beach nourishment. Panel nine is an oblique, three-dimensional visualization of the profile configuration through time, where the left side of the image represents the profile at time 1. Vertical datum is NGVD 1929.

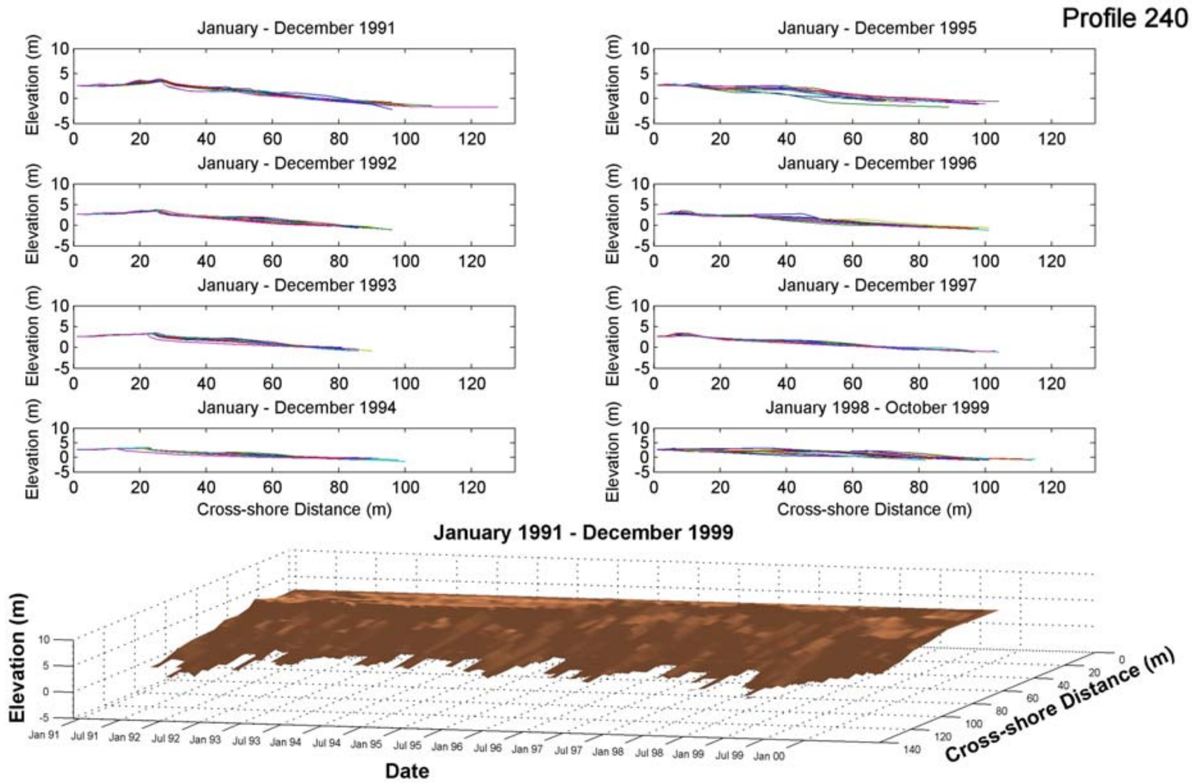

Figure 10: Wading-depth beach profiles surveyed monthly at location 240 (see Figures 5 and 6 for location). The figure is divided into nine panels; the first eight panels display profile subsets, each labeled with a specified time interval. The eighth panel (second column, fourth row,) shows all profiles surveyed within six months before or within sixteen months after beach nourishment. Panel nine is an oblique, three-dimensional visualization of the profile configuration through time, where the left side of the image represents the profile at time 1. The twenty-two profiles from panel 8 are further highlighted in Figure 12 and illustrate the variability inherent in the beach profile configuration following beach nourishment. Vertical datum is NGVD 1929.

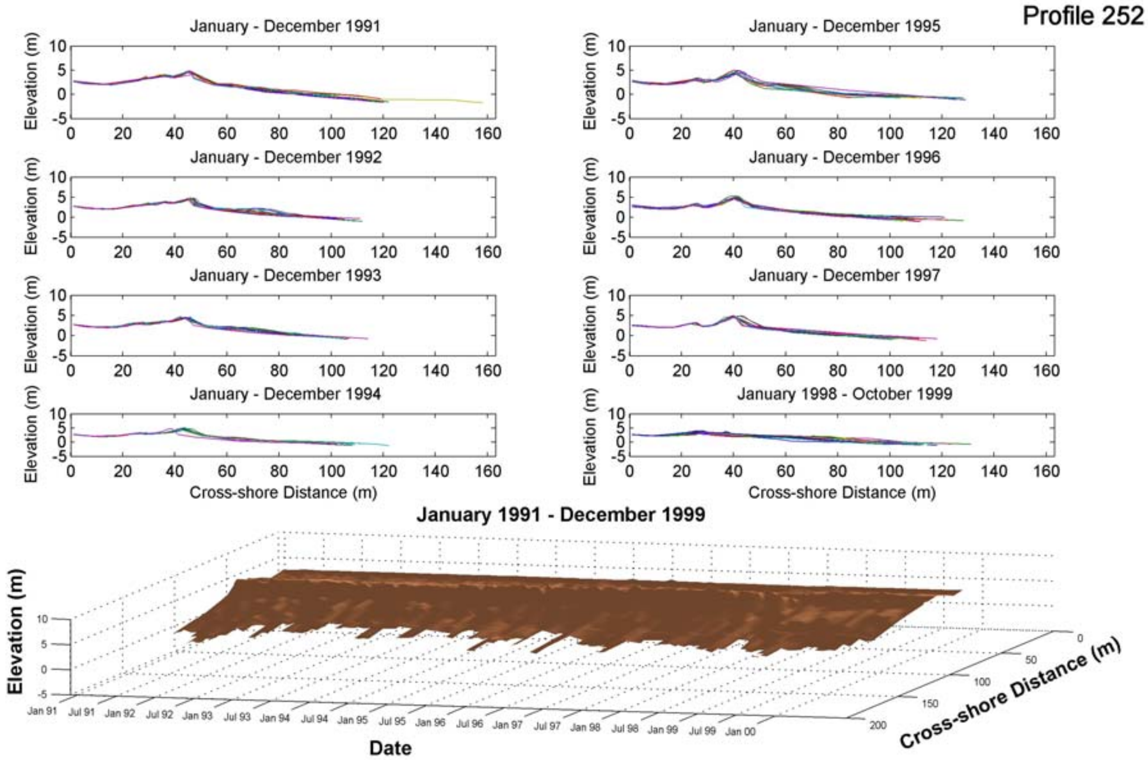

Figure 11: Wading-depth, beach profiles surveyed monthly at location 252 (see Figures 5 and 6 for location). The figure is divided into nine panels; the first eight panels display profile subsets, each labeled with a specified time interval. The eighth panel (second column, fourth row) shows all profile surveyed within six months before or within sixteen months after beach nourishment. Panel nine is an oblique, three-dimensional visualization of the profile configuration through time, where the left side of the image represents the profile at time 1. Vertical datum is NGVD 1929.

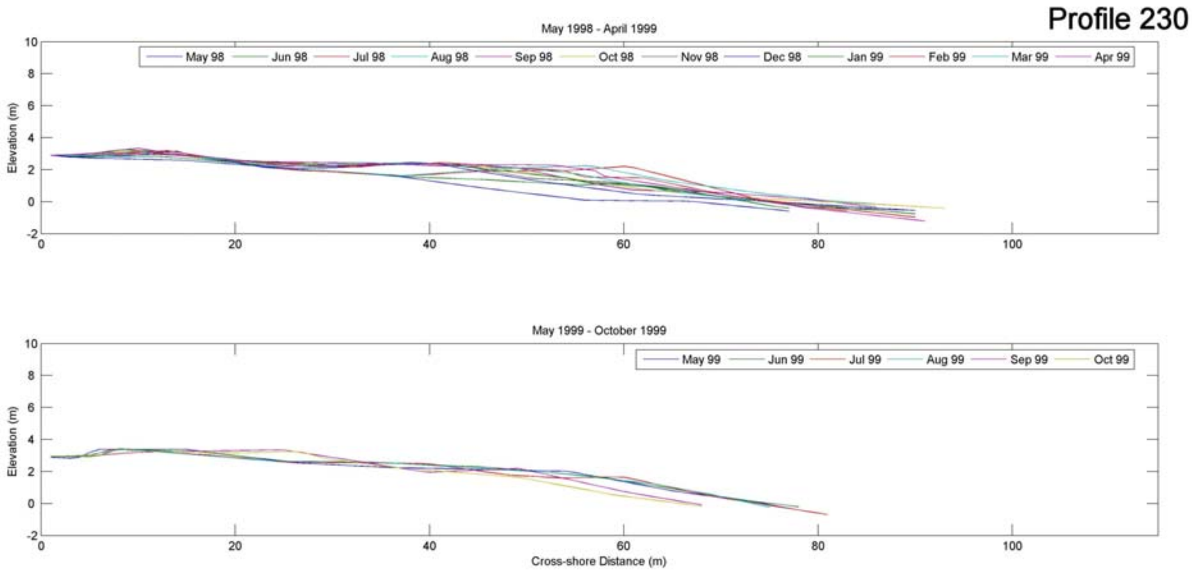

Figure 12: Profile surveys of location 230 from May 1997 through October 1999 (1-yr pre-nourishment, 1-yr post-nourishment, and 6 months thereafter). Vertical datum is NGVD 1929.

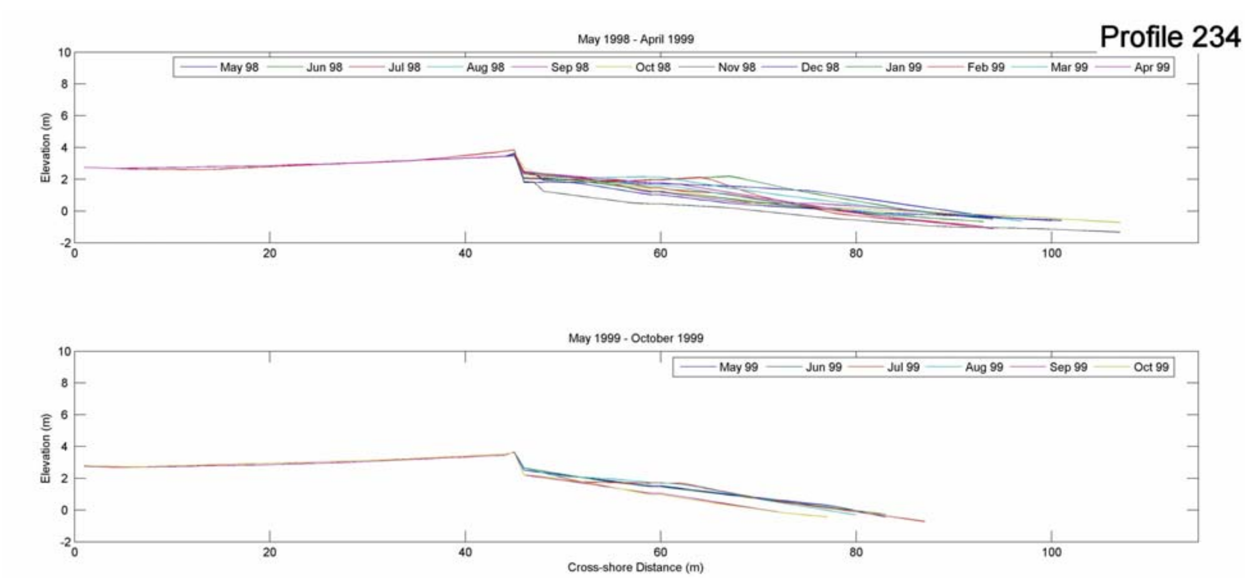

Figure 13: Profile surveys of location 234 from May 1997 through October 1999 (1-yr pre-nourishment, 1-yr post-nourishment, and 6 months thereafter). Vertical datum is NGVD 1929.

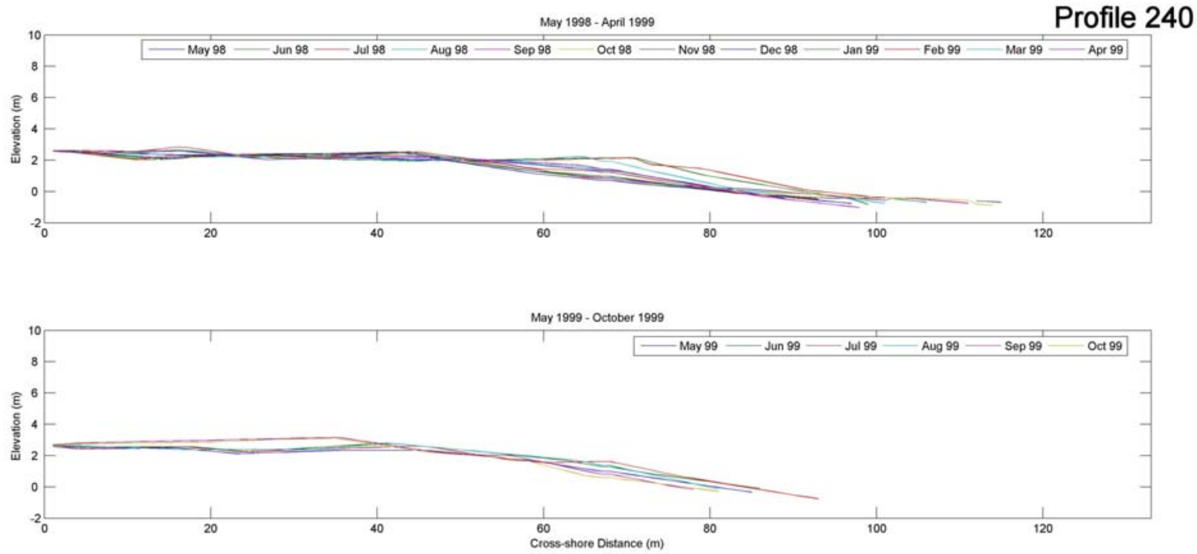

Figure 14: Profile surveys of location 240 from May 1997 through October 1999 (1-yr pre-nourishment, 1-yr post-nourishment, and 6 months thereafter). Vertical datum is NGVD 1929.

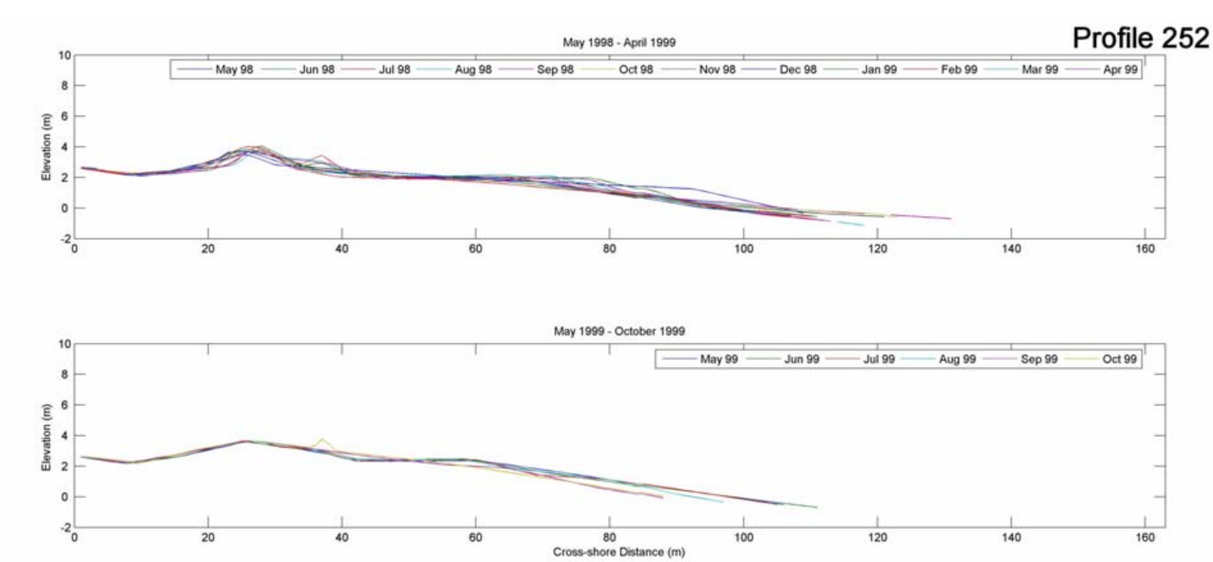

Figure 15: Profile surveys of location 252 from May 1997 through October 1999 (1-yr pre-nourishment, 1-yr post-nourishment, and 6 months thereafter). Vertical datum is NGVD 1929.

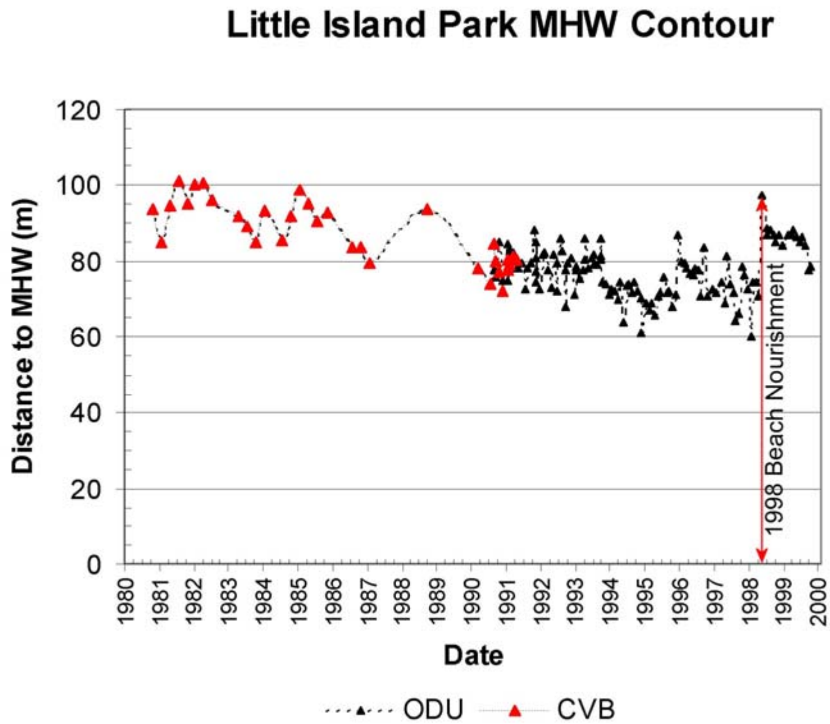

Figure 16. Migration of the Mean High Water contour from late 1980 to late 1999 at Little Island Park (CVB profile location 57, ODU profile location 252; See Figures 5 and 6 for location).

3.3.2. Profile Variability Method and Results

Empirical eigenfunction analyses were used to examine the spatial and temporal variability of historic beach profiles (Wijnberg and Terwindt 1995). The technique greatly reduces the number of variables required to represent a specified dataset. In general, the first three eigenfunctions describe most of the mean square value of the data. Eigenfunctions effectively separate the spatial and temporal dependence of the data so that it can be represented as a linear combination of space and time functions. The first eigenfunction is analogous to the mean profile at each profile location, whereas the second and third eigenfunctions generally describe variability in bar-berm-dune topography. The temporal variation expressed in the weightings can delineate seasonal and event signals, as well as longer term temporal trends, such as profile recession or progradation. All profile lengths were clipped to match the length of the shortest profile for each profile location since, for the analysis, the lengths of analyzed profiles must be constant. This requirement limited analysis to the subaerial beach, effectively disregarding shoreface changes.

Empirical eigenfunction analysis was performed on monthly profile data measured at four profile locations during nine consecutive years of surveying (Table 6). These surveys generally were limited to the cross-shore width of the subaerial beach, effectively representing the zone from the

Table 6
The four profile locations analyzed using the empirical eigenfunction technique. Profiles 57 and 252 are the same site but were collected by different agencies during different time intervals.

Profile (N to S)	Period	Number of Surveys	Length (m)	Agency
230	1/91-10/99	106	42	ODU CEC
234	1/91-10/99	106	60	ODU CEC
240	1/91-10/99	106	67	ODU CEC
252	1/91-10/99	106	84	ODU CEC
57	10/80-9/93	16	608	CVB

back dune to the MHW shoreline. A complementary analysis was performed on a set of 16 profiles collected periodically by the City of Virginia Beach Department of Public Works from 1980 to 1993 and spatially coincident with one of the aforementioned profile locations (location 252). These sixteen surveys cover from landward of the dune to approximately 7 m below MSL (NGVD 1929) offshore (Table 6).

The variations in profile configuration for the four profile locations, represented by the first three empirical eigenfunctions, are presented in Figures 17 through 21. The profiles in this 700 m shoreline reach are characterized by extremely different and highly variable configurations. The dominant profile features range from backshore low-lying dunes to artificially inflated dunes, from bulkhead to low-profile swash and overwash dominated beach. Information contained in profile 230 (Figure 17) is limited by a relatively short analysis length. The mean shape (EF1 left side) features an inclined backshore backed by a low-profile dune. The profile shows maximum variability associated with the position and elevation of the dune as depicted in the second and third spatial eigenfunctions (EF2/EF3 left hand side). The mean beach profile at 234 (Figure 18) shows a gently inclined foreshore intersecting a bulkhead. The second and third spatial eigenfunctions exhibit maximum variability in foreshore elevation and slope and in the configuration of the sand deposit immediately landward of the bulkhead. The mean profile at 240 (Figure 19) shows a slightly inclined foreshore and low-profile backshore. The second and third spatial eigenfunctions show significant fluctuation in backshore configuration. A low-profile dune can be seen in the profile through 1994, and it is leveled in late 1994. The mean profile at 252 (Figure 20) shows an inflated dune and gently inclined foreshore. The variable position and elevation of the dune is reflected in the second and third eigenfunctions. The third eigenfunction points to fluctuations in the concavity of the foreshore shape. The record of offshore profiles collected at this same location (Figure 21) shows a more complete profile shape for the subaerial beach and nearshore of a moderately sloped shelf. The mean profile features a moderate-relief dune, berm, and a substantial nearshore terrace that represents the location of seasonal nearshore bar formation. The second and third spatial eigenfunctions reflect both the spatial and elevation change of the dune, berm, and nearshore bar.

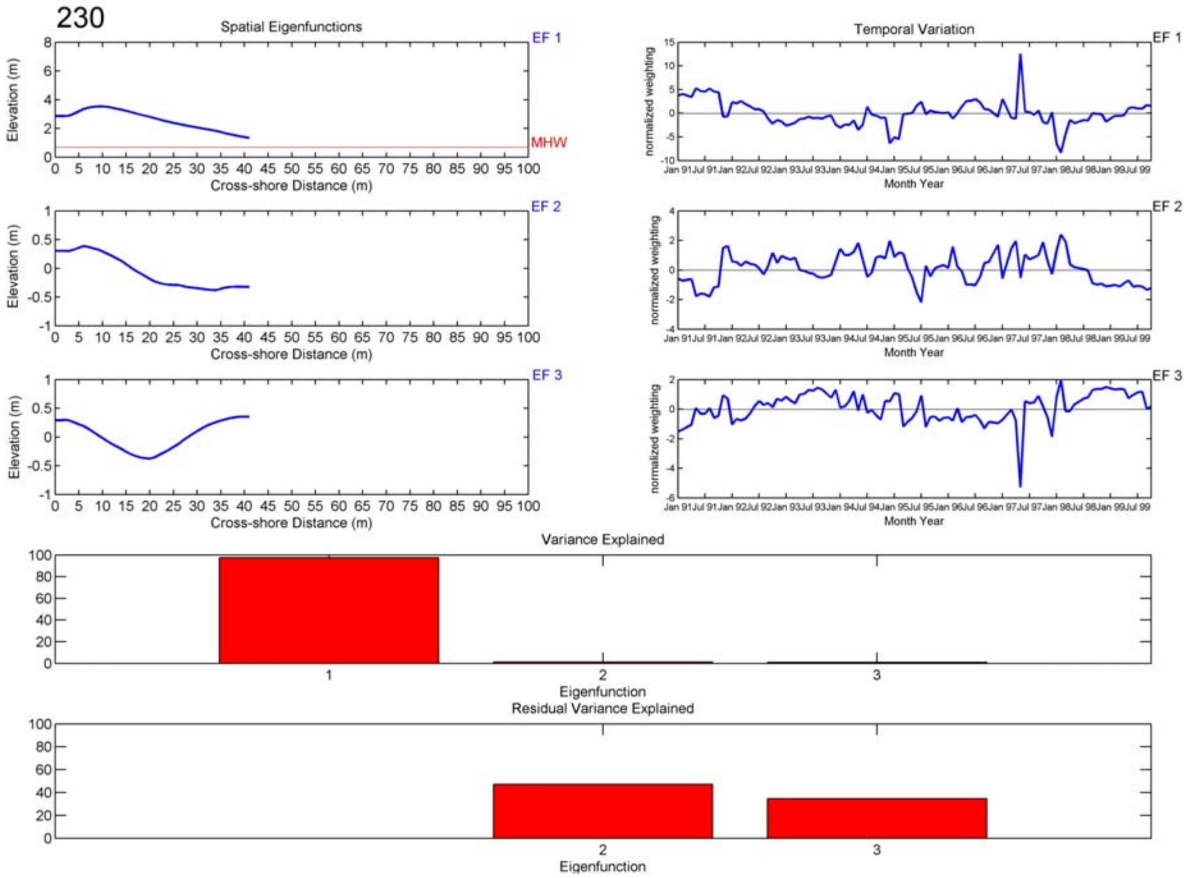

Figure 17. First three eigenfunctions for monthly profile surveys collected at location 230 from 1991-1999. The first three panels on the left show the first three spatial eigenfunctions. The first spatial eigenfunction represents the mean profile shape. The second and third spatial eigenfunctions describe changes in dune and berm topography. In the second and third spatial eigenfunctions, a positive deviation presents a positive elevation change, whereas a negative deviation is a negative elevation change. The first three panels on the right hand side of each figure present the temporal variability in the profile. A positive weighting on the first eigenfunction means the observed profile is generally 'flatter' than the mean profile, where as a negative weighting means the observed profile is steeper than the mean profile. Positive weightings on the second eigenfunction mean the described topography should be added to the mean profile. Negative weightings should be mirrored along the distance axis and then added to the mean profile. The third eigenfunction is similar in interpretation to the second eigenfunction. The final two panels present the relative variance and relative residual variance described by each eigenfunction. Elevation datum is NGVD 1929.

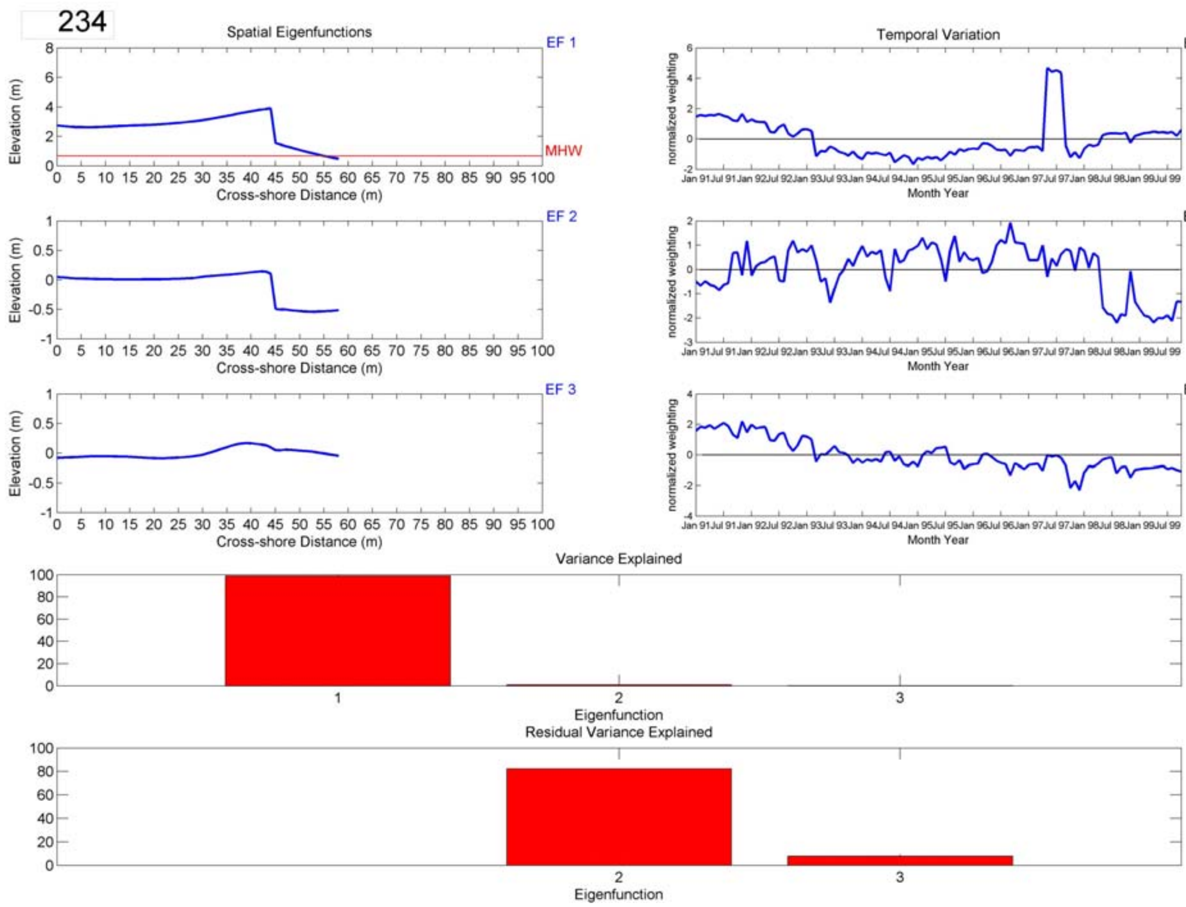

Figure 18. First three eigenfunctions for monthly profile surveys collected at location 234 from 1991-1999. The first three panels on the left show the first three spatial eigenfunctions. The first spatial eigenfunction represents the mean profile shape. The second and third spatial eigenfunctions describe subtle fluctuations in the mean profile shape; the second eigenfunction describes the variation in elevation where the foreshore intersects the bulkhead. In the second and third spatial eigenfunctions, a positive deviation presents a positive elevation change, whereas a negative deviation is a negative elevation change. The first three panels on the right hand side of each figure present the temporal variability in the profile. A positive weighting on the first eigenfunction means the observed profile is generally 'flatter' than the mean profile, where as a negative weighting means the observed profile is steeper than the mean profile. Positive weightings on the second eigenfunction mean the described topography should be added to the mean profile. Negative weightings should be mirrored along the distance axis and then added to the mean profile. The third eigenfunction is similar in interpretation to the second eigenfunction. The final two panels present the relative variance and relative residual variance described by each eigenfunction. Elevation datum is NGVD 1929.

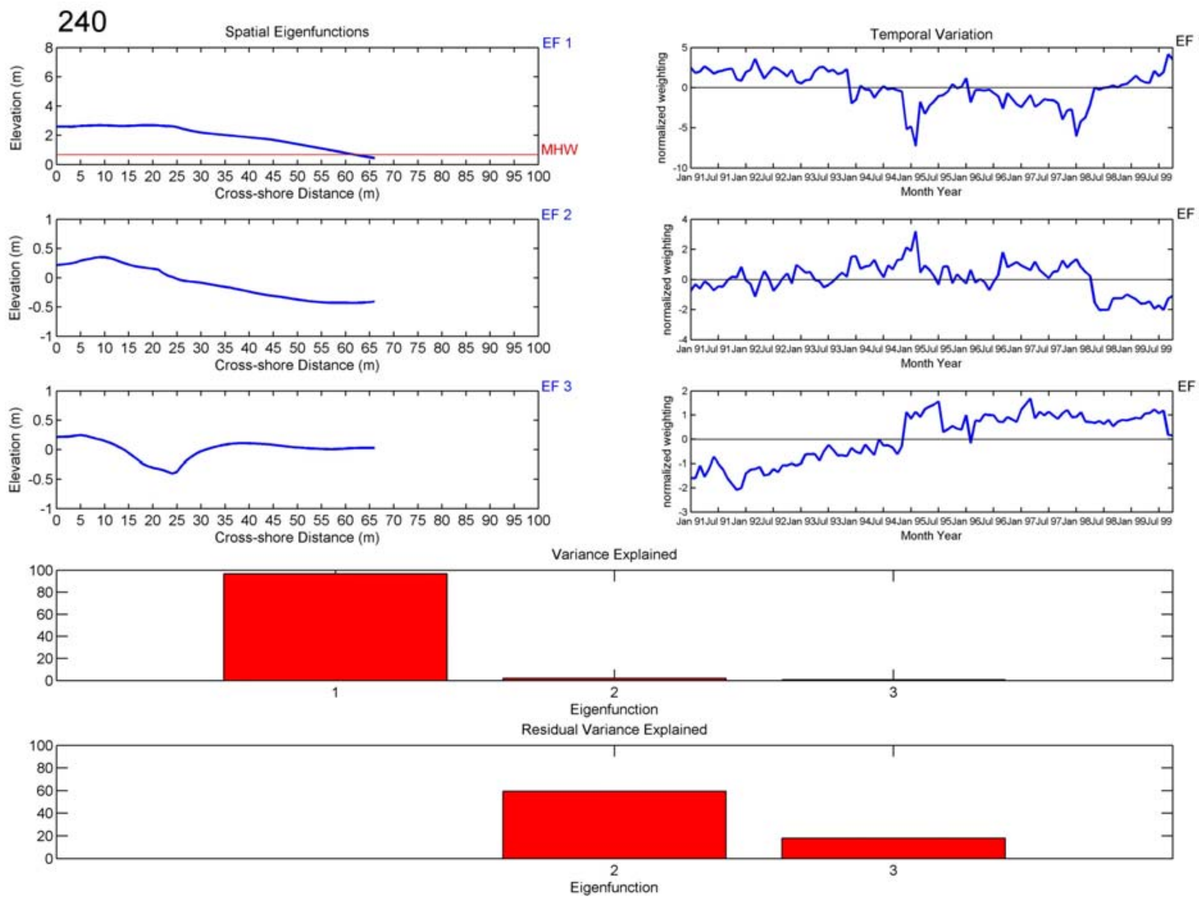

Figure 19: First three eigenfunctions for monthly profile surveys collected at location 240 from 1991-1999. The first three panels on the left show the first three spatial eigenfunctions. The first spatial eigenfunction represents the mean profile shape. The second and third spatial eigenfunctions typically describe subtle fluctuations in the mean profile shape. In the second and third spatial eigenfunctions, a positive deviation presents a positive elevation change, whereas a negative deviation is a negative elevation change. The first three panels on the right hand side of each figure present the temporal variability in the profile. A positive weighting on the first eigenfunction means the observed profile is generally ‘flatter’ than the mean profile, where as a negative weighting means the observed profile is steeper than the mean profile. Positive weightings on the second eigenfunction mean the described topography should be added to the mean profile. Negative weightings should be mirrored along the distance axis and then added to the mean profile. The third eigenfunction is similar in interpretation to the second eigenfunction. The final two panels present the relative variance and relative residual variance described by each eigenfunction. Elevation datum is NGVD 1929.

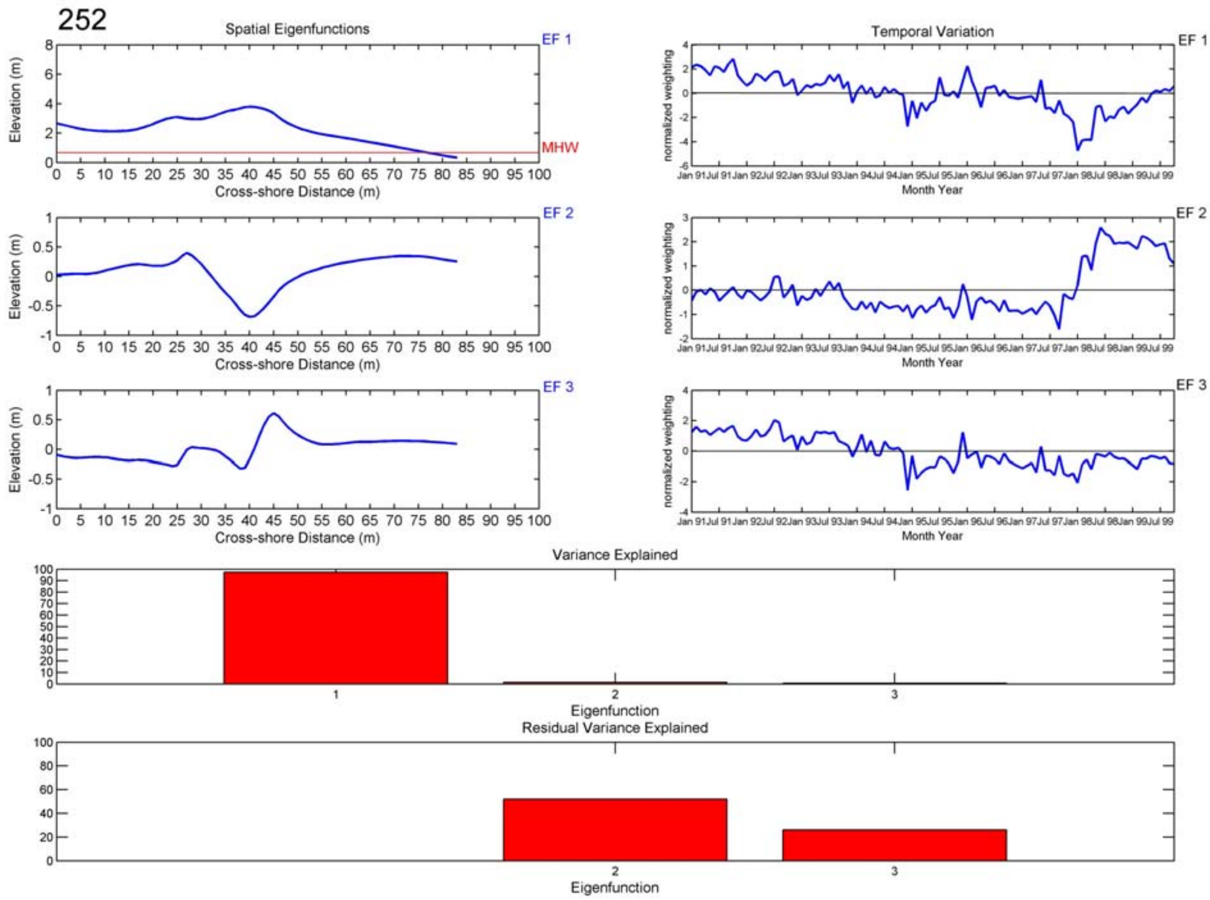

Figure 20. First three eigenfunctions for monthly profile surveys collected at location 252 from 1991-1999. The first three panels on the left show the first three spatial eigenfunctions. The first spatial eigenfunction represents the mean profile shape. The second and third spatial eigenfunctions describe changes in dune and berm topography. In the second and third spatial eigenfunctions, a positive deviation presents a positive elevation change, whereas a negative deviation is a negative elevation change. The first three panels on the right hand side of each figure present the temporal variability in the profile. A positive weighting on the first eigenfunction means the observed profile is generally ‘flatter’ than the mean profile, where as a negative weighting means the observed profile is steeper than the mean profile. Positive weightings on the second eigenfunction mean the described topography should be added to the mean profile. Negative weightings should be mirrored along the distance axis and then added to the mean profile. The third eigenfunction is similar in interpretation to the second eigenfunction. The final two panels present the relative variance and relative residual variance described by each eigenfunction. Elevation datum is NGVD 1929.

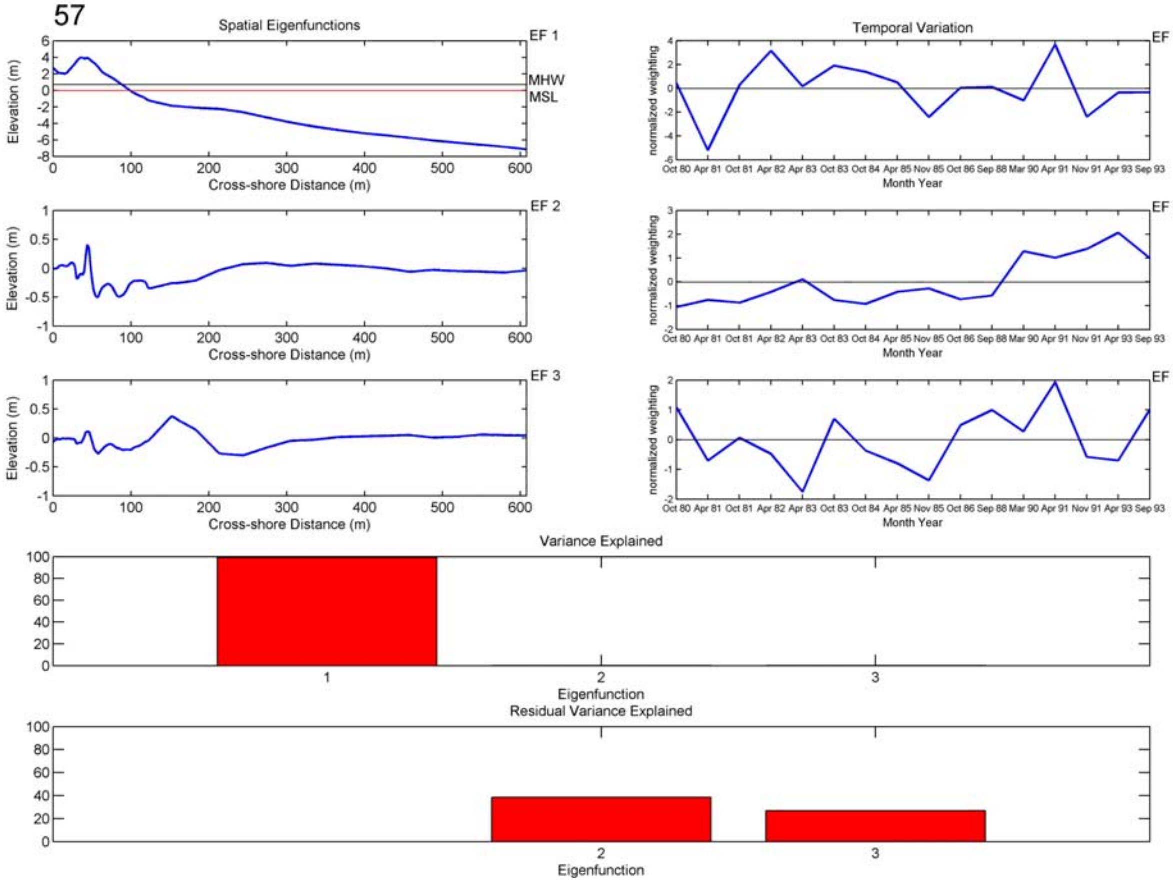

Figure 21. First three eigenfunctions for CVB profile surveys collected at location 57 from 1980-1993. The first three panels on the left show the first three spatial eigenfunctions. The first spatial eigenfunction represents the mean profile shape. The second and third spatial eigenfunctions describe modulations in the bar height and position. I n the second and third spatial eigenfunctions, a positive deviation presents a positive elevation change, whereas a negative deviation is a negative elevation change. The first three panels on the right hand side of each figure present the temporal variability in the profile. A positive weighting on the first eigenfunction means the observed profile is generally ‘flatter’ than the mean profile, where as a negative weighting means the observed profile is steeper than the mean profile. Positive weightings on the second eigenfunction mean the described topography should be added to the mean profile. Negative weightings should be mirrored along the distance axis and then added to the mean profile. The third eigenfunction is similar in interpretation to the second eigenfunction. The final two panels present the relative variance and relative residual variance described by each eigenfunction. Elevation datum is NGVD 1929.

For all four profile locations, the temporal variation of the first eigenfunction (EF 1 right side) is characterized by a net trend indicating moderate erosion along this stretch of coastline, a decadal process modified by beach nourishment in the late spring and early summer of 1998. The trend is especially evident in the top right panels (EF 1) in profiles 240 and 252. Fifteen months after the onset of nourishment activities, all three eigenfunctions show consistent spatial and elevation trends. The mean beach profile builds slowly seaward, with the exception of small seasonal fluctuations, and the profile generally flattens given offshore movement of sand as the profile equilibrates. Relative shoreline recession rates increase drastically as the profile equilibrates, foreshore slope decreases, and the landward reach of wave run-up increases. The temporal dependence of the first eigenfunction also reveals the impact of storm events; for example, a major winter storm occurred in late December 1994 and can be visualized as lagged negative weightings (right side) in profiles 230, 240, and 252. Anthropogenic impacts are also discernable in the temporal signal of the first eigenfunction. Sand was often bulldozed by local homeowners in attempts to create artificially elevated dunes to protect their private property. These short-lived elevation maxima occur in backshore and dune areas and are prominently reflected in temporal signal (right side) in profiles 230 and 234 in the late spring of 1997. The temporal variation of the second eigenfunction exhibits an annual periodicity, representing the difference in summer and winter profile configurations. This signal is more difficult to discern after nourishment, related in part, perhaps, to the timing of nourishment. Nourishment during the winter, for example, might give a summer signal. An interpretation of the third eigenfunction time signal is more complicated and is typically indicative of high-frequency changes.

3.3.3. Lessons Learned

Eigenfunction analysis unequivocally shows the inherent variability of profile configuration in natural conditions and anthropomorphically induced changes. In the profiles analyzed, the width of the subaerial beach at Sandbridge generally increases from north to south and generally narrows with time prior to beach nourishment in 1998. The flattening trend of the subaerial and foreshore segments of post-nourishment profiles is indicative of offshore movement of placed sediment. This is consistent with profile equilibration after the natural beachface is extended at a fairly steep slope at its seaward limit. Larson and Hanson (1999) showed that the perturbation of natural conditions by beach nourishment typically disappeared after a year, provided that the material is available for cross-shore adjustment by the waves. The nourishment signal at Sandbridge Beach was still present fifteen months after the sand was placed on the beach..

It is important to recognize that the subaerial beach comprises only a fraction of the zone of active sediment transport. A sound understanding of nearshore variability also is necessary to develop predictive capabilities of shoreline and nearshore change (Ruggiero *et al.* 2000). Since offshore sandbars can dissipate and, conversely, shoal and sand ridges can focus incident waves, the spatial and temporal variability of nearshore morphology is a primary control of wave energy, sediment transport, and shoreline/nearshore change. Two-dimensional beach profiles typically are used to capture and evaluate beach morphologic change in both the subaerial beach and adjacent nearshore and are integral to the recommended monitoring protocols. The natural variability in the studied profiles suggests that smaller scale changes will be challenging to decipher from wading depth, two dimensional beach profile data collected over a short time period, especially two to three years. Complex spatial variations observed between or beyond profiles may not be captured, especially when profiles are too widely spaced or only extend to wading depth. This argument encourages the adoption at a minimum of depth-of-closure surveys to document both subaerial and nearshore changes and encourages the consideration of advanced 3D subaerial beach and nearshore surveys.

It is always important not to overstate the usefulness of monitoring given the inherent complexity and variability of the coastal zone. The task of distinguishing anthropogenic impacts from natural variability is difficult at best. While the technique presented here was clearly successful in delineating effects of beach nourishment on profile configuration, it may not be so for detecting the effects of mining on a nourished beach and post-nourished beach profiles. The naturally occurring variability of the profile may alone mask the signals of mining-induced morphologic change, especially when the beach is being renourished every three to four years. The survey period documenting post-nourishment change must be long enough to document longer-term response trends. It also is important to realize that higher frequency changes, including those reflecting subtle variations in wave regime, might only be revealed given more spatially resolved and frequent surveying.

3.4. Shorezone Monitoring Methodology Applied

New methods to monitor beach and nearshore morphology and the morphological response to sand nourishment have evolved with the advent of new technology. Advances in PC-based Geographic Information Systems allow historic and recent aerial imagery to be ortho-rectified so that shorelines can be digitized. These images provide a basis for understanding the geomorphic development of a reach from the early 1900s. Real-Time Kinematic Global Positioning System (RTK-GPS) technology allows users to obtain centimeter accuracy horizontally and vertically when surveying. When mounted on an all-terrain vehicle (ATV), the accuracy is not as high; however, the trade-off is that shoreline can be surveyed more rapidly. For an accurate cross-shore depiction of profile shape and volume change, beach surveys at regularly-spaced intervals combined with a nearshore survey are necessary.

3.4.1. Reach-Based Morphologic Analysis Method and Results

In order to assess the impact of shore change on the beach/dune system along Dam Neck, recent and historic aerial photography was used to estimate, observe, and analyze past shoreline and dune positions and trends. Aerial imagery from 1937, 1970, 1976, 1980, 1985, 1994 and 2002 was obtained from various sources. The 1994 photographs are from the United States Geological Survey (USGS) and the 2002 imagery was processed and mosaicked by the Virginia Base Mapping Program (VBMP). The aerials for the remaining flight lines were processed and mosaicked by VIMS Shoreline Study Program.

The images were scanned as tiffs at 600 dpi and converted to ERDAS IMAGINE (.img) format. They were orthorectified to a reference mosaic, the 1994 Digital Orthophoto Quarter Quadrangles (DOQQ) from the USGS. ERDAS Orthobase image processing software was used to orthographically correct the individual flightlines. Control points from 1994 USGS DOQQ images provided the exterior control, which was enhanced by a large number of image-matching tie points produced automatically by the software. A minimum of four ground control points were used per image, allowing two points per overlap area. The exterior and interior models were combined with a 30-meter resolution, digital elevation model (DEM) from the USGS National Elevation Dataset (NED) to produce an orthophoto for each aerial photograph. The orthophotographs that cover each USGS 7.5 minute quadrangle area were adjusted to approximately uniform brightness and contrast and were mosaicked together using the ERDAS Imagine mosaic tool to produce a one-meter resolution mosaic. To maintain an accurate match with the reference images, it was necessary to distribute the control points evenly. This was challenging in areas with little development such as the 1937 photos. Good examples of control points were permanent features such as manmade structures and stable natural landmarks. The maximum root mean square (RMS) error allowed was 3 for each block.

Once the aerial photos were orthorectified and mosaicked, the shorelines were digitized in ArcMap© with the mosaics in the background to help delineate features. In areas where the shoreline was not clearly delineated on the aerial photography, the location was estimated based on the experience of the digitizer. An extension called "shoreline" was used to analyze rates of shoreline change. A shore parallel landward baseline was drawn, and the extension then created equally-spaced transects along the baseline and calculated the distance from the baseline at that location to each year's shoreline. The outputs from the extension were perpendicular transects of a length and interval specified by the user. The extension provided the transect number and the distance from the baseline to each digitized shoreline in an attribute table. The attribute table was exported to a spreadsheet, and the distance of the digitized shoreline from the arbitrary baseline was used to determine the rate of change.

Maps showing all the aerial photography rectified, shorelines digitized, and rates calculated for this project are shown in Appendix B in the digital format only. The section of the coast at Little Island Park is shown through time in Figures 22 through 25. The overall rates of change are shown in Figure 26. In 1937, Sandbridge and Dam Neck were undeveloped with the exception of a few access roads (Figure 22). The beach/dune system was sparsely vegetated indicating that the area may have been impacted by a large storm and that the dune areas were recovering. The hurricane of August 23, 1933, with its storm surge of 7.5 feet at Hampton Roads, may have been that event, and it may have caused the vegetation to move back onto what appear to be large washover fans. Two lesser storms occurred in the years between that hurricane and the photography: a hurricane in September 1933 with a storm surge of 5.6 feet and another with a storm surge of 6.2 feet on September 18, 1936. The final significant storm prior to 1970 was the Ash Wednesday storm of March 8, 1962 which had a storm surge of 6.7 feet.

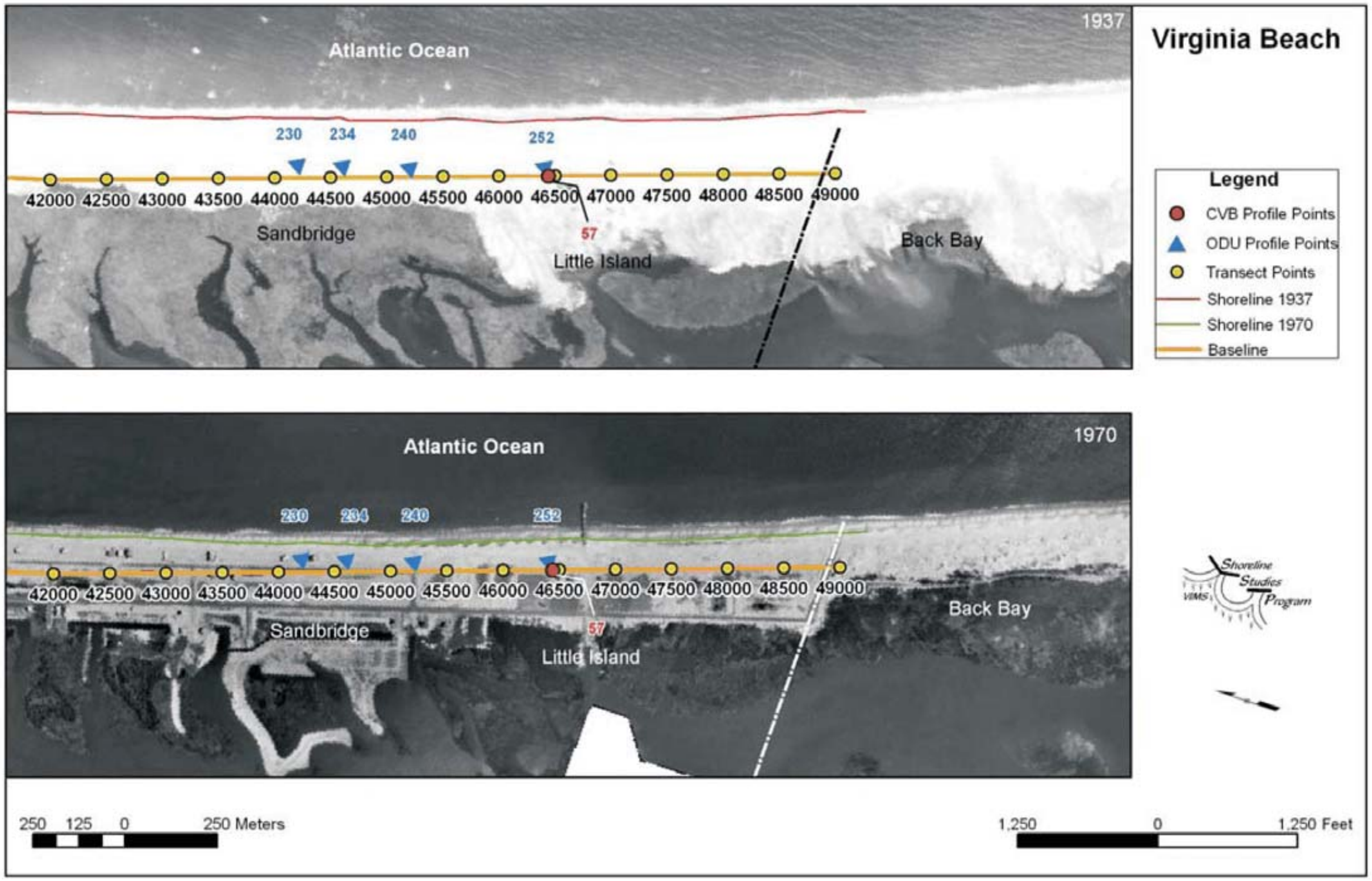

Figure 22: Ortho-rectified historic aerial imagery from 1937 and 1970 showing the rate of change baseline and locations of profiles discussed in detail in this report.

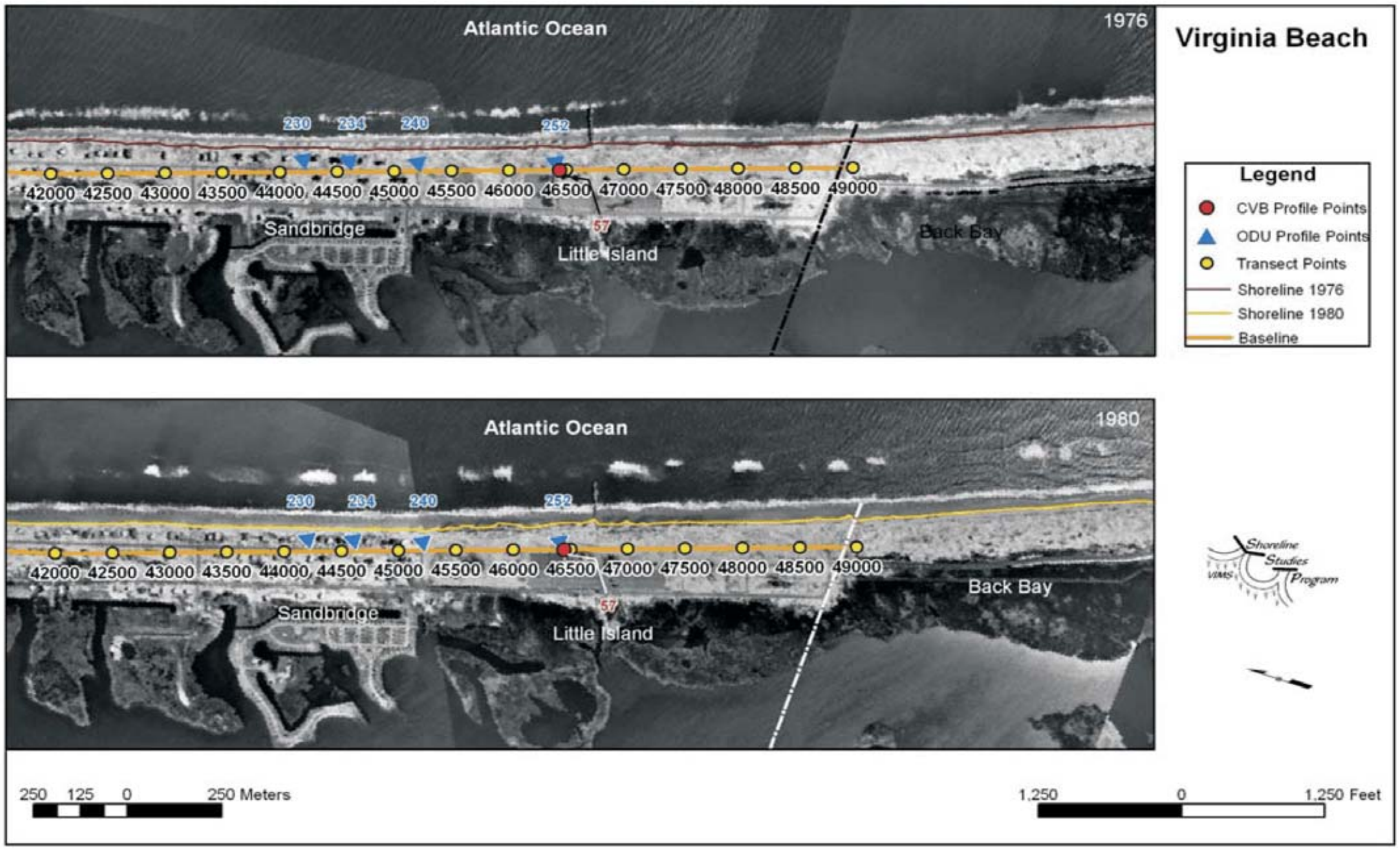

Figure 23: Ortho-rectified historic aerial imagery from 1976 and 1980 showing the rate of change baseline and locations of profiles discussed in detail in this report.

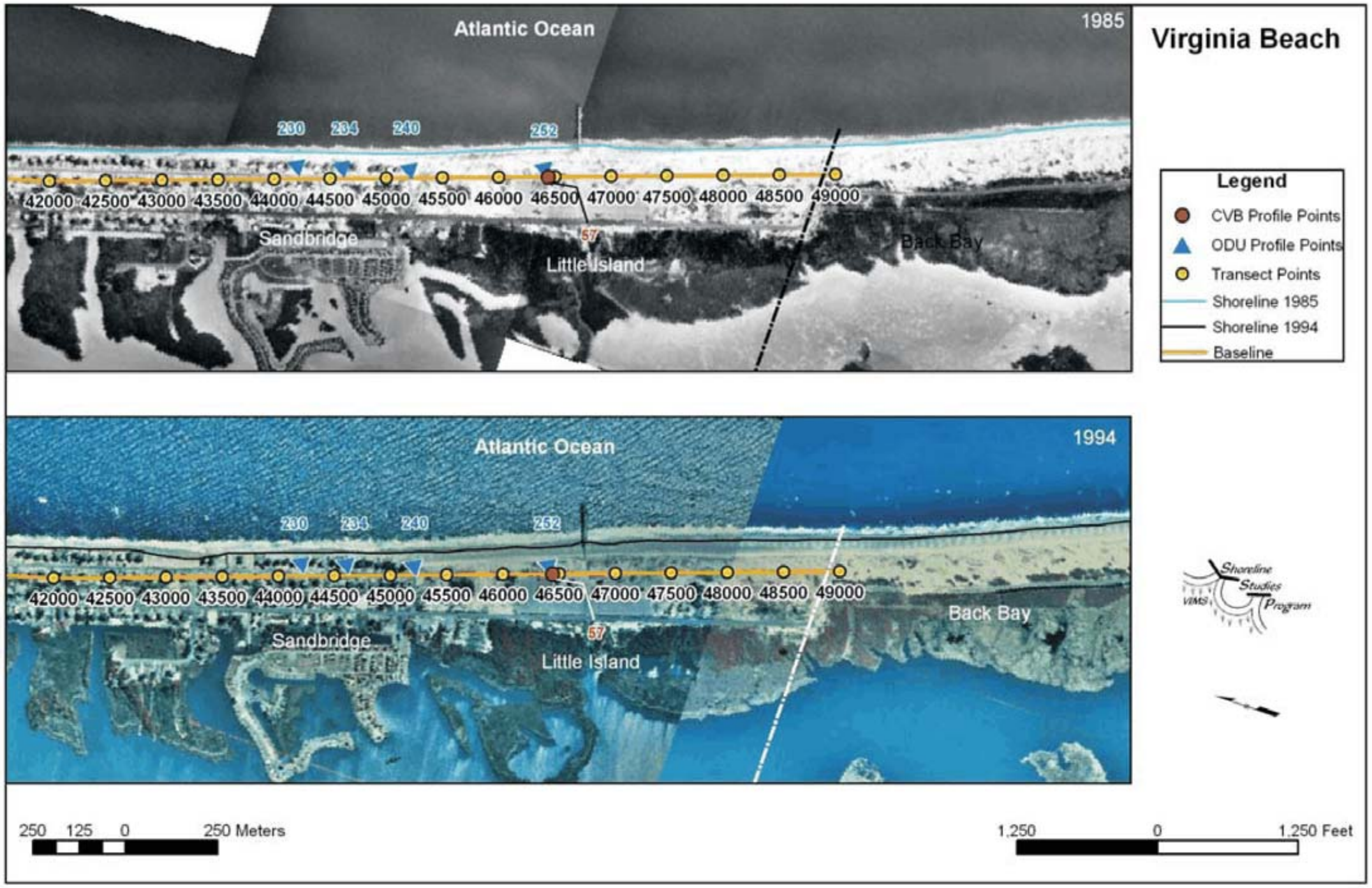

Figure 24: Ortho-rectified historic aerial imagery from 1985 and 1994 showing the rate of change baseline and locations of profiles discussed in detail in this report.

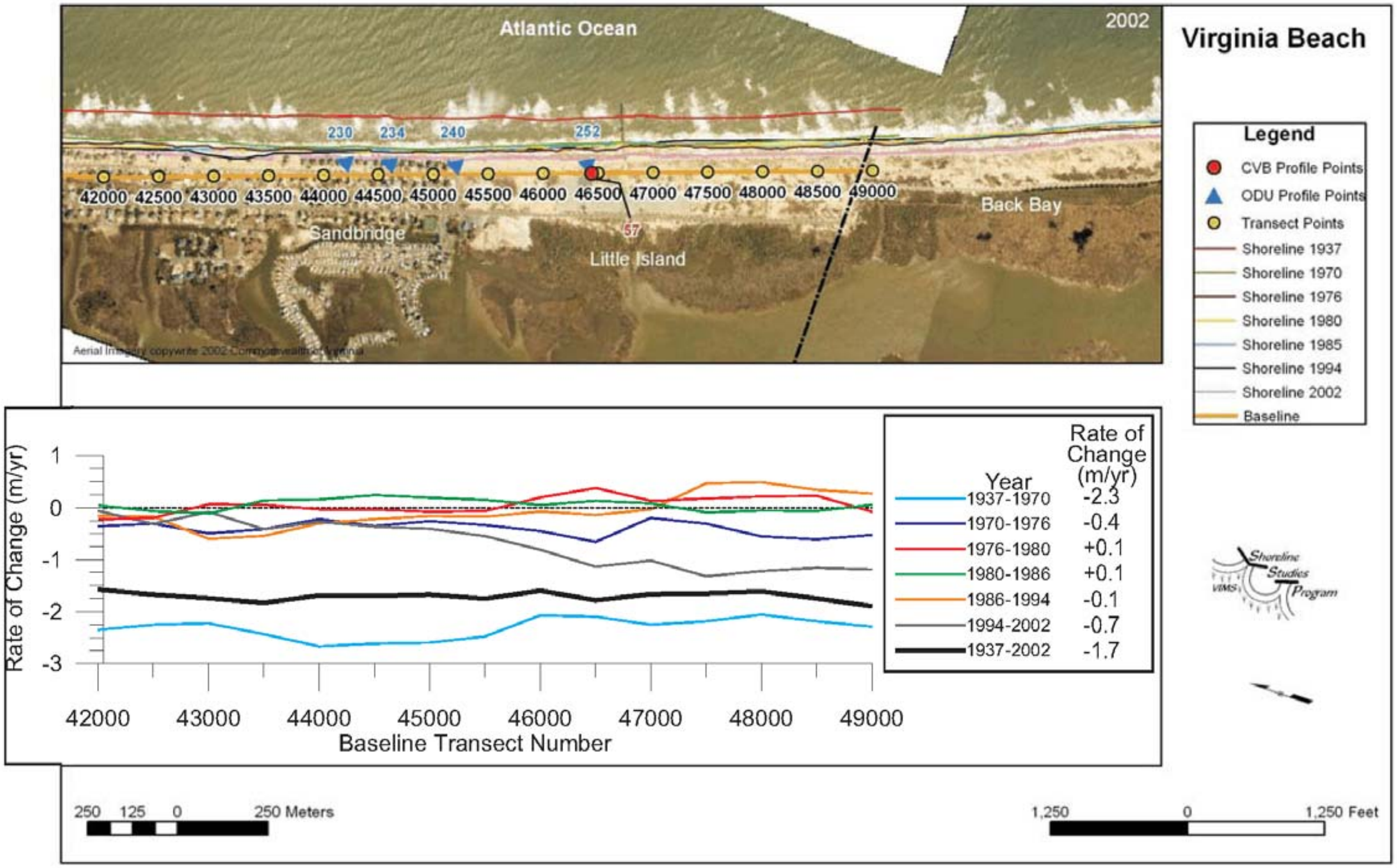

Figure 25: Shoreline rates of change for the Dam Neck/Sandbridge shoreline as determined by digitizing ortho-rectified historic and recent aerial images. The net End Point Rate is measured between 1937 and 2002. Rates shown in the legend are for this section of coast only.

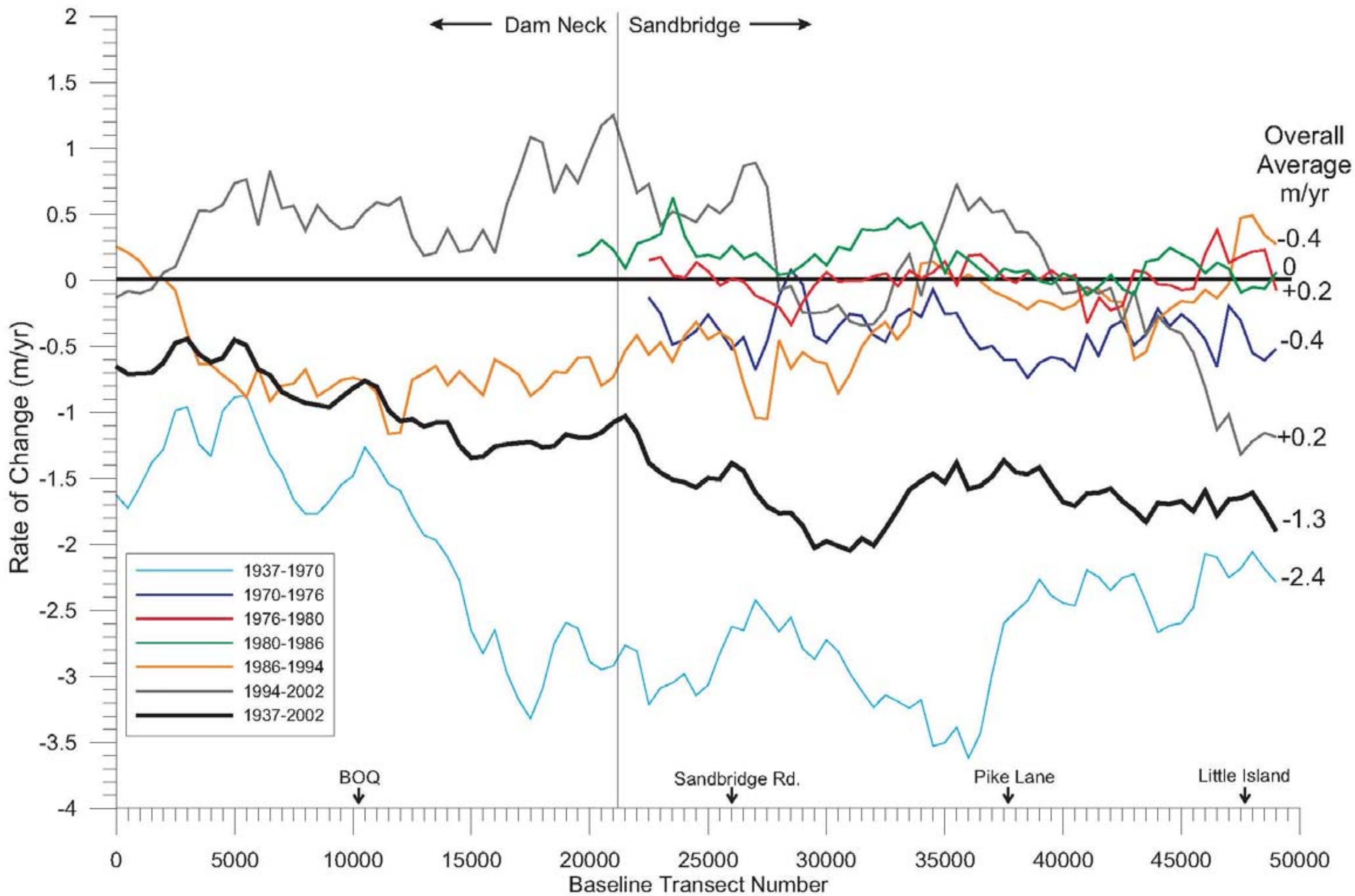

Figure 26: Shoreline rates of change for the Dam Neck/Sandbridge shoreline as determined by digitizing ortho-rectified historic and recent aerial images. The net End Point Rate is measured between 1937 and 2002. Rates shown in the legend are for this section of coast only.

By 1970, residential development had occurred along the coast at Sandbridge, much of it on the washover fans seen in 1937 and in the marshes (Figure 22). Several Navy buildings at Dam Neck, including today's Bachelor' Officer Club (BOQ) and the Enlisted Club, were within 100 feet of the edge of vegetation (EOV). Numerous smaller facilities were close to the EOV, and more roads and parking lots were evident. Military construction was evident on the 1950s aerial imagery.

Numerous storms occurred between 1970 and 1994 (Figure 23 and 24) which led to the slight overall recession of the shoreline. By 1994, Sandbridge was nearly built out. Dune recession was threatening the BOQ and Enlisted Club due to their proximity to the eroding dune face. This prompted the Navy to design a beach nourishment project that which constructed in 1996. Sandbridge was nourished in 1998. The combination of these beach nourishment projects placed about 1.5×10^6 m^3 (2×10^6 yd^3) of sand. The aerial imagery from 2002 (Figure 25) shows the state of the beach/dune zone just before the most recent beach fill projects. This section of shoreline is highly erosional; even after the beach fill projects placed sand within the system, the overall rate of change between 1994 and 2002 is erosional.

Overall rates of change are negative for this shore reach (Figure 26). Between 1937 and 1970, the average rate of change was -2.4 m/yr. Later time periods were consistent in the rate of change between +0.2 and -0.4 m/yr. Two periods were slightly accretionary. Only one substantial storm occurred between 1976 and 1980. Although Hurricane David was a killer hurricane in the Caribbean, it was much less intense in the United States. It made landfall on the East Coast in South Carolina and passed through Virginia landward of the coast and did not significantly impact the shore. A northeast storm in January 1978 had observed water levels just inside the Chesapeake Bay mouth only 0.4 m (1.3 ft) above the level predicted. Between 1994 and 2002, the rate of change clearly is influenced by the beach nourishment projects and modifies the long-term EPR. Interestingly, the nodal zone at Little Island that is obvious in the profile data is shown in several time periods; however, the shore 3 km to the north, near Pike Lane, has the highest long-term erosion rates. It appears the nodal point moves through time.

3.4.2. Rapid Assessment Longshore Surveys Method and Results

In order to monitor alongshore changes accurately, quickly, and cost-effectively, a vehicle-based system for measuring shoreline change was developed. The system was modeled after the USGS's SWASH system. A roving unit from an RTK-GPS was mounted to an all-terrain vehicle (ATV). A base station at a known point constantly relays corrections to the rover which then determines and records highly accurate horizontal and vertical positions as the vehicle runs along the shoreline. At least two lines were collected for each survey date: one along the berm and the other near the base of the beach. Most survey dates have at least four survey lines. From this information, we calculate the beach slope and project a MHW line whose position can be measured through time. Using this method the entire Sandbridge shoreline can be surveyed in a single day. Comparison of the location of the MHW shoreline from different dates provides the change in beach position data.

Of the data collected in 20 ATV runs over three years, 15 (Table 7) resulted in MHW shoreline data that could be used for analysis. In order to verify the accuracy of the data collected with the ATV, several analyses were run. Beach and nearshore survey data collected in April 2003 at Dam Neck were obtained from Dr. David Basco at ODU. A MHW shoreline was generated from these data and for data collected by WSE in May 2004 along Sandbridge. These MHW shorelines were plotted along with ATV data collected on comparable dates. The April 2003 ODU survey was compared with the May 2003 ATV survey. Even though the data are separated by about a month, the average change in the lateral position of the MHW line was only 3 m. The average change between the WSE data and ATV data collected in May 2004 was nil. The maximum and minimum excursions were +3 m and -4 m. However, the WSE data were collected over several days just after a beach fill when the profile was equilibrating rapidly. Consistently along the shore, the ATV shoreline was in front of the digitized shoreline by an average of 8 m. The total excursion was +4 m to +12 m. The MHW line is below the berm at Sandbridge and when digitizing, the only possible feature seen clearly along the entire length of the photo is the wet/dry line which is the limit of runup. This is clearly landward of the position of MHW.

Selected rates of change calculated from the ATV MHW shorelines are shown in Figure 27. In Figure 27A, the overall EPR was positive as a result of the beach fill. The pre-post fill dates show large positive rates as do the year after the fill EPR with the exception of beach at Little Island which had significant losses. The monthly rates shown in Figure 27B are much more variable and show seasonal differences. The June-July 2004 plot shows less variation than the Fall (Oct-Nov) data. Even between years, there is a large variation in shoreline-change rates. The data from Oct-Nov 2004 is much more variable than the data from Oct-Nov 2005. In fact, the 2005 period shows overall accretion as opposed to the 2004 period that was erosional (Table 8).

Table 8 shows the calculated shore change rates for various time intervals. In the “average all” column, the entire length of shoreline data collected for that date was used to calculate the rate of change. The “average SB” column only uses data collected along Sandbridge. The data show several large erosion events. These correlate with wind and elevated water levels from the northeast (Figure 28). These data was obtained from National Oceanic and Atmospheric Administration Center for Operational Oceanographic Products and Services (CO-OPS) Homepage. The wind data show that October to November 2005 was a fair weather period. Records from the Chesapeake Bay Bridge Tunnel indicate that the average wind direction between 18 October and 17 November was 201^{o} TN at 6 m/s which accounts for the accretionary period.

Table 7.
ATV Survey Dates with Usable Shorelines

Survey No.	Date
1	20-Aug-2002
2	19-Nov-2002
3	19-Feb-2003
4	14-May-2003
5	7-Aug-2003
6	9-Mar-2004
7	4-May-2004
8	9-Jun-2004
9	8-Jul-2004
10	13-Oct-2004
11	9-Nov-2004
12	31-May-2005
13	22-Sep-2005
14	18-Oct-2005
15	17-Nov-2005

Table 8
Change Rates for the 15 Shorelines Collected with the ATV

Survey No.	Change Between			Avg All Data m/yr	Avg SB m/yr
2-1	20-Aug-02	19-Nov-02	pre fill SB	5.9	5.9
3-2	19-Nov-02	19-Feb-03		38.8	64.8
4-3	19-Feb-03	14-May-03		53.8	71.9
5-4	14-May-03	7-Aug-03	post fill SB	8.8	14.9
6-5	7-Aug-03	9-Mar-04	pre fill DN	-0.9	-4.4
7-6	9-Mar-04	4-May-04	Event 1	-46.8	-54.8
8-7	4-May-04	9-Jun-04	Post fill DN	9.9	12.4
9-8	9-Jun-04	8-Jul-04		9.8	7.0
10-9	8-Jul-04	13-Oct-04	Event 2	-21.1	-21.8
11-10	13-Oct-04	9-Nov-04	Event 3	-37.7	-37.9
12-11	9-Nov-04	31-May-05		9.0	11.1
13-12	31-May-05	22-Sep-05		-8.0	-8.9
14-13	22-Sep-05	18-Oct-05		2.8	3.4
15-14	18-Oct-05	17-Nov-05		22.3	15.2
15-1	20-Aug-02	17-Nov-05	EPR	7.2	7.2
4-2	19-Nov-02	14-May-03	pre-post fill	46.6	64.9
6-4	14-May-03	9-Mar-04	the year after	18.6	22.2

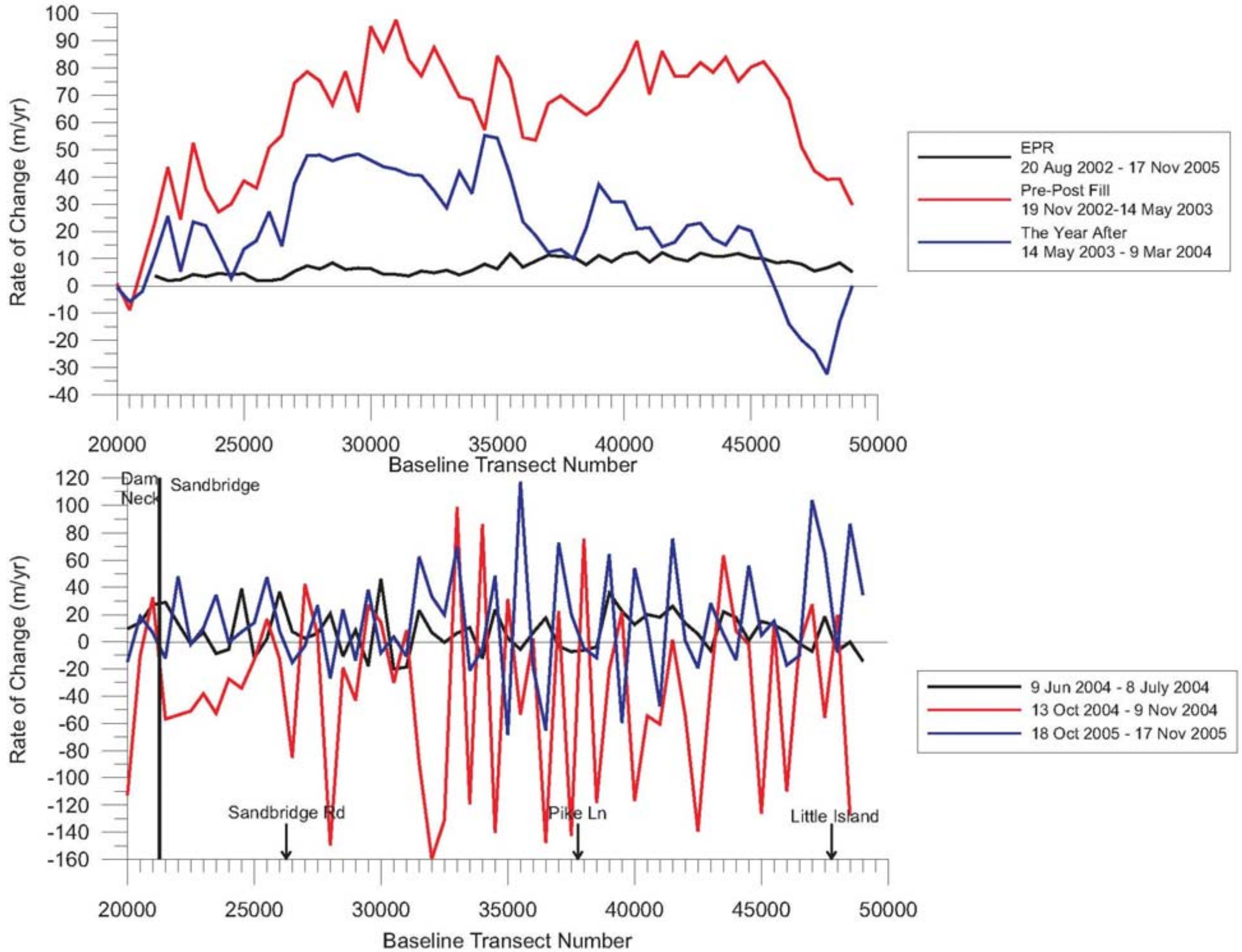

Figure 27: Selected rates of shoreline change as calculated from MHW generated by data collected with the ATV RTK-GPS system.

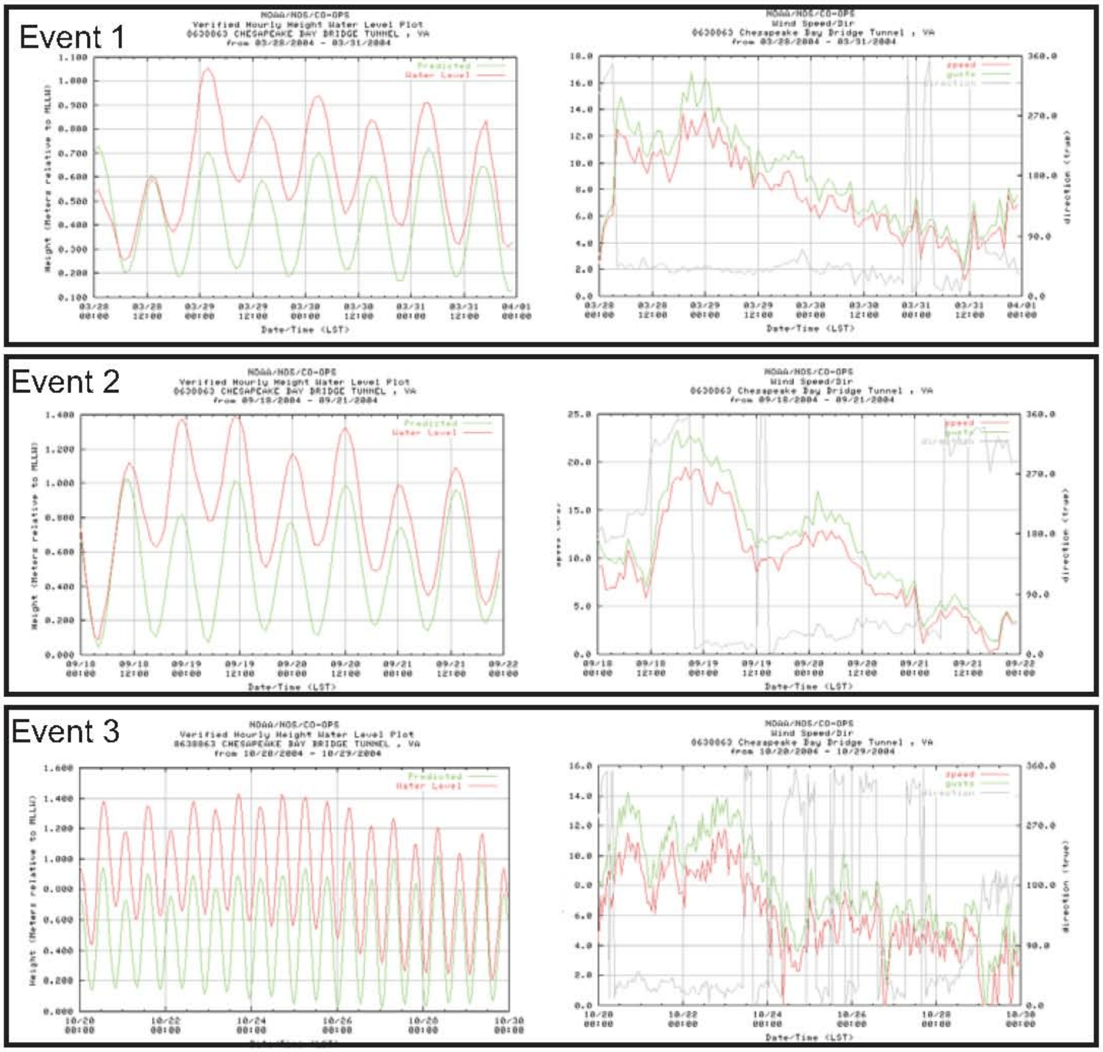

Figure 28: Observed water levels and wind speeds with direction at the Chesapeake Bay Bridge Tunnel for selected dates that were indicated in the ATV data as having an erosion event.

3.4.3. Cross-Shore Beach Monitoring

Beginning in 1998, Waterway Surveys and Engineering (WSE) commenced a beach monitoring program of 56 profile locations along Sandbridge Beach (Figure 6). This program was charged with monitoring shoreline change accompanying the beach nourishment of Sandbridge Beach in 2003. Construction began at the south end of Sandbridge Beach in January 2003, and the final section to the north was completed by mid-May 2003. The reach immediately north of the fishing pier was renourished a second time towards the end of May 2003. Profile data show that approximately 1,440,000 m^3 of fill from Sandbridge Shoal was placed between the construction baseline and a depth of -1.829 m NGVD 1929 (WSE, 2005). The volume of fill per unit length placed on Sandbridge Beach generally decreased from the fishing pier at Little Island Park north (Table 9). As of February 2005, approximately 803,440 m^3 of placed sediment remained in the project area, approximately 56 percent of what was originally placed above -1.829 m NGVD 1929 (WSE, 2005). Recent analysis indicates that the entire reach will recede landward of its design template between the winter and summer of 2006 (WSE, 2005).

Table 9
Average Fill Rates (South to North) along Sandbridge Beach from Winter/Spring 2003 Nourishment

Shoreline Reach	Average Fill Rate
Profile 0 to 30 (Bay Back to Fishing Pier)	111.1 m^3/m
Profile 35 to 85 (Fishing Pier to Molly Cooper Road)	274.9 m^3/m
Profile 90 to 145 (Molly Cooper Road to Rock Lane)	203.2 m^3/m
Profile 150 to 225 (Rock Lane to Sandbridge Road)	152.8 m^3/m
Profile 230 to 275 (Sandbridge Road to Dam Neck)	78.5 m^3/m

Profiles were surveyed every 150 m from Bay Back National Wildlife Refuge to Dam Neck. Each profile line extended offshore to at least wading depth; every other profile (0, 10, …270) extended approximately 1,000 m offshore to approximately 10 m below NGVD 1929. Profiles were surveyed following completion of the nourishment in early 2003, Hurricane Isabel in fall 2003, in spring 2004, and, in winter 2005 (Table 10). The monitoring data provide for a review of approximately two years of change following the early 2003 nourishment. It is important to realize that the most significant changes occur immediately after nourishment during the profile equilibration process. This dynamic period was significantly enhanced by Hurricane Isabel.

Table 10
Beach Profile Surveys Following Nourishment

Survey Name	Time Period
Post-Nourishment	January – May 2003
Fall 2003	October 2003
Spring 2004	May 2004
Winter 2005	December 2004 – February 2005

3.4.3.1. Shoreline and Linear Change Analyses

Shoreline change and nearshore elevation changes can be examined by tracking the cross-shore migration of a datum-derived contour. At Sandbridge Beach, the 0.67 m contour approximates the Mean High Water (MHW) datum (Basco *et al.* 1997). In this analysis, the cross-shore positions of 0.67 m, -1.5 m, -5 m, and -9 m (2, -5, -15, and -30 ft) NGVD 1929 were compared (Figure 29). A MathWorks MATLAB™ script was written to linearly interpolate beach profile elevations between survey points and to extract the distance between the profile's baseline and elevations specified intersecting the cross-shore profile. Endpoint change rates, normalized to a yearly rate, were calculated for each distinct and net time periods to describe the variability in change.

3.4.3.2. Volumetric Change Analyses

Volumetric change analysis was conducted to determine temporal volumetric change above and between specified vertical datums along each profile. For each survey (post nourishment, fall 2003, spring 2004, and winter 2005), volumes were calculated from the monitoring baseline (0 m cross-shore position) out to and above the following elevations: 0.67 m (MHW), -1.5 m, -5 m, and -9 m NGVD 1929 (Figure 20). Since the post construction survey only extended to wading depth, volume calculations for that specific survey were only possible above ~ -1.5 m. All volumes were calculated using CEDAS-Beach Morphology Analysis Program (BMAP). Net volumetric change rates, which reflect both deposition and erosion, were determined by comparing volume calculations between surveys and then normalized to a yearly rate (PN-Fall03; Fall03-Spring04; Spring04-Winter05; Net). Zonal volumetric change rates were also determined by comparing volume calculations above each datum and across available survey dates. Zonal volumetric change rates were determined above MHW, between MHW and -1.5 m , between -1.5 m and -5 m, and -5 m and -9 m (Figure 29). It is important to note that the bin sizes and cross-shore distance represented by each bin (at each profile) are not uniform, although the volume changes were normalized to cross-shore distance.

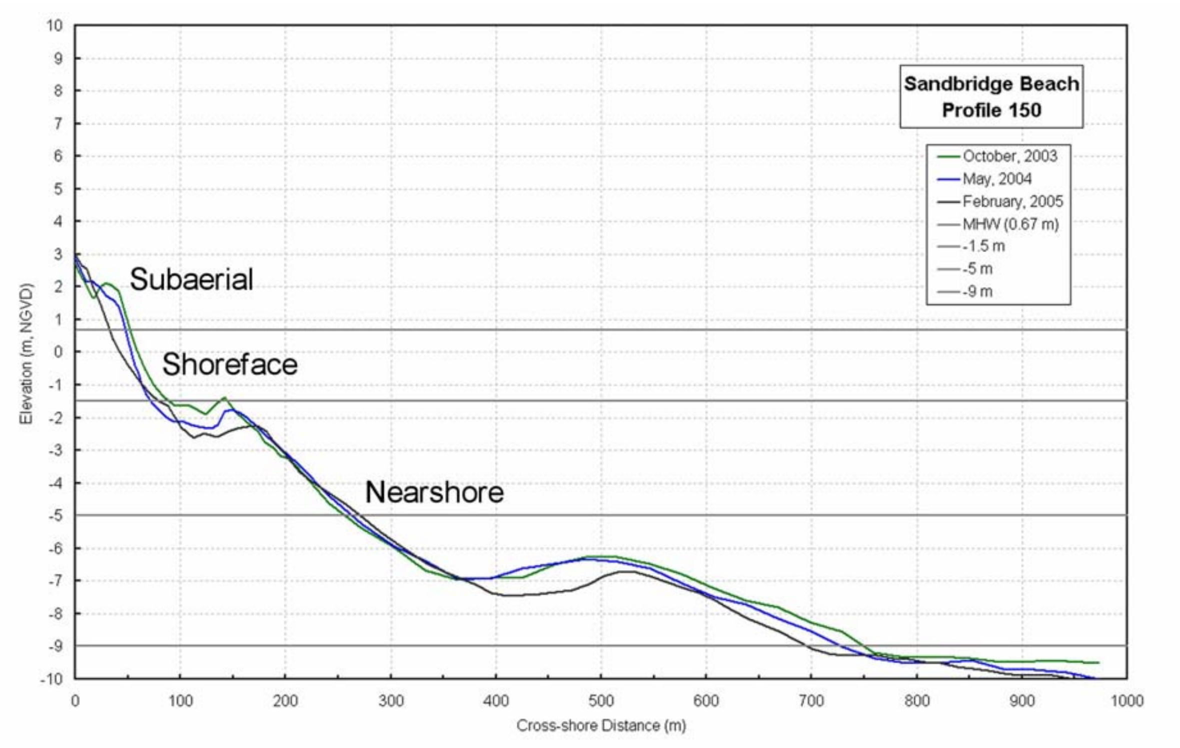

Figure 29. WSE profile location 150 at Sandbridge Beach. The profile is intersected by a shore oblique bar at -7 to -9 m water depth. Volumetric change was calculated above and between the four elevations designated.

3.4.4. Nearshore Geophysics

Interferometric swath bathymetry and chirp seismic profile data were collected in May 2002, providing a three-dimensional picture of the nearshore region to approximately 1 km offshore. The interferometric system (Submetrix, Series 2000) yielded bathymetry data as well as characteristics of surface sediments through acoustic backscatter. A chirp sub-bottom profiler (Edgetech 216S) was used to map the underlying geology of the area. Results of this initial effort prompted a repeat and more focused survey of the area in June of 2003.

Unique morphological features, shore-oblique bars coupled with patches of coarse gravel, were the focus of the repeat survey; similar features had previously been mapped in the Outer Banks of North Carolina (McNinch 2004) and have since been correlated with heightened shoreline erosion (Schupp 2005). A 6 km stretch of the original region was mapped with a 600 kHz Marine Sonics side scan sonar and an Edgetech 512I chirp sub-bottom profiler. The higher-frequency side scan data provided more detail and sharper contrast of surface sediment characteristics. The newer model chirp system is equipped with more options for frequency range. The chosen range, 0.5-6kHz, allowed penetration of the nearshore Holocene sand layer, while at the same time resolving the acoustic layers to within ~10 cm. This resolution allowed the identification of paleo-channels which were later found to correlate spatially with the shore-oblique bar / gravel outcrop regions (Browder 2005; Appendix C).

A series of comparisons was made between modeled bathymetric data, beach profile data, and data extracted from the swath bathymetry using the Waterways profile locations (spaced 150 m and 300 m). It is important to note that while the Waterways profile locations were used, the lengths were not. The extracted profiles all were ~1 km long, whereas only every other Waterways profile (~300 m spacing) is ~1 km long.

3.4.5. Discussion

3.4.5.1. Subaerial Beach Morphology

Shoreline change rates, based on the relative movement of the MHW contour normalized to 1 year, were compared for two different time periods following two nourishment events at Sandbridge Beach (Figure 30). Old Dominion University (ODU) surveyed 28 profile locations for 14-16 months following beach nourishment in 1998, whereas Waterways Surveys and Engineers (WSE) surveyed 56 profile locations three times over the two years following beach nourishment in 2002. The left panel of Figure 21 uses a weighted classification to show the relative difference in shoreline change in the first 6 months or so for the ODU profiles and first 9 months or os for the WSE profiles. The right panel of the figure uses a weighted classification to show the relative difference in shoreline change in the first 15 months for the ODU profiles and the first 20-24 months for the WSE profiles. The time interval could not be standardized because of the variation in the completion of nourishment activity and the timing of beach profiling. The shoreline change rates following the second nourishment are much greater than those following the first nourishment period, showing the significant impact of Hurricane Isabel. A close examination reveals subtle patterns of change in erosion. For example, the central reach (near Northing 4065000 in Figure 30) experienced the greatest relative increase in erosion rate.

3.4.5.2. Nearshore Morphology

Using two dimensiona,l beach profile data from WSE, shoreline change was compared to nearshore change, portrayed by the movement of elevation-derived contours through time. The top panel of Figure 31 plots the movement of the Mean High Water (MHW) contour and -1.5 m, -5 m, and -9 m contours (NGVD 1929) from post-nourishment through February 2005. The middle panel and bottom panel of Figure22 display the change or migration rate of the MHW and -1.5 m contours then the -5 m and -9 m contours respectively. It is important to note that only change was measured at the profile locations and not in between locations. The maximum change in the position of the MHW contour (middle panel of Figure 31) reflects profile equilibration immediately after nourishment and erosion during Hurricane Isabel in September 2003. The apparent variability in the -1.5 m contour is related to the cross-shore position and relative elevation changes of the longshore bar (middle panel of Figure 31). The variability in the -9 m contour (bottom panel of

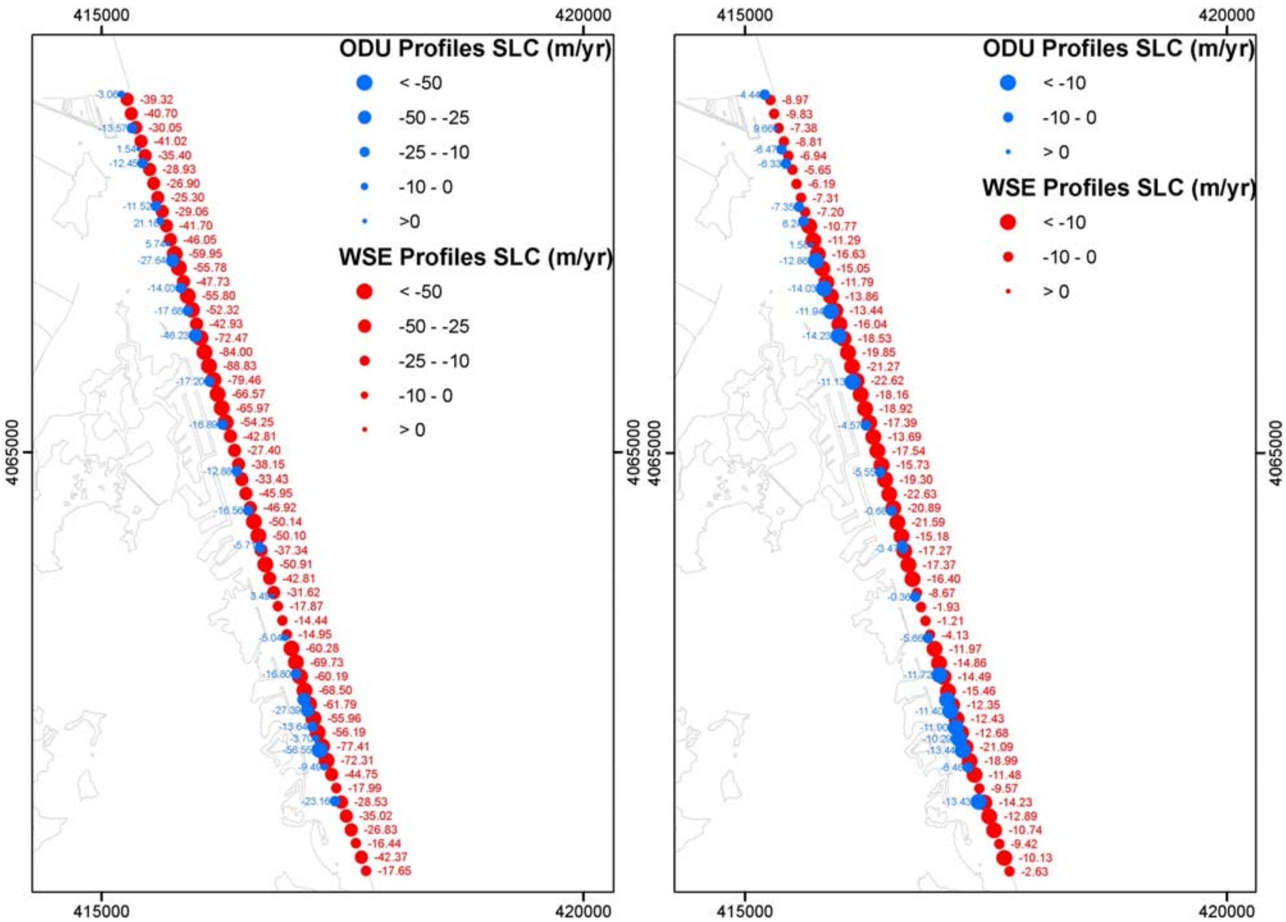

Figure 30. Shoreline change rates compared for two different time periods following two different nourishment events (1998/2002) at Sandbridge Beach. WSE surveyed 56 profile locations three times over the two years following beach nourishment in 2002. The left panel shows the relative difference in shoreline change in the first ~6 months for the ODU profiles (1998) and first ~9 months for WSE profiles (2002-2003). The right panel uses a weighted classification to show the relative difference in shoreline change in the first 15 months for the ODU profiles (1998-1999) and the first 20-24 months for the WSE profiles (2002-2005). Note the shoreline change rates represent different time periods, but are normalized to a yearly rate. Coordinates in UTM NAD 1983 (m).

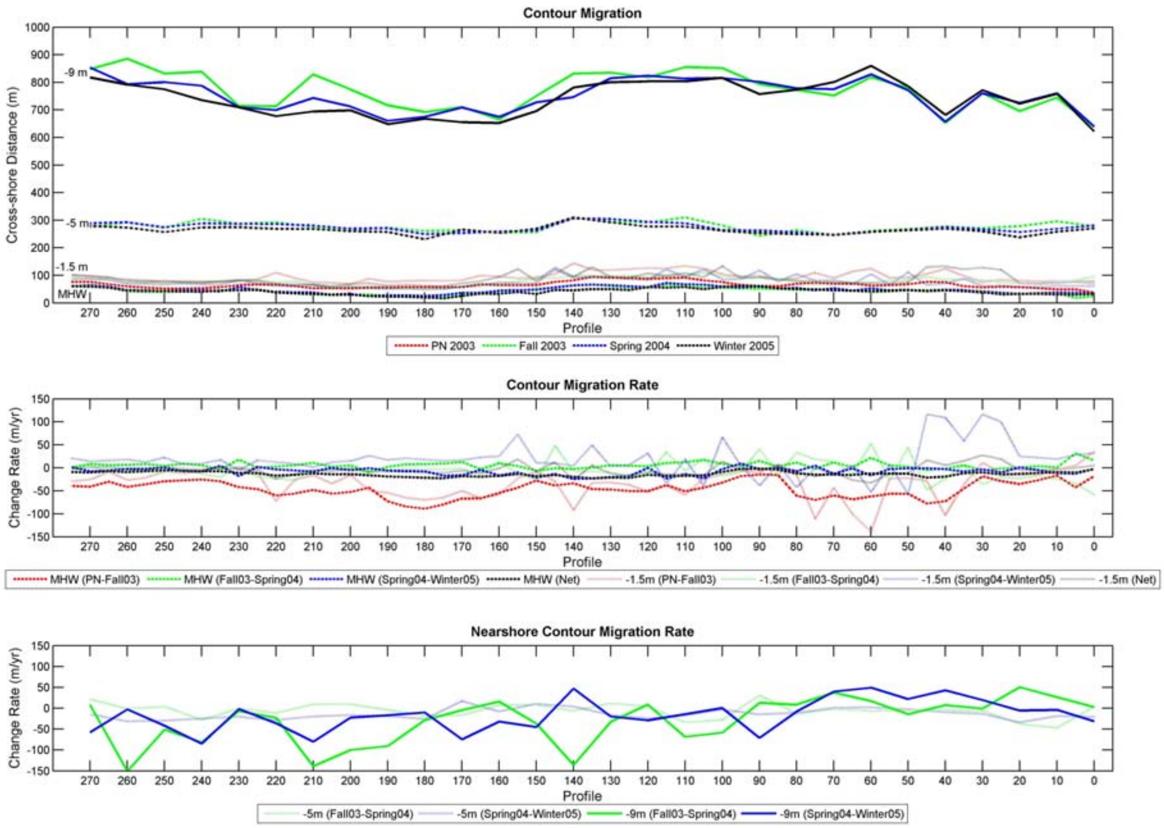

Figure 31: The top panel plots the movement of Mean High Water and -1.5 m, -5 m, and -9 m (NGVD 1929) contours from post-nourishment through February 2005. The other panels display the migration rate of the MHW and -1.5 m contours and -5 m and -9 m contours respectively.

Figure 31) is most likely a result of not reoccupying the same offshore location between subsequent surveys or dynamic nearshore morphologic/hydrodynamic interactions or a combination thereof. McNinch (2004) recently documented complex, nearshore morphology along Sandbridge Beach, characterized by a series of shore-oblique sand bars and gravel patches. Examination of Figure 29 clearly depicts the potential complexity of the profile shape in the nearshore and shows the potential variability in elevation measurements between subsequent surveys, again signifying surveying limitations and or migrating features.

Rates of volumetric change were calculated for each time interval and a net time interval when possible (Table 9). The middle and bottom panels of Figure 32 show the volumetric change rate ($m^3\ m^{-1}\ yr^{-1}$) over various time periods for the portions of the shorezone above MHW, -1.5 m, -5 m, and -9 m. It is important to note that only change was measured at the profile locations and not in between locations; connecting the volumetric change rates between locations is used to visualize significant trends. The most significant subaerial and shoreface volumetric change (>MHW on middle panel of Figure 32) occurred over the first period (PN-Fall 2003) and was associated with profile equilibration and storm-driven sediment transport coincident with Hurricane Isabel (including overwash and aeolian transport). The shoreline reaches characterized by maximum subaerial beach loss during this period (profiles 150 to 230 and profiles 30 to 80) are located adjacent to and immediately to the northwest of shore-oblique sand bars (middle panel of Figure 32, Figure 35). This pattern is also discernable in the volumetric change rate calculated above -1.5 m(>-1.5 m on middle panel of Figure 32). Comparatively, there is relatively little change, excluding seasonal fluctuations, that occurs within the surf zone following this initial dynamic period. The volumetric change rates calculated above nearshore contours of -5 and -9 m are highly variable and completely incoherent (bottom panel of Figure 32). Again, this variability is indicative of not reoccupying the same offshore location between subsequent surveys or significant cross-shelf and alongshelf migration of the bars.

Comparisons between shoreline change rate and nearshore contour migration rates and shoreline change rate and volumetric change rates are shown in Figure 33 to explore the variability in the shape of the beach profile. The concept of an equilibrium beach profile is important since it is the underpinning of the numerical model recommended for use in evaluating shoreline change, inner shelf wave transformation, and corresponding sediment transport (Dean 1991; Thieler *et al.* 2000). The top panel of Figure 33 shows the rather complex relationship between shoreline change rate and the migration rate of the -1.5 m contour, one complicated by seasonal berm-bar translations. There is no immediately discernable relationship between shoreline change and the translation of the -5 m and -9 m contours over the same time period (top panel of Figure 33). It is possible that sediment transport within the nearshore is lagged, such that there is increased correlation between change in the surf zone and inner shelf over different time scales. Such an analysis was not performed. The spatial distribution of points reveals a clear storm and seasonal signal, where offshore sediment movement is greatest when storm waves remove sand from the subaerial beach and transport it seaward. The bottom panel of Figure 33 compares the volumetric change above MHW with that above -9 m. There is an unambiguous relationship between shoreline change and subaerial beach volumetric change compared to a tenuous, temporally and spatially dependent relationship between shoreline change and large-scale, nearshore volumetric change.

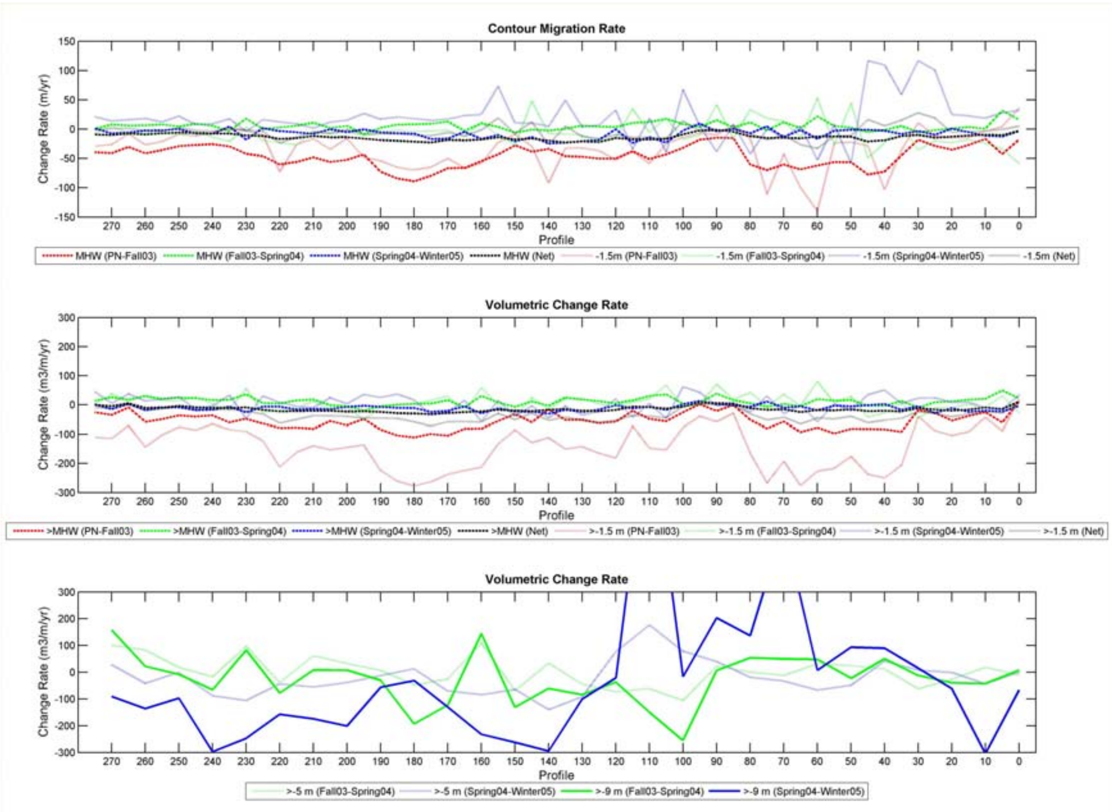

Figure 32: The top panel shows the change rate for MHW and -1.5 m contour over the study period. The middle and bottom panels show the volumetric change rate ($m^3/m/yr$) over various time periods for volumetric changes above MHW, -1.5 m, -5 m, and -9 m. See Figure 29 for clarification of zonal volume calculations.

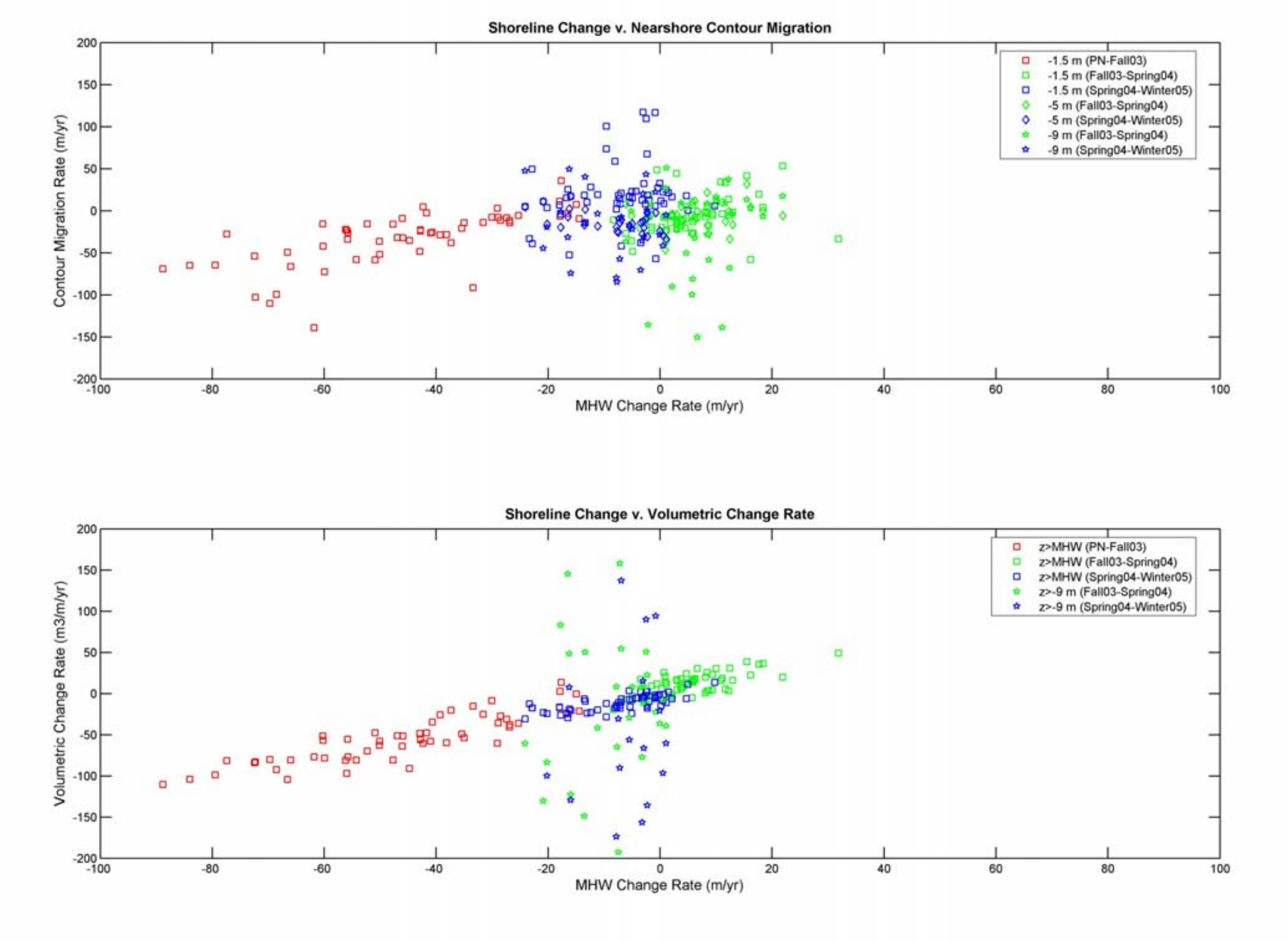

Figure 33. The top panel shows the relationship between shoreline change rate and the migration rate of the -1.5 m contour. The bottom panel compares the volumetric change above MHW with that above -9 m.

Figure 34 shows a series of plots delineating the relationship between shoreline change and zonal volumetric change. The title of each panel indicates the vertical zone in which volumetric change rates were calculated. The top left panel shows a clear relationship between shoreline change and the volumetric change rate above MHW. The top right panel shows a relatively clear relationship between shoreline change and the volumetric change rate between MHW and -1.5 m. The spring 2004- winter 2005 trend shows shoreline retreat (negative shoreline change rate) with concomitant deposition (positive volumetric change rate) in the surf zone; examination of the actual profiles suggests convergent transport from the berm seaward and bar landward. The bottom left panel shows no relationship between shoreline change and the volumetric change rate between -1.5 m and -5 m. The bottom right panel shows no relationship between shoreline change and the volumetric change rate between -5 m and -9 m. In contrast to volume change rates above -1.5 m, change rates calculated above -5 and -9 m contours show no seasonal coherency. Again, it is possible that sediment transport within the sweep zone is lagged, such that there is increased correlation between change in the surf zone and inner shelf over different time scales. Again, this variability might be indicative of not reoccupying the same offshore location between subsequent surveys or significant cross-shelf and alongshelf migration of the bars.

Browder and McNinch (Appendix C) documented complex nearshore morphology along the southern end of Sandbridge Beach, characterized by a series of shore-oblique sand bars and gravel patches using swath bathymetry and chirp seismic data (Figure 35). Two dimensional beach profiles surveyed in the fall 2003, spaced 300 m (~1,000 ft) apart and interpolated to create an elevation model, fail to capture these complex spatial variations (Figure 36). In this figure, alongshore position was calculated as the distance between profile monument locations, and cross-shore position was taken directly from the beach profile data. The topographic variations in the nearshore centered around 500 m and 5,000 m (longshore distance) are positive relief changes. When qualitatively compared with high-resolution swath bathymetry and side-scan sonar collected in the area in 2002, the beach profiles significantly under-represent the nearshore variability.

The same elevation model (Fall 2003) was compared to profile data (gridded and plotted in the same manner) collected at the same location the following spring (May 2004) (Figure37). The number, scale, and orientation of shore-oblique sand bars are not captured in either of the 2D surveys; moreover, the features are inaccurately represented as mounded sand deposits. The only substantive change observed in the 7-month isopach can be attributed to seasonal bar change.

Another comparison was made by extracting differently spaced profiles from the swath data using the Waterways profile locations and then gridding that data to generate a nearshore bathymetric model. It is important to note that while the WSE profile *locations* were used, the *lengths* were not. The extracted profiles all were ~1 km long, whereas only every other Waterways profile is ~1 km long. Figure 38 shows the gridding results using profiles spaced 300 m and profiles spaced 150 m. Clearly, the refined spacing is adequate to at least capture the presence of these features, if not the finer detail.

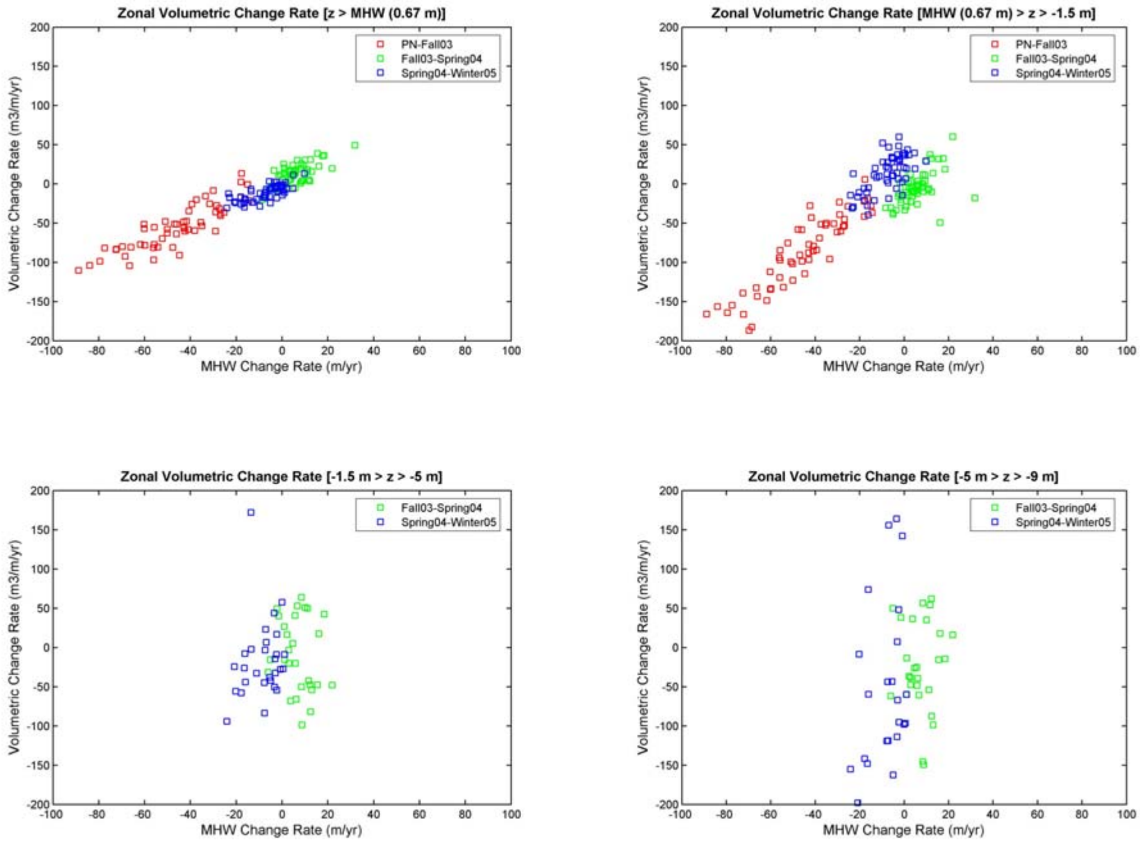

Figure 34: This series of plots shows the relationship between shoreline change and zonal volumetric change. Each panel title indicates the vertical zone in which volumetric change rates were calculated.

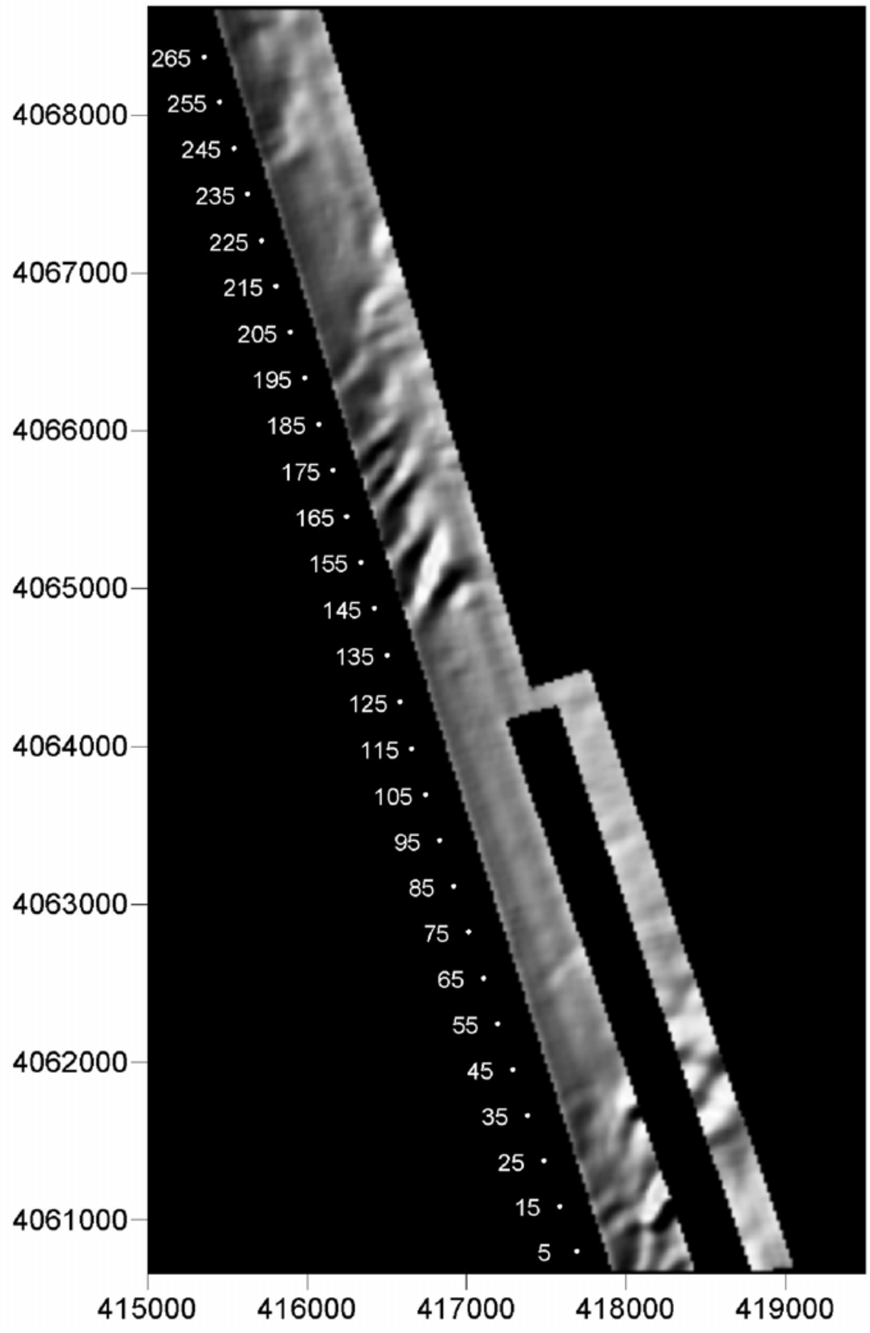

Figure 35: A 2002 interferometric swath bathymetry survey documented complex nearshore morphology along the southern end of Sandbridge Beach. This reach was characterized by a series of shore-oblique sand bars and gravel patches. Every other WSE beach profile location is provided for reference; profiles ending in 0 are profile lines that actually extended offshore (not shown). Coordinates in UTM NAD 1983 (m).

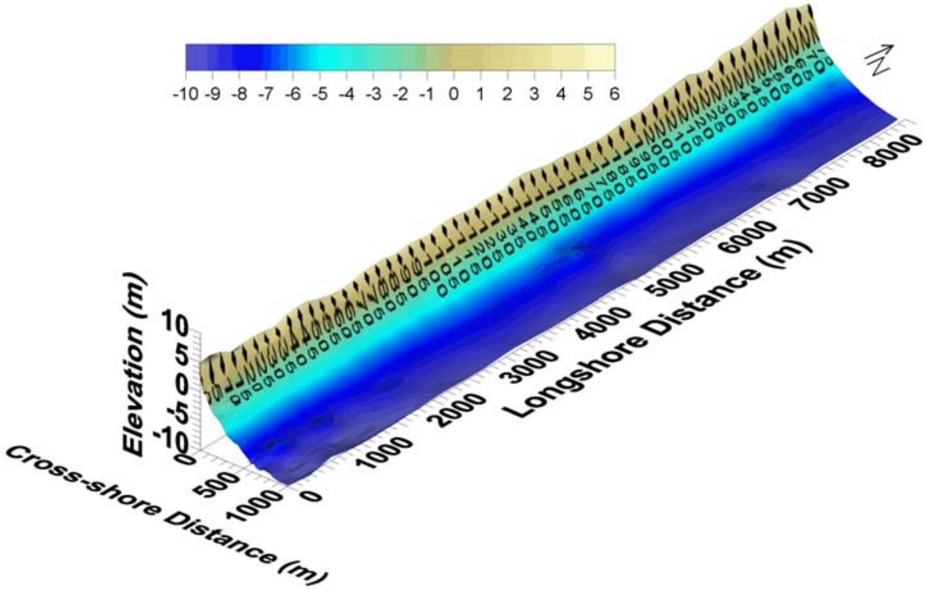

Figure 36: Two dimensional beach profiles (spaced 300 m extending offshore and spaced 150 m to wading depth) were used to create a spatially-relative nearshore bathymetry model. The elevation anomalies (0-1,000 m and 4,000-5,000 m) are the best representation of the nearshore complexity given the profile data.

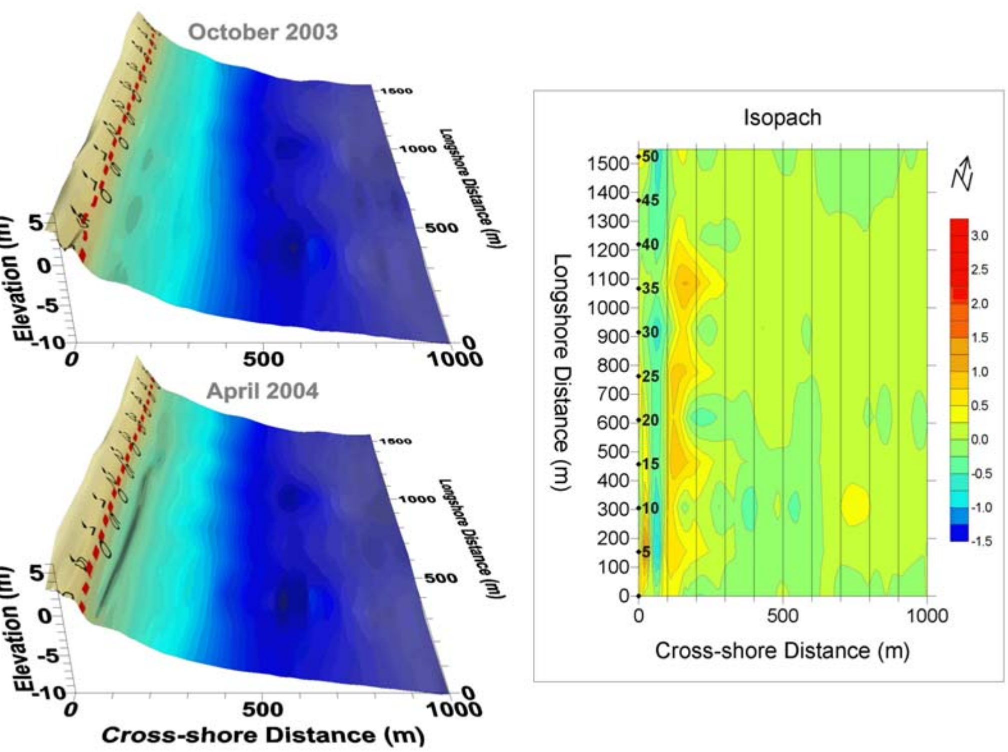

Figure 37: Using the same gridding parameters, the fall 2003 profile-derived bathymetry model was compared to Spring 2004 profile-derived bathymetry model in the focus area near Little Island Park (see Figure 2). The only substantial change was the formation of a nearshore bar.

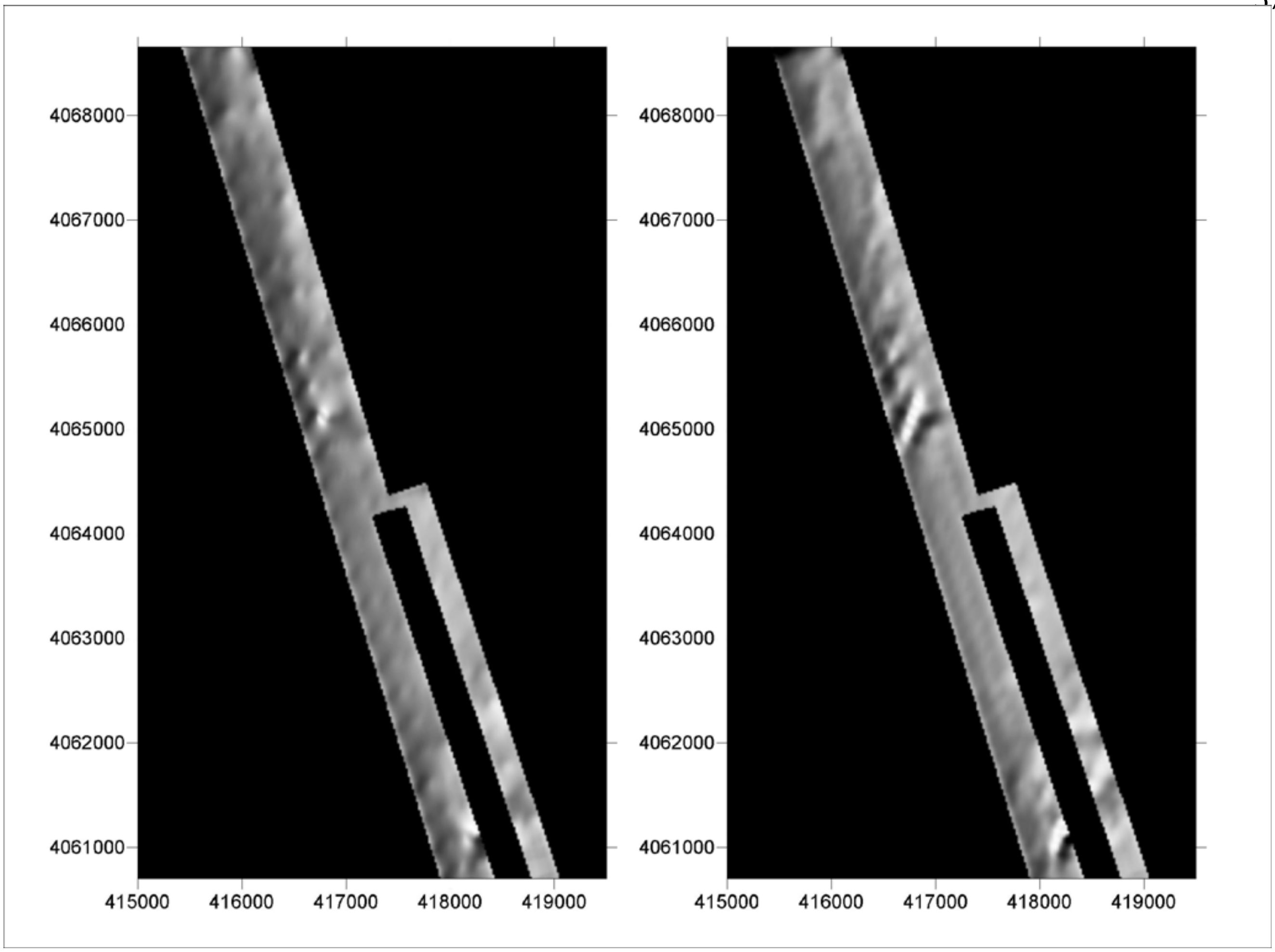

Figure 38: Nearshore bathymetric terrain at Sandbridge Beach derived using alongshore profile spacing of 300 m (left) and profile spacing of 150 m (right). High resolution swath bathymetry data were sampled along each profile line, sorted, and gridded. Coordinates in UTM NAD 1983 (m).

3.4.6. Lessons Learned

3.4.6.1. Issues and Pitfalls

The region of complex nearshore morphology points out some potential shortcomings of the proposed protocol. First, the spacing (scaling) of profiles should be sensitive to features of interest. This means that a shore reach might be better represented by variably spaced profiles with a greater density of alongshore profiles in more complex areas. The profiles should be part of a three dimensional monitoring program to validate comparisons of subsequent profiles in areas of complex and variable relief. The complexity of the nearshore adjacent to Sandbridge Beach highlights the need for a 3D survey at the outset of a project to document the presence of variably sized features. While shore-normal profiles accurately describe the beach profile at discrete locations, such profiles assume little variation in the alongshore direction. An initial, high resolution evaluation of the morphology will allow refinement of the site-specific protocol, and also will provide a better understanding of framework geology and improve subsequent assessment of any shoreline change.

Second, the complex nearshore morphology likely will make shoreline change modeling arduous, since most numerical models assume perfectly smooth, parallel bottom contours (Thieler *et al.* 2000). As complex bathymetry and irregular bedforms can have significant impact on wave refraction and diffraction, wave energy attenuation, and the magnitude of nearshore wave energy, a solid understanding of the nearshore environment is essential. Fluctuations in alongshore and cross-shore sediment transport are probable given the previous examination of volumetric change data. Numerical models, including GENESIS (Hanson and Kraus 1989), generally assume sediment transport on the shoreface to be uniform both across-shore and alongshore and do not consider sediment transport seaward of the surf zone (Hanson and Kraus 1989). At Sandbridge Beach, cross-shore transport appears to be non-uniform and tenuously related to subaerial shoreline movement.

Third, the combined use of two-dimensional and three-dimensional data in monitoring has inherent problems, as the does the use of data collected in inconsistent vertical datums. Vertical datum transformation errors (even on the order of cm) can account for significant volumes of sediment. In this study, two dimensional beach profile data were collected relative to the NGVD 1929 vertical datum, whereas the nearshore surveys were collected in NAVD88 vertical datum. Any comparison across datasets is particularly laborious and suspect because of the obvious problem in accurately determining the position and elevation of the beach profile data in three-dimensional space.

Finally, another common problem in monitoring is the spatial and temporal disconnect between data collected from the beach and from the nearshore. To minimize this issue, it is important to conduct beach and nearshore surveys as close in time as possible, to use the same vertical and horizontal datums and tidal corrections if and when necessary, and to ensure that the hydrographic cross-shore profiles overlap spatially with the nearshore swath bathymetry survey. This suggests that it is important that the terrestrial profiles be carried as far into the water as possible.

3.4.6.2. Metadata

The documentation of metadata, which often is neglected, is of utmost importance if there is to be continuity and sharing of data. Accurate records of data collection methodology and projections in a format that is straightforward and meaningful to future readers is essential. It is also beneficial to package metadata in such a way that it is automatically transferred with raw data files. The National Research Council (NRC) (2004) discusses the problems associated with the geospatial framework in the coastal zone. Monitoring protocols should endeavor to follow the recommendations developed by NRC.

4. Existing State Beach and Beach Nourishment Monitoring Efforts

Numerous state, regional, local, and federal entities and academic institutions employ a variety of research proxies to monitor shoreline change. Systematic time series shoreline change and monitoring data generally are used to evaluate short-term and long-term beach and nearshore accretion and erosion, determine building setbacks and construction control areas, develop and maintain land management and stewardship practices, establish insurance rates, and evaluate the performance of beach nourishment projects or coastal stabilization structures (NRC, 1990; NRC, 1995; Bernd-Cohen and Gordon, 1999). Twenty-three state programs, mostly sponsored by CZM track shoreline change using beach profiles, whereas twenty-nine state programs track shoreline change through digital orthophotography, remotely sensed data (Bernd-Cohen and Gordon, 1999). The scale and duration of these monitoring programs varies and depends on the monitoring requirements and mechanism. On the national level, at least fifteen federal agencies are involved in the primary collection or use of coastal geospatial data (NRC, 2004). The rationalization, scope, methodologies, effects, and recommendations of these longstanding programs were not directly mentioned in either the protocol or review documents and can offer insight and direction for future refinement and implementation of shoreline monitoring activities. This section provides a cursory summary of some programs with a focus on beach topographic surveys and seeks to contextualize the need, design, and import of monitoring programs. Table 11 presents summary data on the programs in eight states.

The availability of funding and resource utilization appear to be the primary determinants of the nature and scope of existing shoreline and nearshore monitoring programs at the state and local level. For example, New Jersey currently conducts biannually surveys at mile (~1600 m) intervals, where as Florida and Delaware conducts regional biannual surveys at 300 m and 150 m intervals along their respective coasts. Beach nourishment projects are more prevalent in these states as well. Methodologies (including technologies), survey frequency, and survey footprint vary from program-to-program. The general methodological trend in the sampled programs is the adoption of RTK-GPS kinematic line surveys in the cross-shore and alongshore dimensions. Offshore, the same positioning technology is coupled with echosounding, varying from single beam to swath. Particularly well-funded programs, usually those with a legislative mandate and revolving funding source, are increasingly using advanced technologies for high resolution 3D mapping, such as topographic / bathymetric lidar and swath or multibeam echosounding. Such efforts emphasize

Table 11. Characteristics of Several State Beach Monitoring Programs

State	Research Agency	Program	Mandate	History	State Recognized Shoreline	Methodology	Beach Topographic Profiles	Coordinate Systems and Datums	Survey Frequency	Data Use	Supporting Shoreline Change Methods
DE	Dept. of Natural Resources and Environmental Control	N/A	N/A	Since 1979 Ocean Coast	MLLW	Present: RTK GPS coupled w/ fathometer w/ heave compensation Historic: Traditional rod survey coupled w/ fathometer using range-azimuth system	Cape Henlopen south to Fenwick Island (from the backdune out 2000 ft) Annual 1 mile spacing (35 lines) Biannual 500 feet at Dewey, Rehobeth, Bethany, South Behany, and Fenwick areas	DSPCS NAD 83 NAVD 88	1 or 2 per year	Long-term erosion trends Beach management planning	Aerial photography
TX	Texas Bureau of Economic Geology	Texas Shoreline Change Project	Coastal Erosion Planning and Response Act (1999)	N/A	MHHW	RTK GPS or Total Station of selected transsects Nearshore GPS single beam echosounding to -7m Lidar	Monitor 150 km of Texas coast	Variable	Variable	Long-term erosion trends Beach mgt Coastal permitting Storm impacts	Interfero-metric airborne synthetic aperature radar
MD	US Army Corps of Engineers, Baltimore District	N/A	N/A	Since 1965	MHW	Conventional beach surveys single beam echosounding	Profiles to closure depth (-21 ft NGVD)	MSPCS NAD 83 NAVD 88	Periodic annual and Post-storm	Long-term erosion trends Beach management planing Storm impacts	Aerial Photography

Table 11. Characteristics of Several State Beach Monitoring Programs (continued)

State	Research Agency	Program	Mandate	History	State Recognized Shoreline	Methodology	Beach Topographic Profiles	Coordinate Systems and Datums	Survey Frequency	Data Use	Supporting Shoreline Change Methods
VA	City of Virginia Beach Waterways Surveys and Engineering Virginia Institute of Marine Science	N/A	N/A	See Appendix A	MLLW	Total Station Surveys ?	Monitor Virginia Beach and Sandbridge w/ profiles spaced 150 m and extending to wading depth Offshore profiles spaced 300 m to -30 ft	VSPCS NAD 83 NGVD 1929	Variable	Long-term erosion trends Beach management planning	Aerial Photography
NY	US Army Corps of Engineers, New York District State Univ. New York at Stony Brook NY Division of Coastal Resources	Atlantic Coast of New York Monitoring Program	Federal Water Resources Developmen t Act	1994 Periodic	MHW	?	Seasonal and post-storm beach profiles at 348 locations	?	Spring and Fall	Design and analysis of Corps projects Beach management plans Permit application evaluation	Aerial Photography
SC	Coastal Carolina Univ SC Office of Ocean and Coastal Resource Management	South Carolina Beach Erosion Monitoning (BERM)	SC Beachfront Management Act	1993	MHW	RTK GPS deployed on an ATV Single beam echosounder on a jet-ski or sled-based profiling	375 annual surveys statewide, quarterly surveys of nourished beaches for 3 years subaerial beach to >-7 m NGVD, to 1 km (3000 ft) offshore	SCSPCS NAD NAVD 88 both in feet	Variable	Erosion trends Set back delineation Monitor beach nourishment	Aerial photography Geophysical surveys Video

Table 11. Characteristics of Several State Beach Monitoring Programs (continued).

State	Research Agency	Program	Mandate	History	State Recognized Shoreline	Methodology	Beach Topographic Profiles	Coordinate Systems and Datums	Survey Frequency	Data Use	Supporting Shoreline Change Methods
NJ	Richard Stockton College NJ Dept of Environmental Protection	New Jersey Beach Profile Network	NJ Public Law 93 Coastal Protection Funding Legislation	1986	MHW	Total station and optical prism on sled	Backdune out to -12 ft 100 profiles at ~1 mile intervals Rariton Bay, Atlantic, and Atlantic Ocean	NGVD 1929	Spring and fall	Assessment of disaster impacts NJDEP permit applications Municipal erosion plans Monitor beach nourishment	Aerial photography
FL	Bureau of Beaches and Coastal Systems Department of Environmental Protection	Statewide Coastal Monitoring Program	N/A	Since 2001 Some since 1970	MHW	Conventional and RTK GPS beach surveys Single or multibeam echosounding Lidar	Beach and offshore profiles spaced 1000 ft apart. Beach profiles from 150 ft landward of vegetation line out to wading depth (approx 1 ft below MLW) Offshore surveys made at high tide, extend landward for continuity, and run 3000 ft offshore or to -30ft.	FSPCS NAD 83 NAVD 88	Periodic Annual and Post-storm	Long-term erosion trends Beach management planning Coastal construction control Joint coastal permitting Storm impacts	Aerial photography aerial videography Wave climate monitoring

the importance of understanding the feedbacks between a variable nearshore morphology, coupled hydrodynamics, and shoreline response. Under normal circumstances, monitoring typically is limited to biannual surveys, although surveying regularly following major storms is common. The longshore and cross-shore extent covered under the auspices of existing programs is especially variable. Some programs focus on the subaerial beach, where as others emphasize nearshore changes surveying to the depth of closure, or the depth beyond which there is no presumed exchange of sediment between the nearshore and the inner shelf. There is a suite of barriers to information exchange across programs, primarily variability in survey resolution and frequency, data projection and formatting, and data documentation. These areas require immediate improvement if the objective of the protocol is to advance regional, information exchange.

4.2. Protocol Models

Florida and South Carolina have leading-edge and well-funded, shoreline monitoring programs. For example, Florida has drafted and implemented suite of formal protocols to be used throughout the state tailored to beach nourishment monitoring. Examination of these efforts offers a more informed context for evaluating the draft monitoring protocols presented by MMS.

4.2.1. Florida

The Florida Department of Environmental Protection’s Bureau of Beaches and Coastal Systems (BBCS) recently developed a suite of monitoring standards for statewide beach erosion control projects (http://www.dep.state.fl.us/beaches, May 2005). The formal guidance is an integral component of the State’s more inclusive, regionally-implemented Statewide Coastal Monitoring Program. The technical specifications for the beach erosion control project monitoring standards were created to provide a consistent data framework for comparison of nourishment project within state, outlining the minimum data collection necessary to document change in beach morphology, under natural and post-storm conditions, as well as beach erosion control project performance. The effort to devise formal monitoring standards was supported by codified legislative commitment and a dedicated and funding source.

Monitoring Standards for Beach Erosion Control Projects (Bureau of Beaches and Coastal Systems, 2004) provides detailed technical specifications for topographic and bathymetric 2D profile surveys, bathymetric surveys in open water, and high-resolution aerial photography. The extent and frequency of surveying is not specified in the standards, but can be assumed to be project and shoreline reach specific. The document also refers to specifications for the use of alternative technologies outlined in the Statewide Coastal Monitoring Program, including high-resolution aerial videography and airborne laser surveying (lidar). Nearshore wave data collection and analysis is an integral component and consist of nearshore wave gages and modeling wave transformation to establish shallow water wave hindcast at 1 mile intervals alongshore for the entire state.

The beach-erosion-control standards give special emphasis to the use of kinematic GPS technology in obtaining highly accurate beach profiles. Topographic and bathymetric data are collected using traditional 2D surveying techniques along profile lines at previously established benchmarks spaced every 1,000 ft (~300 m) along the coast. The profiles generally extend 1,500 feet onshore from mean low water or 150 feet landward of vegetation line and extend offshore from mean high water to the depth of closure, generally 3,000 feet offshore at water depths exceeding 30 feet. If a wading depth survey is performed without offshore survey component, the survey extends 1 ft below mean low water. Profile data are collected in State Plane Coordinate Systems using NAD83 and NAVD88 horizontal and vertical datums respectively. Profile specifications require that 1) all grade breaks be reflected and 2) intervals between survey points not to exceed 25 feet. Specifications for data delivery include x,y,z profile data, distance, elevation/depth data, monument information report, complete federally compliant metadata, and digitally scanned field books.

The protocol for nearshore and offshore bathymetric surveying calls for the mandatory use of echosounding equipment coupled with kinematic GPS. Profile data are collected in State Plane Coordinate Systems using NAD83 and NAVD88 horizontal and vertical datums respectively. Surveying must performed during calm sea conditions with maximum wave heights less than 3 feet. Point spacing along profile lines and/or in three-dimensional surveys cannot exceed 25 ft. Specifications describe the acquisition, position control, processing, and deliverables are applicable to all offshore areas including ebb and flood shoals and borrow sites. Specifications for data delivery are virtually identical to those for the terrestrial profiles.

Unfortunately, the Florida guidance offers no instruction in terms of data analyses and/or use, but tangential products indicate effective use for beach management and regulatory purposes. Most common use of the derivative data includes the evaluation of short-term and long-term coastal behavior (i.e. assessing regional erosion/accretion trends/rates, sediment pathways and budgets, and project performance/impacts). Data collected under the guise of beach erosion control projects are also supplemented by data from the concurrent Regional Coastal Monitoring Program (Bureau of Beaches and Coastal Systems, 2001). Florida has focused on a regional approach to sediment management rather than project-specific monitoring alone. A concerted effort was applied to consolidate various monitoring taking place within each coastal region (*i.e*., consulting and governmental) to minimize redundancy and maximize service value and data output. Since 2001, quadrants of the state are monitoring comprehensively through beach profiles, aerial photography, videography, and other technologies, such as lidar, aerial videography, and wave data (since 2000), on a rotating basis. The Bureau of Beaches and Coastal Systems also maintains an extensive database of coastal data for evaluating beach change in context of historical trends and regional processes. Beach and nearshore profile surveys date back to the early 1970s, aerial photography (since 1930), and historic shoreline and bathymetric data dating back to the late 1800s. Beaches and Shores Resource Center at Florida State University, sponsored by the Florida Department of the Environment, also is compiling a comprehensive review of recent beach nourishment project monitoring and data (http://beach15.beaches.fsu.edu, May 2005). The website includes monitoring data, collected by various consulting and governmental agencies, design parameters, regional and site conditions, and project performance.

While Florida's standards appear to offer a template replicable for the MMS protocol, it is imperative to consider the geologic nature and relative complexity of the coastal system undergoing monitoring and to evaluate the appropriateness of the specific monitoring protocols for use in the local environment. In areas and on scales of interest, where the nearshore is characterized by relative uniformity, the Florida protocol could prove sufficient. However, alongshore and cross-shore variation in the subaerial beach, nearshore, and inner shelf complicates monitoring design, data collection, and data analyses.

4.2.2. South Carolina

The experience of the South Carolina Beach Erosion Research and Monitoring program (BERM) is particularly illustrative in that it offers applied knowledge. The BERM statewide monitoring program has evolved with new methodology and technology since 1993 and now includes 375 annually measured profiles. Statewide surveys are supplemented by those being performed in designated areas geared towards scientific interests and localized problems. In beach nourishment surveys are also performed quarterly for three years to evaluate performance of the nourishment and to assess any regionally-induced change. Currently, onshore surveying is performed using RTK GPS and offshore surveying uses motion-corrected, single beam echosounding mounted on all-terrain vehicle and rigid hull inflatable boat or jet ski. The beach profile is surveyed from the primary dune offshore to approximately 3000 feet or below the assumed depth of closure (-8 m NAVD88). The subaerial beach is surveyed at or close to low tide and the subaqueous portion is surveyed at or close to high tide to ensure overlap of data in the surf zone. Backpack RTK surveys are conducted in terrain where the use of the ATV is a problem. Spacing of profiles for nourishment projects does not generally exceed 500 feet (~150 m) alongshore. Shore-parallel tie lines are run to check cross-shore profiles and enhance three-dimensional data modeling. Data are collected in the South Carolina State Plane Coordinate System using NAD83 horizontal and NAVD88 and vertical datums. Vertical/horizontal positioning is verified with a statewide network of benchmarks. Data are acquired and processed using Hypack software and distributed as x,y,z data accompanied with federally compliant metadata. Historic data were converted to modern datums and provide a valuable reference for coastal change analyses.

Recent studies at Folly Beach and Grand Strand of beach nourishment projects have been used to evaluate the response of the nourished beaches over longer time periods (3+ years). Surveying was performed pre- and post-nourishment, at a quarterly basis for three years following nourishment, and then annually thereafter. The beach profile surveys occasionally were supplemented by bathymetric surveying at the borrow site and periodic nearshore sidescan sonar and videography. In general, the trend conveyed in the analyzed data reflected pre-nourishment patterns of accretion and erosion. Historical hotspots and highly vulnerable areas rapidly lost sand from the nourished, subaerial beach, whereas adjacent beach areas maintained volumes near or in some cases above expected performance levels (Gayes *et al.*, 2001). Geophysical mapping identified large-scale movement of sediment within the nearshore and inner-shelf systems adjacent to nourished beaches (Thieler *et al.*, 1999). At Folly Beach, beach sand moved rapidly offshore to the inner shelf through a linear rippled scour depression (RSD) (Gayes *et al.*, 2001). At North Myrtle Beach, approximately 90 percent of the placed volume was remeined at the placement site three years after construction. The stability was unanticipated and did not follow the anticipated exponential loss in volume associated with a profile in disequilibrium with natural processes (Gayes *et al.*, 2001).

Bernstein *et al.* (2003) conducted a study in a region of South Carolina's coast characterized by a diverse and complex nearshore morphology to determine the data density necessary to accurately represent beach and nearshore morphology in three dimensions. The resolution limitations of traditional beach profiles, where large sand volumes can be reflected as a few centimeter vertical change over large geographic footprints, present problems for accurate and effective evaluation of beach morphology and change. The relative complexity of the nearshore and intricacies in the interaction between beachface sediment supply and cross-shore sediment movement must be considered in sediment-starved coastal regions. The pilot survey included 10 shore-normal surveys spaced 150 m apart from the primary dune out to -8 m NAVD 88, 4 offshore shore-parallel profiles spaced 140 m apart, and 5 subaerial beach shore-parallel profiles spaced by slope breaks. Results indicated that the use of shore-normal data alone leads to significant interpolation artifacts, volumetric inaccuracies, and misrepresentation of true nearshore morphology. For example, in an offshore area between th 4 m and 6 m isobaths, there was an elevation discrepancy between all-data surface and shore-normal data surface of ~1 m. This elevation difference translated to a 15percent volumetric difference over the entire study area. The combined use of shore-parallel and shore-normal profiles significantly reduces modeling artifacts and provides overall better representation of three-dimensional surfaces and morphologic change.

A complementary analysis was performed to assess the field-based, time differential for improved surface representation. Approximately 1.85 as much time was required to collect the complete profile dataset as compared to cross-shore data only. The study included the suggestion that future surveys include all alongshore beach profiles, all cross-shore profiles, and a minimum of two nearshore alongshore profiles. In this compromise scenario, the survey time only increased 1.4 times.

4.3. Lessons Learned

It is important to note a fundamental difference between the Florida and South Carolina beach management programs: The Florida protocol is standardized such that it can be performed by any entity technically qualified to perform the work. The South Carolina program, on the other hand, is entity-specific and is carried out according to one research group's funding mechanism and timeline. Should any key personnel in the South Carolina group leave the system, the future of the program could be in doubt and various elements of the work could change. The program in Florida had the potential to be more stable but it might be more difficult to update the protocol with improved or new technologies.

To avoid redundancy in any monitoring effort, it is important to consider the scope and merits of external, existing efforts. This mandates improved communication and changes of information and data exchange. That being said, it is possible that existing programs will not be robust enough to document change on the scale of interest. This highlights the importance of an adaptive management approach that balances the study design, existing research efforts, and information needed or gained for each and across OCS target areas. It is worth mentioning that a wide-ranging suite of data from the growing network of coastal observing systems will be beneficial to studies of offshore mining and beach nourishment. For example, observed offshore wave conditions can be used as input for wave transformation models and related to shoreline change observed by the monitoring program.

5. X,Y,Z Monitoring

5.1. X,Y,Z Monitoring

A strong case for tracking shoreline and nearshore changes can be made when the is more than an academic or research exercise, but rather one that serves real and pragmatic purposes. In order to detect the changes, the implemented monitoring program must be adaptive, reflect the spatial and temporal scale of features of interest, and balance scientific need and project cost. It is important to remember this is *monitoring*. It makes sense for a monitoring protocol to specify collection of the minimum data necessary to evaluate the relative shoreline and nearshore change at each site, as compared to specifying the optimum or even average knowledge. Of course, in any system the more one knows the better, but it is most practical to define a protocol where the minimum provides enough information about a system to make decisions. It may be that tracking both the subaerial beach and subaqueous nearshore over the long term is necessary, or it may be that monitoring only the subaerial beach is necessary to gain the insight sought. In other words, a minimum is just that; an adaptive monitoring approach allows the freedom to collect data beyond the least needed.

In general, the procedures, techniques, and tools advanced in a widely implemented protocol should be sufficient for the conditions at each study site. More specifically, however, the adaptive nature of the protocol should be emphasized over standardization. The most substantial change is the recommendation for a detailed nearshore survey of the proposed affected area prior to the mining and construction phases, if one does not already exist. This will help in the design and performance evaluation, post-construction evaluation of system changes, as well as in the design of a site specific and project specific monitoring scheme. Thereafter, the only requirement is that physical monitoring produce x,y,z data. The profile data should be three dimensional, but not necessarily of refined spatial density. This requirement and that of metadata ensures that data are transferable among projects, among research agencies, among management organizations, and generally compatible with historical data.

5.2. Specific Minimum Standards

5.2.1. Methodology

The conceptual approach combining shoreline position surveys and subaerial beach / nearshore topographic surveys should provide adequate description of morphologic changes. Hobbs *et al.* (2002) specifically addressed the importance of monitoring the beach and nearshore to document shore change inshore of the borrowed site, also warning of the potential problems with modeling and predicting shore behavior using solely the change in shoreline position.

The monitoring protocol for the beach and nearshore regions initially should be thorough then it should be adaptive. We recommend an extensive 3 dimensional survey at the outset of a project with the collection of side-scan, bathymetry, and seismic subbottom data. Either swath or multibeam techniques are sufficient as long as the system provides data from a wide footprint. Thereafter the nearshore could be documented with depth-of-closure beach profiles spaced appropriately for the scale of the bottom features observed in the original survey. The efficiency, re-survey frequency, and subaerial beach coverage is maximized using RTK-GPS surveying equipment and complements data collected in profile and nearshore geophysical monitoring. Such a survey collects alongshore profiles at topographic reference features such as toe of dune, berm, high water line, etc.

Subaerial and subaqueous beach surveys should be performed as closely together in time as possible. The ultimate goal is synoptic and spatial overlap between the beach and nearshore surveys. Such an evaluation of the stratigraphy and morphology of a field site will allow the assessment of the framework and surficial geology and provide valuable baseline data for future comparison.

Ideally, the surveys required as part of a nourishment project's dredging and engineering activity, *i.e.* surveys required to determine dredged volume for payment or other specific compliance issues, should be wholly compatible with the monitoring surveys. At a minimum, the data collected for one activity should serve the other thereby eliminating the need for duplicate efforts.

5.2.2. Spatial Coverage

The draft protocol recommends that the minimum longshore length of the monitored area be ten times the width of the borrowed deposit projected on the shore. This recommendation was based on the work of Basco *et al.* (1999) that determined that the area of measurable impact of waves reaching the coastline in response to hypothetical removal of shoal offshore in Sandbridge was three times lateral extent of borrow area. The ten times requirement may not be necessary for every study site or for the duration of the monitoring program. Reducing the longshore dimension of the monitored area should lead to substantial cost savings over the recommended ten-year monitoring period. Numerical modeling of potential wave transformation and shoreline response conducted with the design criteria in hand could help better define this requirement for each area.

5.2.3. Consistent Datum Use and Conversions

A conversion between datums, especially vertical datums, only serves to introduce more error into a data analysis. Therefore it is beneficial to define geodetic, vertical, and horizontal datums at the outset of a project and make it mandatory for all data to be collected using those datums. Consistent use of unit systems (metric or English) is also recommended. The National Research Council (2004) makes a series of recommendations related to mapping and charting in the coastal zone and shoreline monitoring programs should be designed with the knowledge of these recommendations. Local engineering and regulatory practices might require use of traditional English units and of the state plane coordinate system. State plane coordinate systems, while providing a very useful and convenient rectilinear system for presenting the data, are problematical in that with the exception of some transit or total station surveys, the original data usually are collected in some other format then converted, perhaps internally, to state plane such that even when the original data display is in state plane, some hidden conversion was applied.

5.2.4. Spatial Density

Profiles should be representative of littoral cells, and the profiles should be representative of conditions on both sides of the profile lines. Grosskopf and Kraus (1994) reported that 1000 ft (~300 m) spacing provides adequate resolution for most open-coast projects characterized by an uncomplicated shoreline and nearshore. However, the authors also indicated that areas characterized by unique morphology or trends, closer spacing, less than 500 ft, may be warranted. Line spacing is a function of the size of features we are interested in capturing. Once again, this is something that is brought to light in the initial 3-D survey. Once the scales of particular features of interest are established, the line spacing should be designed to resolve these features.

The length of the profile, point spacing, and tie lines (shore parallel surveys) also need to be considered.

- Length: The cross-shore range required for a survey is site specific and should reflect the active processes. Ideally, profiles should extend across the entire active zone of sediment transport (Grosskopf and Kraus, 1994; Weggel, 1995) to determine the nature of onshore-offshore transport. Profiles extending only to wading depth limit the usefulness for evaluating sand movement between the nearshore and subaerial beach. Offshore bathymetric and geophysical surveys should overlap with the extended portion of the subaerial beach surveys.

- Point Spacing: Data density along profiles should be adequate to define slope changes, subaerial beach reference features, and prominent morphologic features. Grosskopf and Kraus (1994) recommend a maximum increment of 20 ft along the profile landward of the most offshore bar and 40 ft seaward of the bar.

- Alongshore Profiles: Longshore profiles may be warranted where the coast is characterized by a complicated shoreline and nearshore. If the region is very 2-D then cross-shore profiles alone might be sufficient. In the large majority of cases, however, this is not the case. Bernstein *et al.* (2003) demonstrated that collecting only shore-normal profiles can lead to interpolation artifacts and typically yields a poor representation of morphology.

5.2.5. Survey Frequency and Length

Survey frequency is a function of the local meteorology and the dynamics of the beach and nearshore. At a minimum, twice yearly surveys should be conducted, given the natural transition between summer and winter beach profiles. In general, larger morphological features have slower response times and vice versa (Plant *et al.*, 2002), so the spatial scales of the features of interest will play a role in determining the frequency of sampling necessary.

Ideally, monitoring should take place at least immediately after, 6 months after, and 1 year after construction. Grosskopf and Kraus (1994) recommend surveys twice a year at the outset, typically at the end of summer and end of winter to reflect seasonal changes. After several years, the survey frequency should reflect the trends of early monitoring. Stauble and Grosskopf (1993) document the value of monitoring the response of the shoreline and nearshore of the nourished beach in Ocean City, Maryland to storms. If funding is available, monitoring following events characterized by significant wave energy should be considered. This might include surveys immediately before (given sufficient forecast lead time) and immediately after the storm, and at a somewhat later date to record the recovery of the beach.

The determination of a 10-year monitoring period is arbitrary; it makes more sense that monitoring be terminated at the time no continuing changes or impacts are observed. However, in instances where the mining site is adjacent to the beach being nourished and re-nourishment takes place frequently (as is the case at Sandbridge), the primary signal might be associated with the profile equilibration process and make detection of the effects of mining difficult.

5.2.6. Deliverables

At a bare minimum, survey data need to be available electronically in x,y,z format, with metadata, so that data exchange and use are made routine. Any additional information (maps, graphs, etc.) should be provided in a common graphical format so that proprietary software is not required for viewing.

5.3. Complementary Monitoring

Provided additional available funding for a project, supplementary monitoring such as chirp seismic, side scan (after the initial survey), lidar (Mitasova *et al.*, 2003), aerial photography, and video monitoring (Elko *et al.*, 2005) can be highly insightful. Such was the case with the repeat seismic and side scan surveys used in this study. Certain variables that had not been considered previously and which influence the locale’s shoreline behavior at a magnitude comparable to the proposed mining were brought to light. Specifically, shore-oblique sandbars and gravel outcrops in the nearshore appear to be associated with areas of shoreline erosion. Further, these morphological features are closely associated with paleo-channels preserved in the framework geology. Identification of factors that might be responsible for increased beach erosion apart from mining and nourishment is crucial (See Appendix B for more details on these findings.)

Repeat side scan surveys can track the heterogeneity of sediment in the nearshore. Variable sediment characteristics directly influence sediment transport in the bottom boundary layer and are now being incorporated in more complex modeling efforts. Recent studies have shown that such heterogeneity can create a partitioning effect, whereby turbulent eddies from over coarse sediment and inhibit settling, ultimately leading to morphologic heterogeneity (Green *et al.*, 2004; Murray and Thieler, 2004; Trembanis *et al.*, 2004). Morphologic heterogeneity can directly influence hydrodynamics and in turn, shoreline behavior. Further, heterogeneous sediments seen in the side scan record may be indicative of first-order control by the underlying geology.

Subsequent sub-bottom studies also may information on the spatial variability of the underlying geology. While it is true that current sediment-transport models have not yet succeeded in incorporating framework geology in any relevant fashion, that level of complexity in modeling is certainly on the horizon. The minimal extra effort required to deploy a sub-bottom prifiling system is bound to be worth the potential pay-off, as the role of framework geology in nearshore processes continues to prove more important than once thought (Belknap and Kraft, 1985; Pilkey *et al.*, 1993; Riggs *et al.*, 1995). Moreover, recent work suggests that nearshore sediment volume, as calculated to a specific stratigraphic layer in the framework geology, is highly correlated to decadal shoreline change such that low sediment volumes seem to indicate regions of shoreline erosion (Miselis and McNinch, in review). In this study, nearshore sediment volume is the total amount of sediment between the seafloor and the specific stratigraphic contact interpreted from high-resolution seismic data. The baseline is not drawn from "depth of closure" to the shoreline making this very different from conventional calculations of sediment volume. By considering framework geology (stratigraphic contact) and hydrodynamic processes (seafloor surface variations) simultaneously, nearshore sediment volume better represents the geologic characteristics of the coastal region and may be a useful parameter for improving the predictive capability of shoreline and nearshore change models.

5.4. Lessons Learned

To illustrate the adaptive approach we advocate, we turn again to the Sandbridge Beach region. The initial 3-D survey highlighted distinct areas of spatial heterogeneity separated by long reaches of convex nearshore. Subsequent nearshore surveys, via beach profiling, would be designed to maximize coverage of the complex areas and minimize data collection in the areas of little apparent variability. At a minimum, this would entail 150 m spacing of profile lines and hydrographic surveys to depth-of-closure in the bar - outcrop regions and perhaps 300 m spacing in the more stable areas. Granted this designation of complex areas is based on the tenuous assumption of stability, an assumption that can be fortified with repeat surveys, or information from the literature or framework geology.

Ultimately, the beach and nearshore monitoring protocol should be dynamic. It should be dependent on the scale of features identified in the initial survey and current technologies—what needs to remain constant are the questions asked and the spatial and temporal scales on which the changes are then evaluated.

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APPENDIX A:
History of Beach Topographic Surveys at Virginia Beach

Many research and government agencies have been involved in the study and documentation of the southeastern Virginia coast, most notably the U.S. Army Corps of Engineers, the Virginia Institute of Marine Science, Old Dominion University, City of Virginia Beach Bureau of Surveys and Mapping, U.S. Naval Fleet Anti-Air Warfare Training Center at Dam Neck, and several local consulting firms, including Glenn and Sadler, Langley and McDonald, Waterway Surveys and Engineering, and Beach Consultants.

Everts et al (1983), Dolan (1985), Wright *et al.* (1987), Basco (1991), and Hobbs *et al.* (1999) provided detailed analyses of shoreline change rates in the study area. Bullock (1971), Goldsmith *et al.* (1974), Goldsmith (1975), Goldsmith et al (1977), Hardaway and Thomas (1990), Basco *et al.* (1997), Hardaway *et al.* (1998), and Hobbs *et al.* (1999) reported on beach profile surveys along various portions of the Sandbridge reach.

Detailed studies of beach changes along the Atlantic coast of Virginia actually date from the 1950s. Harrison and Wagner (1964) measured monthly, weekly, and daily changes at four locations in northern Virginia Beach. These profiles, immediately south of Rudee Inlet north to Sea Shore State Park, were measured intermittently between November 1956 and May 1963. The U.S. Army Corps of Engineers Norfolk District also collected beach profile data in the resort area of Virginia Beach from January 1954 through September 1975 (Goldsmith, 1975).

Bullock (1971) made the first detailed study in the vicinity of Sandbridge Beach and Dam Neck occurred. He monitored sixteen beach transects along the coast of Virginia monthly for a period of 20 months from July 1969 to March 1971 to determine the feasibility of developing a system to forecast changes in beach sand volume resulting from storm conditions. Three profiles (11, 12, and 13) were surveyed in the vicinity of Sandbridge, with profile 13 located at the northern boundary of Back Bay National Wildlife Refuge. Researchers at the Virginia Institute of Marine Science monitored beach profiles over a stretch of coast between Rudee Inlet and the Virginia-North Carolina border at bi-monthly intervals from September 1972 through January 1974 (Goldsmith *et al.*, 1974) and occupied two of the Sandbridge-reach profile lines monitored by Bullock (1971).

From September 1974 to December 1976, the Virginia Institute of Marine Science and U.S. Army Corps of Engineers Coastal Engineering Research Center (CERC) coordinated a robust beach survey program of eighteen profiles within the Virginia Beach Coastal Compartment (Goldsmith et al., 1977). Many of these profile locations reoccupied older profile locations. This study investigated beach behavior for 27 consecutive months; beach profile surveys were completed monthly and after eight significant storms or wave events. Each profile line included measurements at significant breaks in slope and was extended as far seaward of mean sea level as possible. Three profiles (6, 7, and 8) were located at Dam Neck in the vicinity of the U.S. Naval Anti-Air Warfare Training Center. Profile lines 9 and 10 were located in Sandbridge, and profile line 11 was near the northern boundary of Back Bay National Wildlife Refuge. Profile lines 7, 8, 9, and 10 occupied historic profile lines. Profile lines 8 and 10 correspond to Bullock's profiles 12 and 13 respectively; profiles 7-10 reoccupied those of Goldsmith et al. (1974).

Between 1980 and 1996, City of Virginia Beach Department of Public Works routinely surveyed over 37 miles of ocean and bay shoreline at 29 ocean coast locations. The work included dune and beach surveys to MLW. Prior to 1987, surveys were made quarterly (*i.e*. spring, summer, fall, and winter). At least two times per year, select profiles were run offshore to approximately 25 feet below mean sea level (MSL). After 1987, the frequency of surveying varied significantly. The survey methods included transit and stadia for the beach and dune portions of the profile and fathometer and sled for the offshore segment. Between 1996 - 2000, VIMS Shoreline Studies Program reset and reoccupied several profile locations and converted and edited earlier profile data to convert them to a common horizontal datum. Beginning in 1993, VIMS began a regular program of archiving beach profile data, including data provided by the City of Virginia Beach. The original City of Virginia Beach profile numbering scheme was developed using historic profiles established by VIMS researchers in the early 1970s (Goldsmith *et al.*). VIMS modified the profile numbering system for ease of use. The Virginia Institute of Marine Science now maintains a database of beach profiles (Milligan *et al.*, 1993, 1995, 1996, 1997, 1998). The profile data are archived in Interactive Survey Reduction Program (ISRP) format, a proprietary program written and distributed by the U.S. Army Corps of Engineers. Nine City of Virginia Beach profiles, numbers 45 to 57, provide excellent reference for the study area. These long-term profiles are located in Sandbridge. Profile 49 is located at the Dam Neck-Sandbridge fence line. Profile 50 is located north of Sandbridge Road; profiles 51, 52, 53, and 54 are located south of Sandbridge Road. Profile 55 is located at the turn in Sandfiddler Road and Profile 56 is located between profile 55 and Little Island State Park. Profile 57 is located in Little Island Park.

Between October 1988 and September 1989, the Sandbridge Bulkhead Impact Study was conducted by the Virginia Institute of Marine Science to access the effects of bulkhead installation on the subaerial beach. Fifteen beach profiles between Pikes Lane and White Cap Lane, a reach characterized by chronic erosion, were surveyed on 18 different occasions. These profiles were run normal to a Sandfiddler Road baseline out to MLW using stadia and level. The profiles were collected to represent three conditions: bulkheaded shoreline, adjacent to bulkheaded shoreline, and non-bulkheaded shoreline. During the study period, all fifteen profiles were affected either by bulkhead construction or bulldozing. Hardaway *et al.* (1990) identified a seasonal thinning of backshore beach width in front of bulkheads. Beach scour and deflation generally were observed in front of and adjacent to bulkheads after significant storms.

Langley and McDonald, PC surveyed 26 beach profiles in September 1988 and March 1989 as part of the environmental assessment for Sandbridge Beach, Virginia Beach (USACE Norfolk District, 1992). These profiles, coupled with offshore bathymetric surveys performed by Waterway Surveys and Engineering, Ltd (Waterway Surveys and Engineering, Ltd, 1986), were used to develop fill volumes for three beach nourishment plans.

The Coastal Engineering Center, Old Dominion University (ODU) surveyed the Sandbridge Beach shoreline monthly and post-storm for nine years from 1990 to 1999 in part to determine the impact of seawalls on erosional trends (Basco et al., 1997). The dataset consists of 28 profiles irregularly spaced at seawall and dune locations along the shoreline. The profiles extend from the middle of Sandfiddler Road to approximately MLW. Thirteen profiles were sites with at sea walls, 11 at dune locations, and four were located at the ends of seawalls. Each profile was numbered by the distance in hundreds of feet south of the Dam Neck-Sandbridge property boundary. The study found that volumetric erosion rates were not higher in front of sea walls and furthermore walled and non-walled beaches recovered at the roughly the same rate after seasonal transitions and significant erosional events. Basco noted that the seasonal variability of sand volume in front of sea walls was greater than at non-walled locations and that erosion rates increased at unprotected beach segments immediately adjacent to sea walls.

In November 1966, approximately 760,000 m^3 of sand from Sandbridge Shoal was pumped onto the beach at the Naval Fleet Anti-Air Warfare Training Center, Dam Neck, immediately north of Sandbridge Beach. Detailed beach monitoring of this location was done for the pre-fill condition (June/July 1995, August 1996). Eight times over three years beginning in November 1996, Glenn and Sadler conducted a beach monitoring study to evaluate the performance of the dune and beach nourishment project. The monitoring system included 17 nearshore profiles spaced approximately 1000 feet apart, starting behind the rebuilt or natural dunes and extending approximately 2000 feet offshore to about 22 feet below MSL (1929 NGVD).

In fall 1985, Waterway Surveys and Engineering, Ltd. surveyed 28 profile lines as part of the coastal engineering design study for the placement of dredged sand on Sandbridge beach (Waterway Surveys & Engineering, 1986). A hydrographic survey out to -30 ft NGVD was also completed. In 1988, Waterway Surveys and Engineering also performed beach surveys before and after the beach fill at Sandbridge (Rebecca Francese, personal communication). In addition, a survey was made after Hurricane Bonnie brushed Virginia on August 27-28, 1998. However, these profiles were not surveyed from the same benchmarks as the City's profiles. Beginning in 1998, Waterway Surveys and Engineering, Ltd. commenced a robust beach monitoring program of over 50 profile locations along the Sandbridge reach. This program is charged with monitoring shoreline change coincident with the second significant beach nourishment project since 1998. Beach profiles at 500-foot intervals are measured from Little Island Park north to Dam Neck along a baseline set by Waterways. Profiles are measured from baseline locations out to wading depth or to a depth of approximately – 7 ft NGVD.

Shoreline position, large-scale coastal behavior, and beach and nearshore topographic changes have been monitored using new airborne scanning laser technology (Stockdon *et al.*, 2002). During the fall of each year from 1996 to1999, Airborne Topographic Mapper LIDAR (Light and Detection and Ranging) data were collected from Cape Henry south to False Cape in southeast Virginia by Airborne LIDAR Assessment of Coast Erosion. The NASA Wallops Flight Facility and the U. S. Geological Survey (USGS) Center for Coastal and Regional Marine Geology also performed pre-and-post LIDAR surveys for southeast Virginia in an effort to assess coastal changes incident with landfall of Hurricane Isabel in September 2003. NASA Experimental Advanced Airborne Research LIDAR (EAARL) data were unavailable due to unresolved problems with the dataset (Sallenger, personal communication, 2004).

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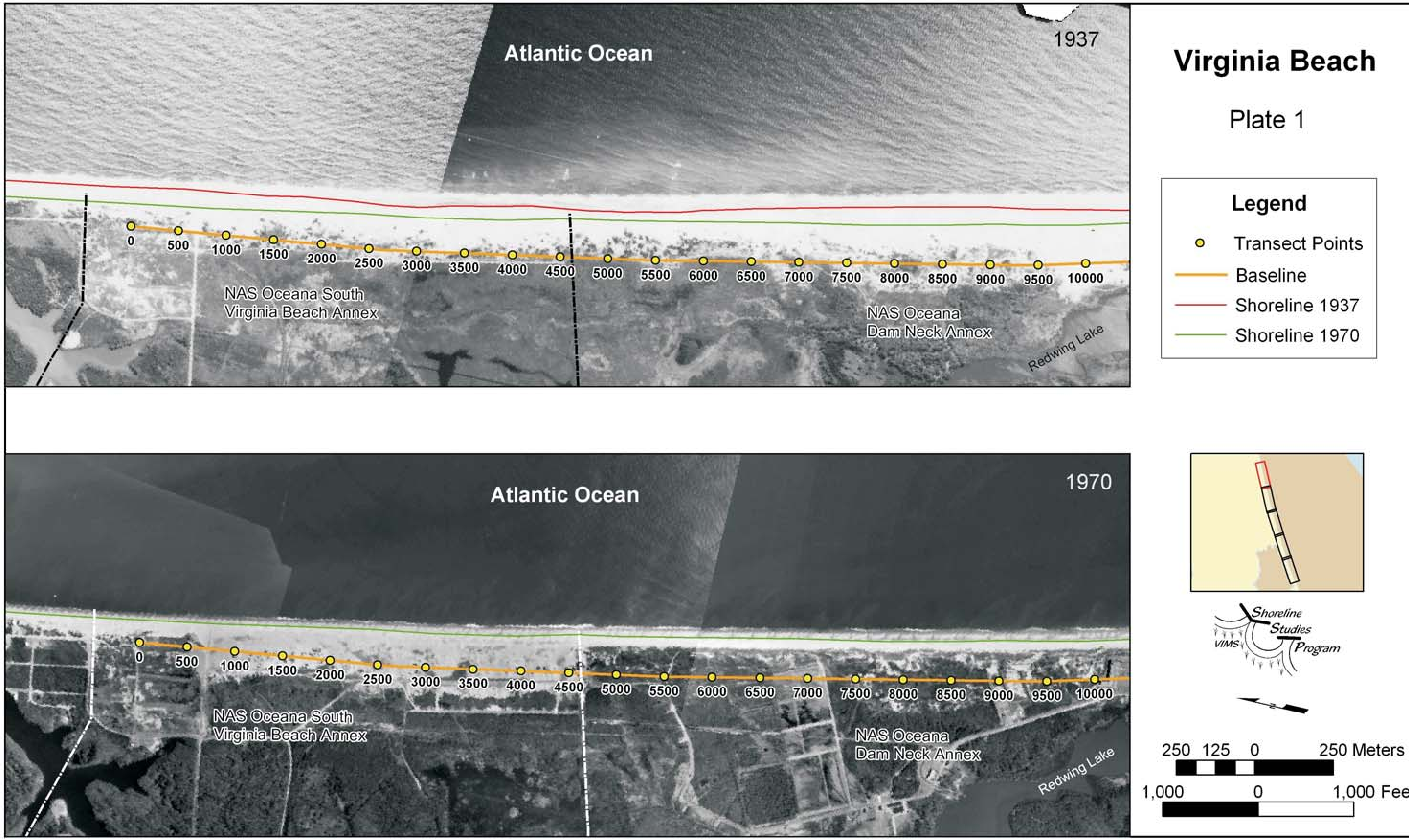
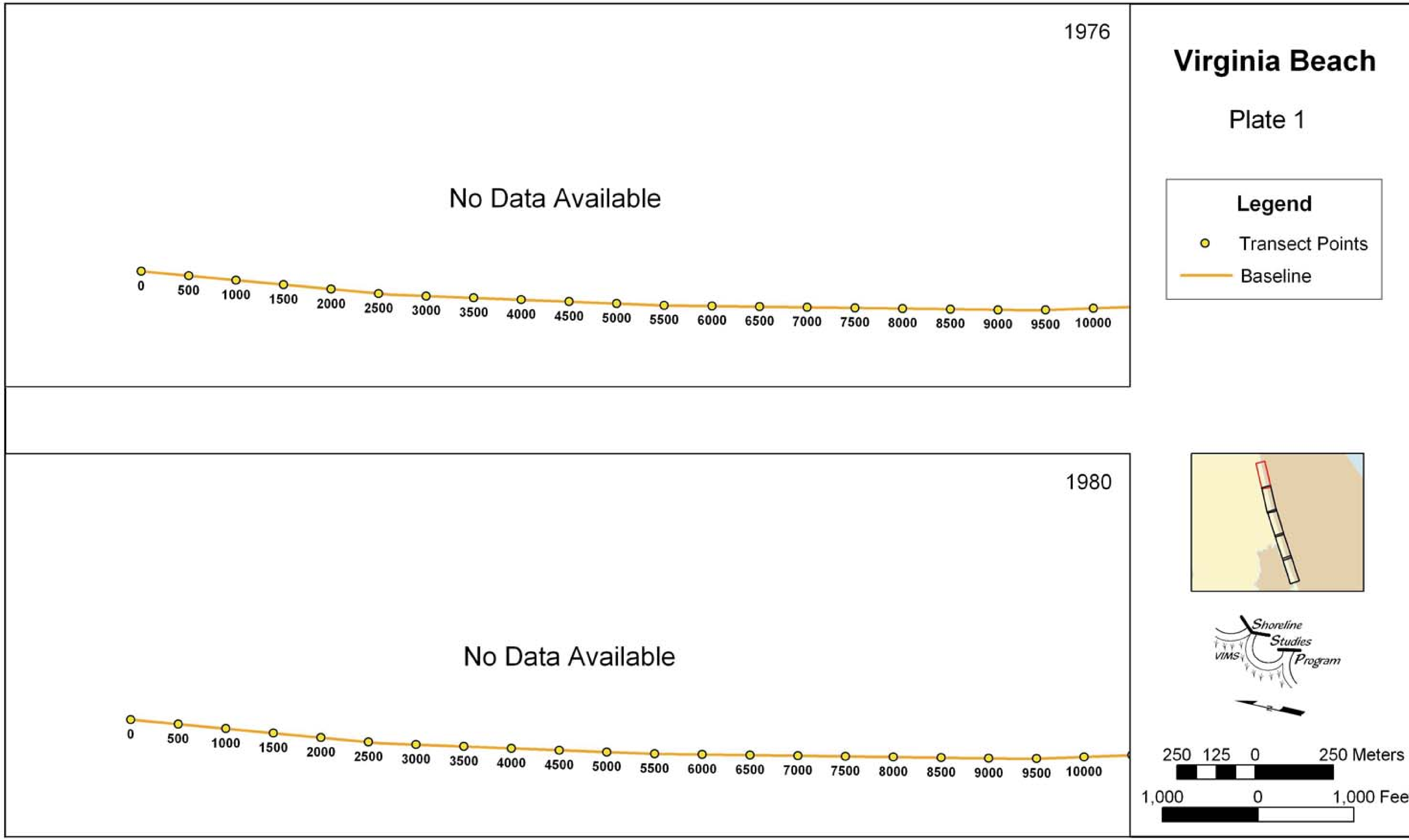
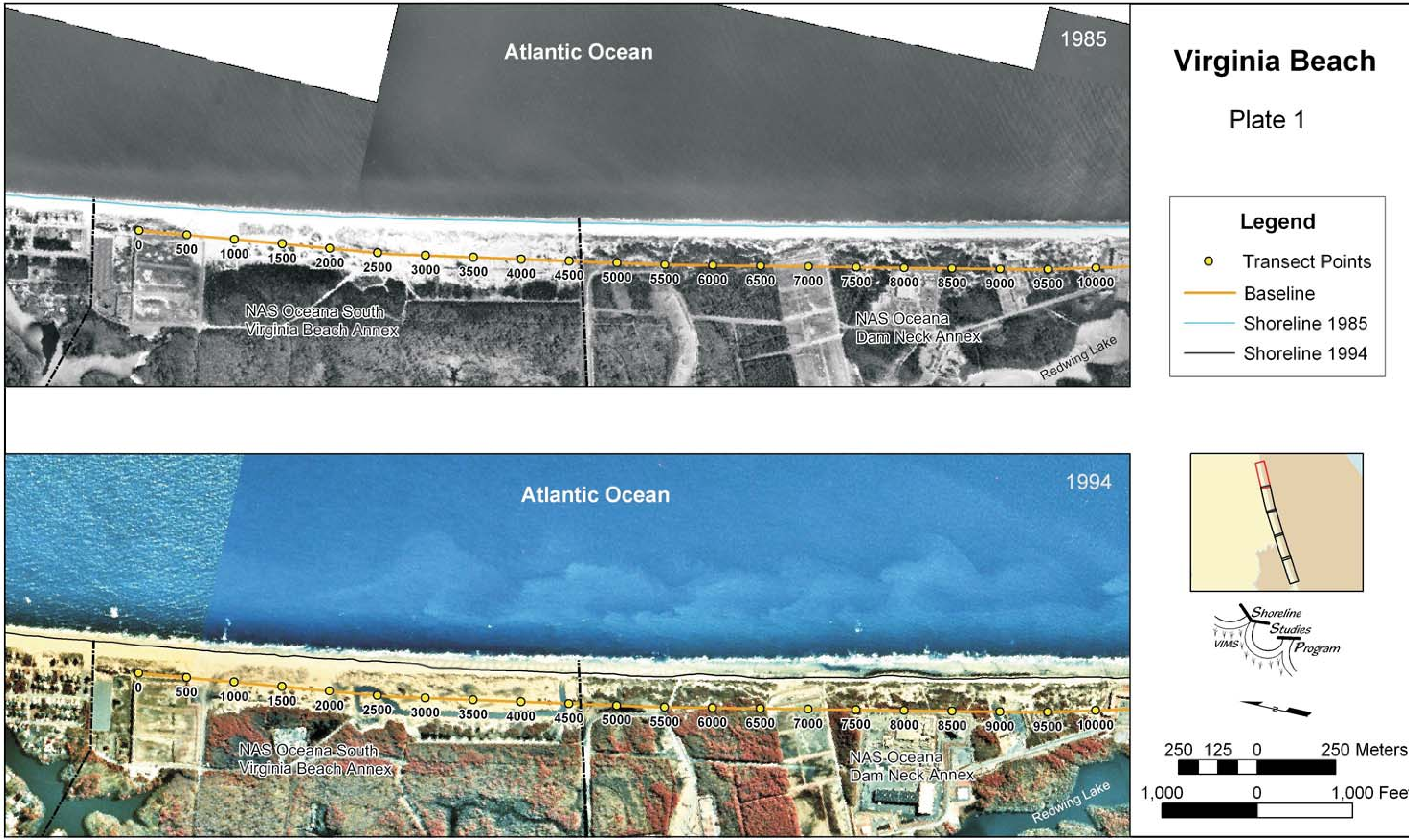
APPENDIX B: Historic and Recent Shore Position Maps


Virginia Beach
Plate 1
Atlantic Ocean
1937
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
NAS Oceana South Virginia Beach Annex
NAS Oceana Dam Neck Annex
Redwing Lake
Atlantic Ocean
1970
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
NAS Oceana South Virginia Beach Annex
NAS Oceana Dam Neck Annex
Redwing Lake
Legend
Transect Points
Baseline
Shoreline 1937
Shoreline 1970
Shoreline Studies Program
VIMS
250 125 0 250 Meters
1,000 0 1,000 Feet


Virginia Beach
Plate 1
Legend
Transect Points
Baseline
1976
No Data Available
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000 9500 10000
1980
No Data Available
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000 9500 10000
Shoreline Studies Program
VIMS
250 125 0 250 Meters
1,000 0 1,000 Feet



Virginia Beach
Plate 1
1985
Atlantic Ocean
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
NAS Oceana South
Virginia Beach Annex
NAS Oceana
Dam Neck Annex
Redwing Lake
1994
Atlantic Ocean
NAS Oceana South
Virginia Beach Annex
NAS Oceana
Dam Neck Annex
Redwing Lake
Legend
Transect Points
Baseline
Shoreline 1985
Shoreline 1994
Shoreline Studies Program
VIMS
250 125 0 250 Meters
1,000 0 1,000 Feet

Virginia Beach

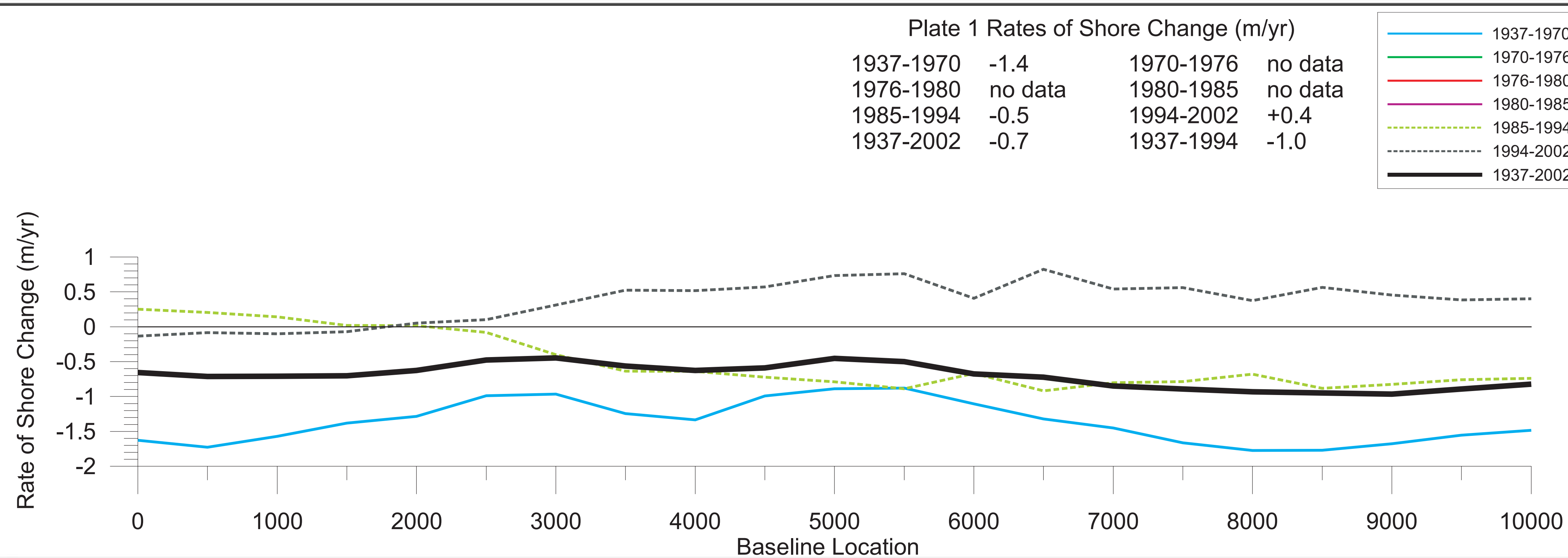
Plate 1

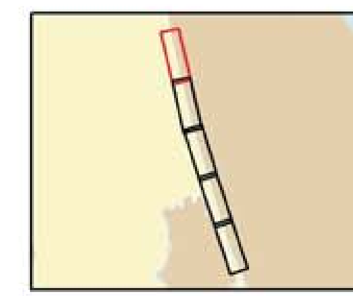
Legend

- Transect Points
- Baseline
- Shoreline 1937
- Shoreline 1970
- Shoreline 1985
- Shoreline 1994
- Shoreline 2002

Plate 1 Rates of Shore Change (m/yr)

1937-1970	-1.4	1970-1976	no data
1976-1980	no data	1980-1985	no data
1985-1994	-0.5	1994-2002	+0.4
1937-2002	-0.7	1937-1994	-1.0

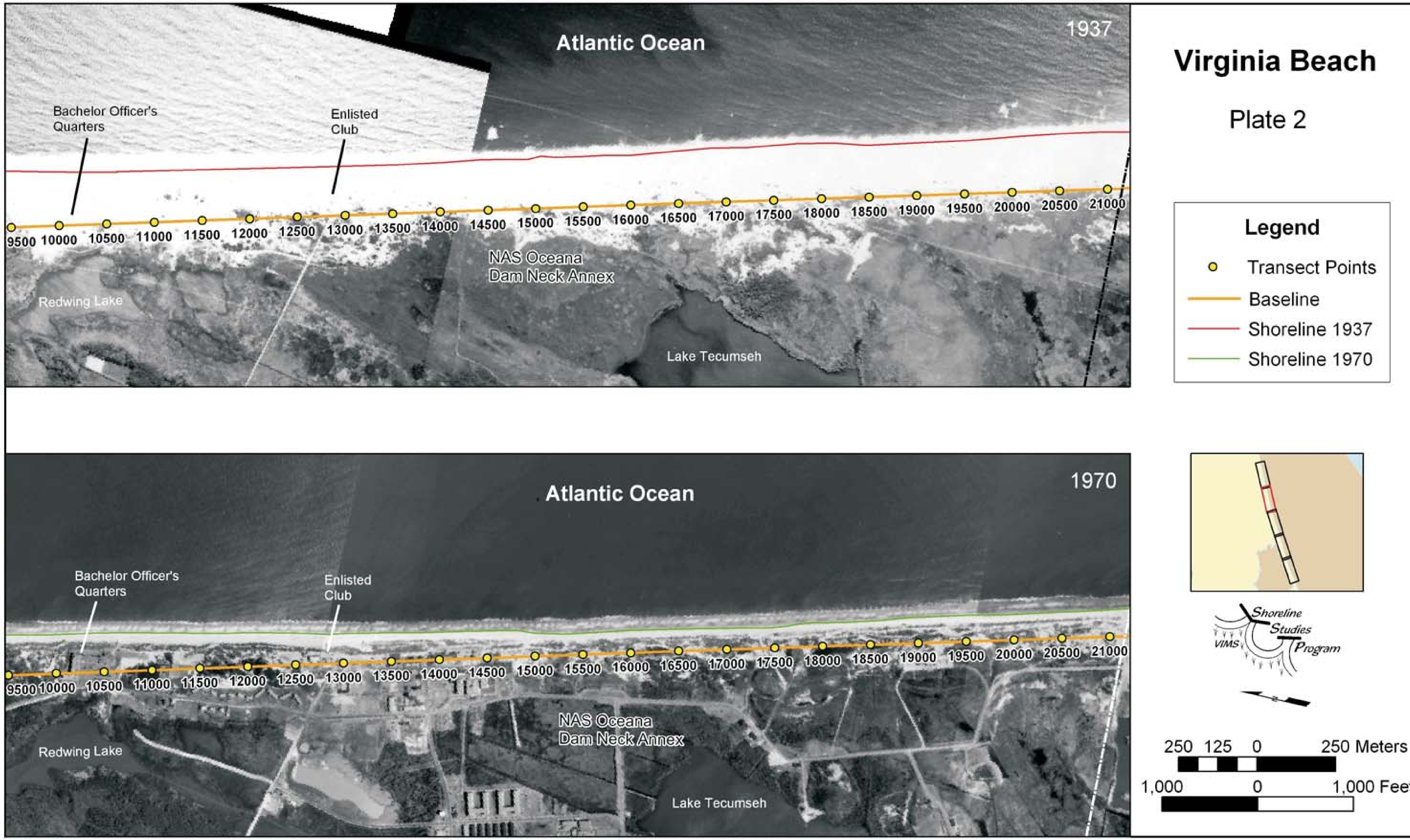


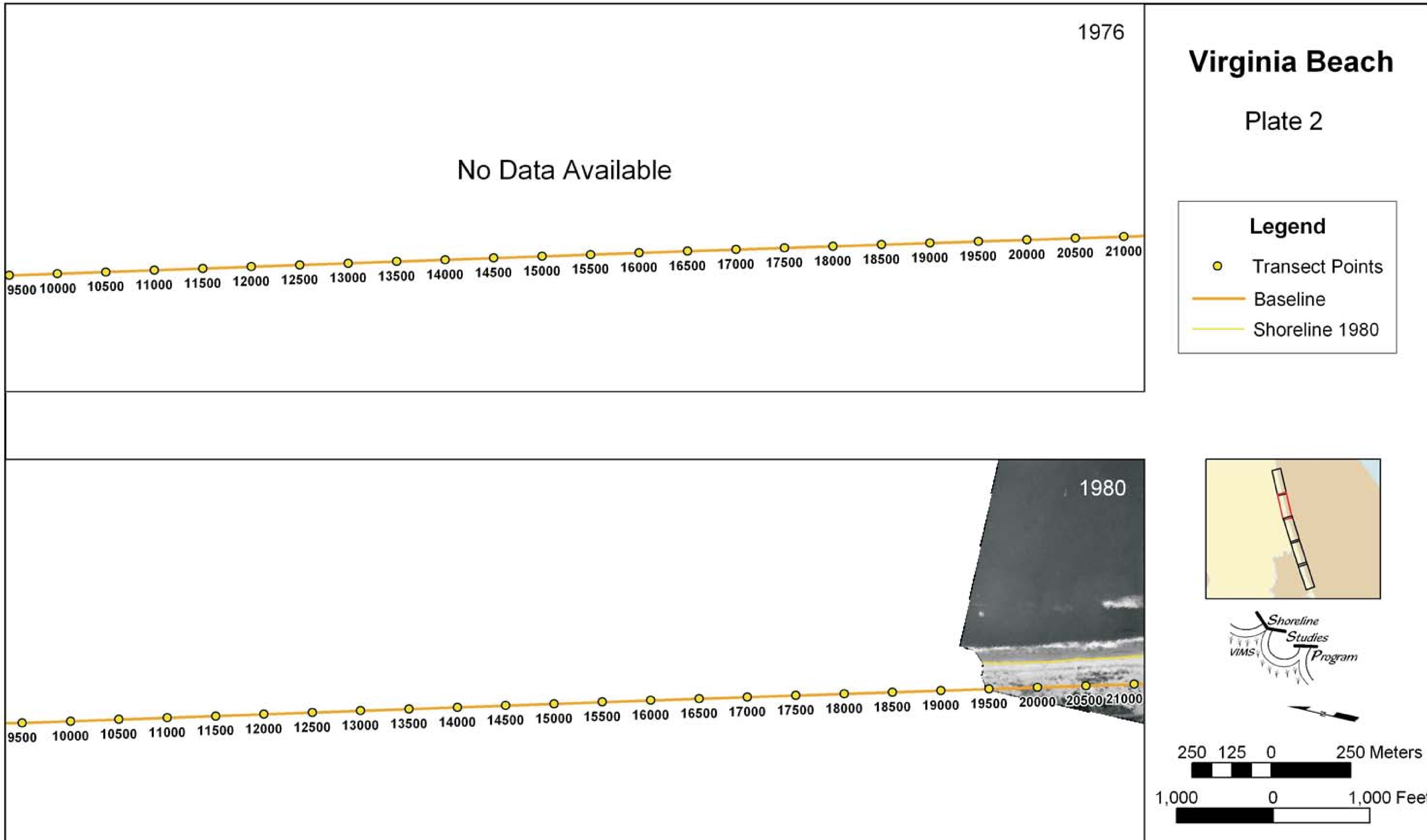


Shoreline Studies Program
VIMS

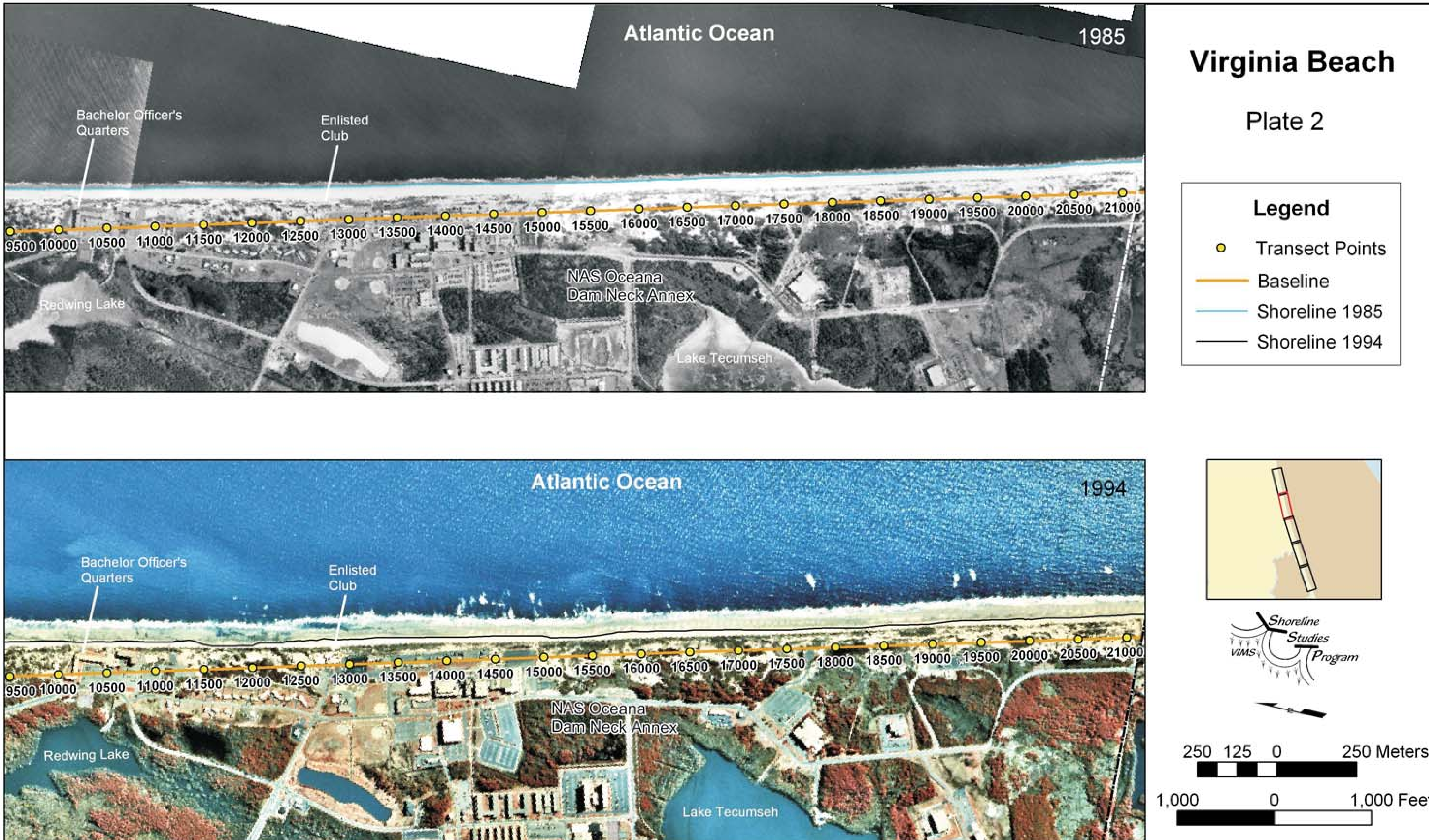
250 125 0 250 Meters

1,000 0 1,000 Feet

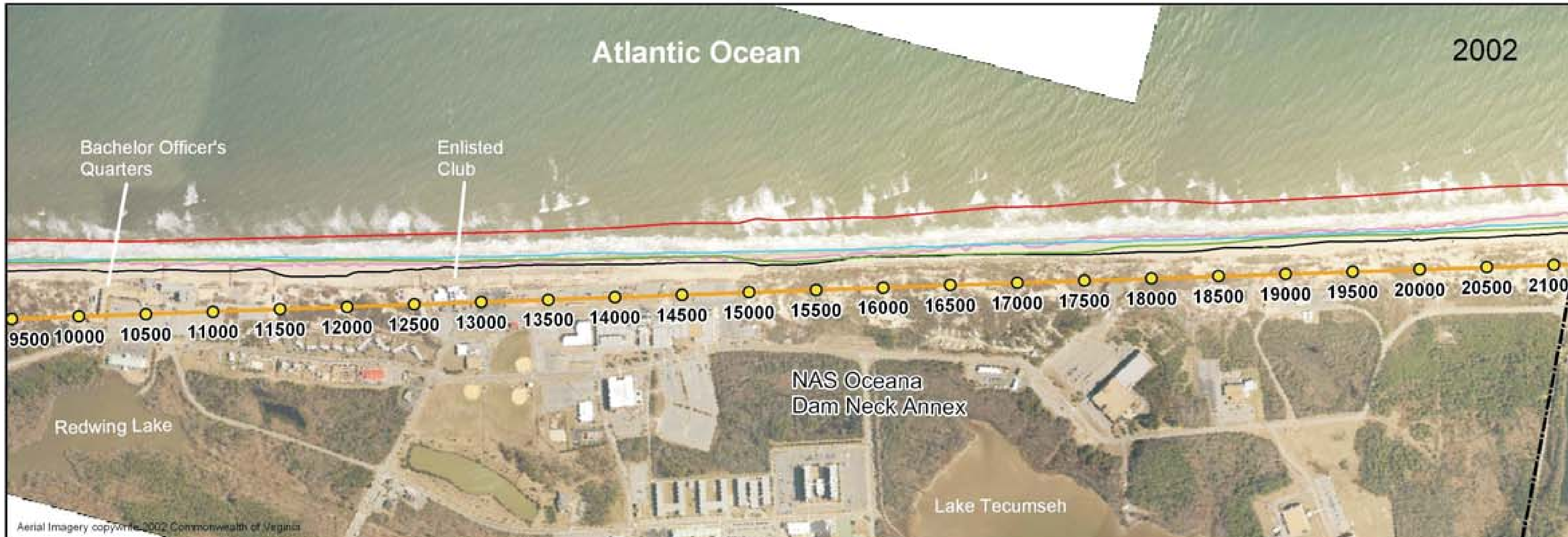

Virginia Beach
Plate 2
1937
Atlantic Ocean
Bachelor Officer's Quarters
Enlisted Club
NAS Oceana Dam Neck Annex
Redwing Lake
Lake Tecumseh
9500 10000 10500 11000 11500 12000 12500 13000 13500 14000 14500 15000 15500 16000 16500 17000 17500 18000 18500 19000 19500 20000 20500 21000
1970
Atlantic Ocean
Bachelor Officer's Quarters
Enlisted Club
NAS Oceana Dam Neck Annex
Redwing Lake
Lake Tecumseh
9500 10000 10500 11000 11500 12000 12500 13000 13500 14000 14500 15000 15500 16000 16500 17000 17500 18000 18500 19000 19500 20000 20500 21000
Legend
Transect Points
Baseline
Shoreline 1937
Shoreline 1970
Shoreline Studies Program
VIMS
250 125 0 250 Meters
1,000 0 1,000 Feet



1976
No Data Available
9500
10000
10500
11000
11500
12000
12500
13000
13500
14000
14500
15000
15500
16000
16500
17000
17500
18000
18500
19000
19500
20000
20500
21000
1980
Virginia Beach
Plate 2
Legend
Transect Points
Baseline
Shoreline 1980
Shoreline Studies Program
VIMS
250 125 0 250 Meters
1,000 0 1,000 Feet



Virginia Beach
Plate 2
Atlantic Ocean
1985
Bachelor Officer's Quarters
Enlisted Club
9500 10000 10500 11000 11500 12000 12500 13000 13500 14000 14500 15000 15500 16000 16500 17000 17500 18000 18500 19000 19500 20000 20500 21000
NAS Oceana Dam Neck Annex
Redwing Lake
Lake Tecumseh
Atlantic Ocean
1994
Bachelor Officer's Quarters
Enlisted Club
9500 10000 10500 11000 11500 12000 12500 13000 13500 14000 14500 15000 15500 16000 16500 17000 17500 18000 18500 19000 19500 20000 20500 21000
NAS Oceana Dam Neck Annex
Redwing Lake
Lake Tecumseh
Legend
Transect Points
Baseline
Shoreline 1985
Shoreline 1994
VIMS Shoreline Studies Program
250 125 0 250 Meters
1,000 0 1,000 Feet



Virginia Beach

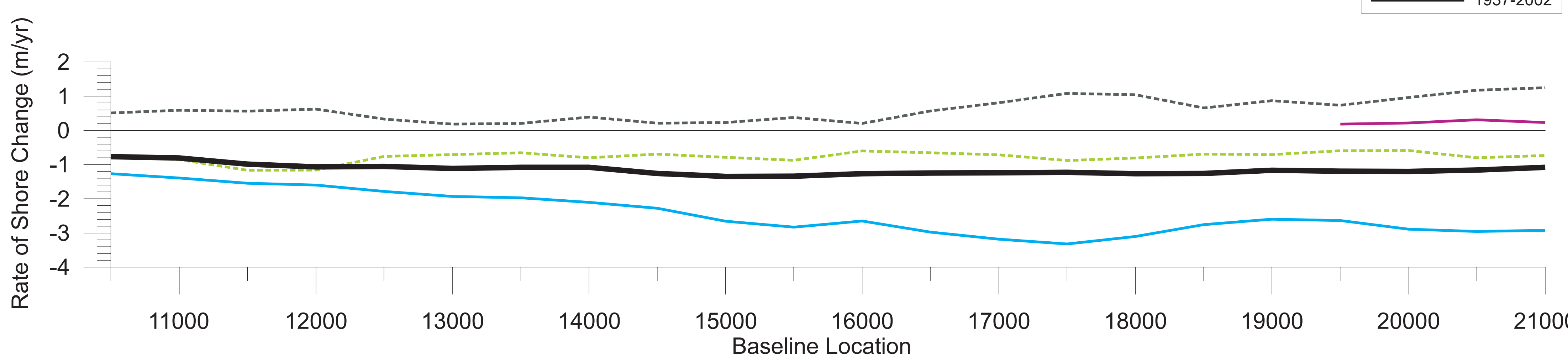
Plate 2

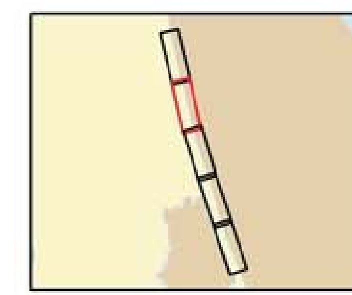
Legend

- Transect Points
- Baseline
- Shoreline 1937
- Shoreline 1970
- Shoreline 1985
- Shoreline 1994
- Shoreline 2002

Plate 2 Rates of Shore Change (m/yr)

1937-1970	-2.4	1970-1976	no data
1976-1980	no data	1980-1985	+0.2
1985-1994	-0.8	1994-2002	+0.6
1937-2002	-1.1	1937-1994	-1.7

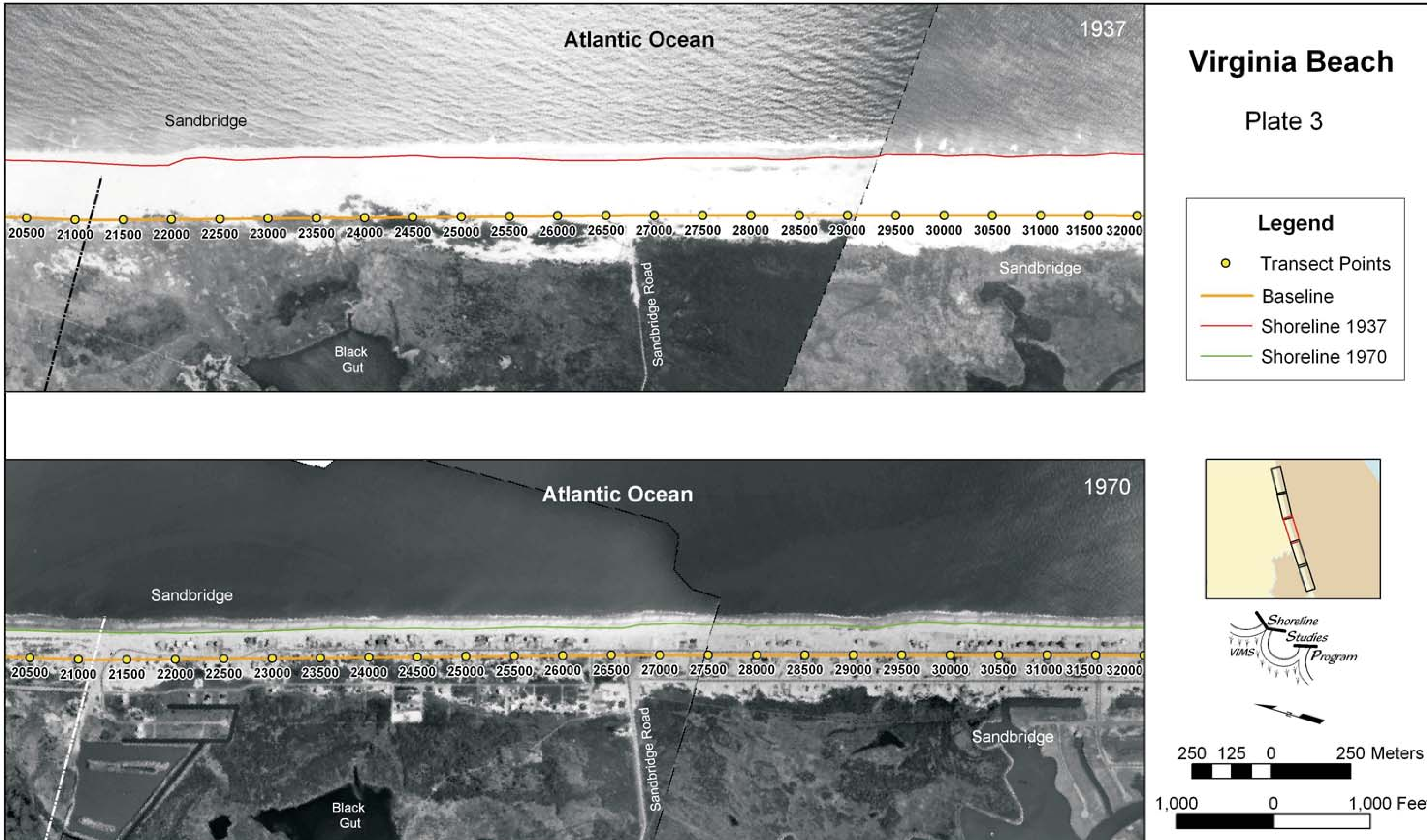


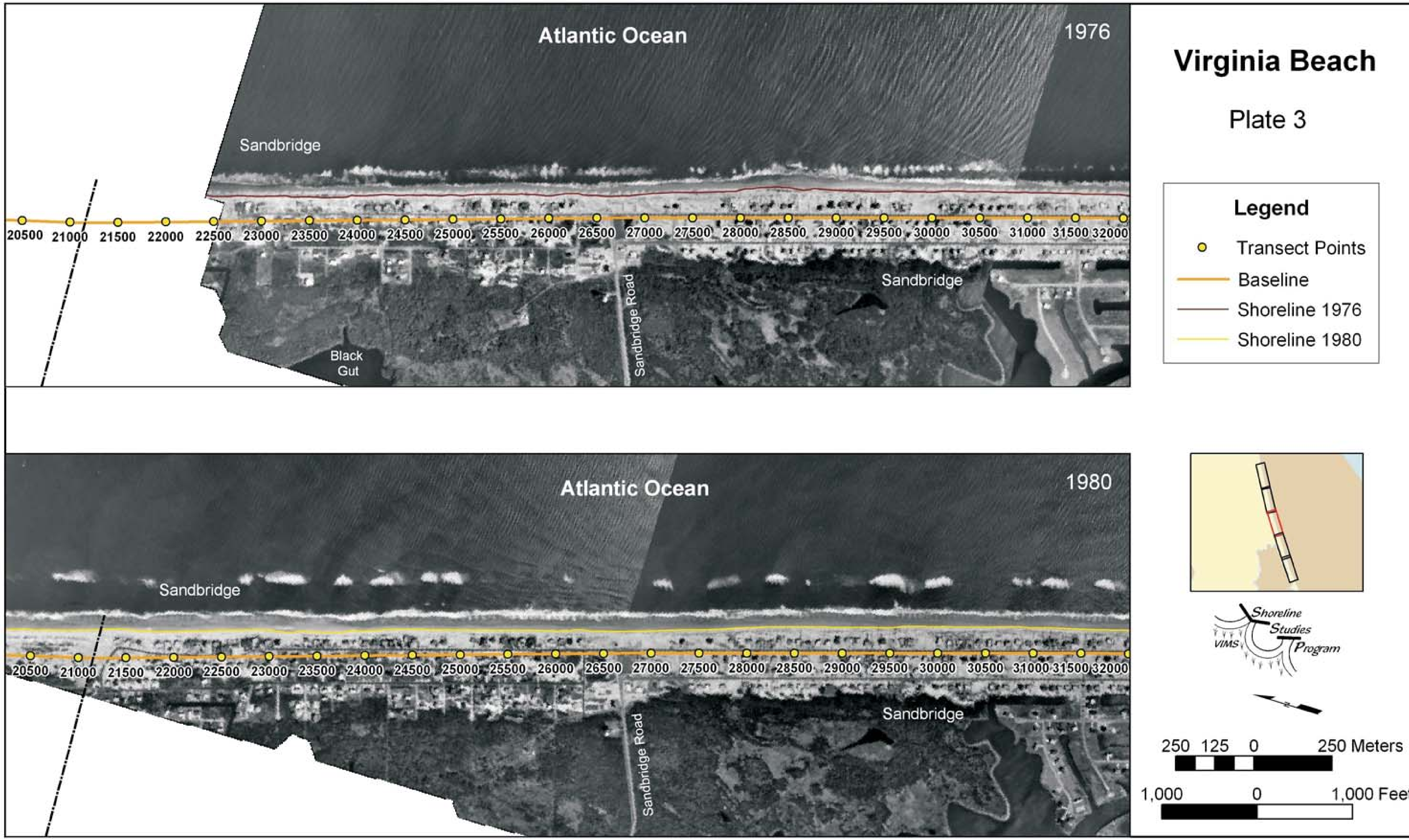


Shoreline Studies Program
VIMS

250 125 0 250 Meters

1,000 0 1,000 Feet


Virginia Beach
Plate 3
Atlantic Ocean
1937
Sandbridge
20500 21000 21500 22000 22500 23000 23500 24000 24500 25000 25500 26000 26500 27000 27500 28000 28500 29000 29500 30000 30500 31000 31500 32000
Sandbridge Road
Black Gut
Sandbridge
Atlantic Ocean
1970
Sandbridge
20500 21000 21500 22000 22500 23000 23500 24000 24500 25000 25500 26000 26500 27000 27500 28000 28500 29000 29500 30000 30500 31000 31500 32000
Sandbridge Road
Black Gut
Sandbridge
Legend
Transect Points
Baseline
Shoreline 1937
Shoreline 1970
Shoreline Studies Program
VIMS
250 125 0 250 Meters
1,000 0 1,000 Feet


Virginia Beach
Plate 3
Atlantic Ocean
1976
Sandbridge
20500 21000 21500 22000 22500 23000 23500 24000 24500 25000 25500 26000 26500 27000 27500 28000 28500 29000 29500 30000 30500 31000 31500 32000
Sandbridge
Sandbridge Road
Black Gut
Legend
Transect Points
Baseline
Shoreline 1976
Shoreline 1980
Atlantic Ocean
1980
Sandbridge
20500 21000 21500 22000 22500 23000 23500 24000 24500 25000 25500 26000 26500 27000 27500 28000 28500 29000 29500 30000 30500 31000 31500 32000
Sandbridge
Sandbridge Road
Shoreline Studies Program
VIMS
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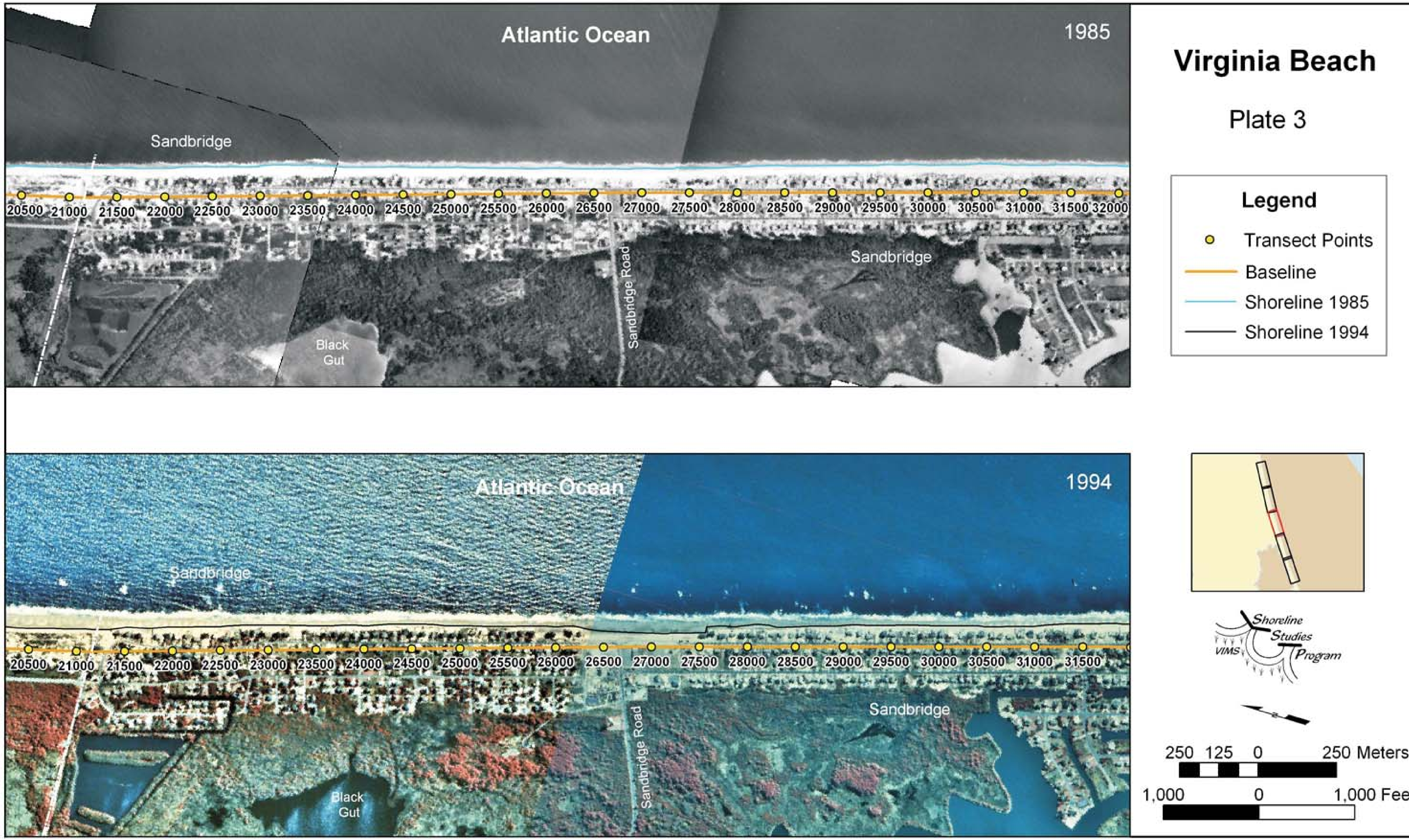
1,000 0 1,000 Feet



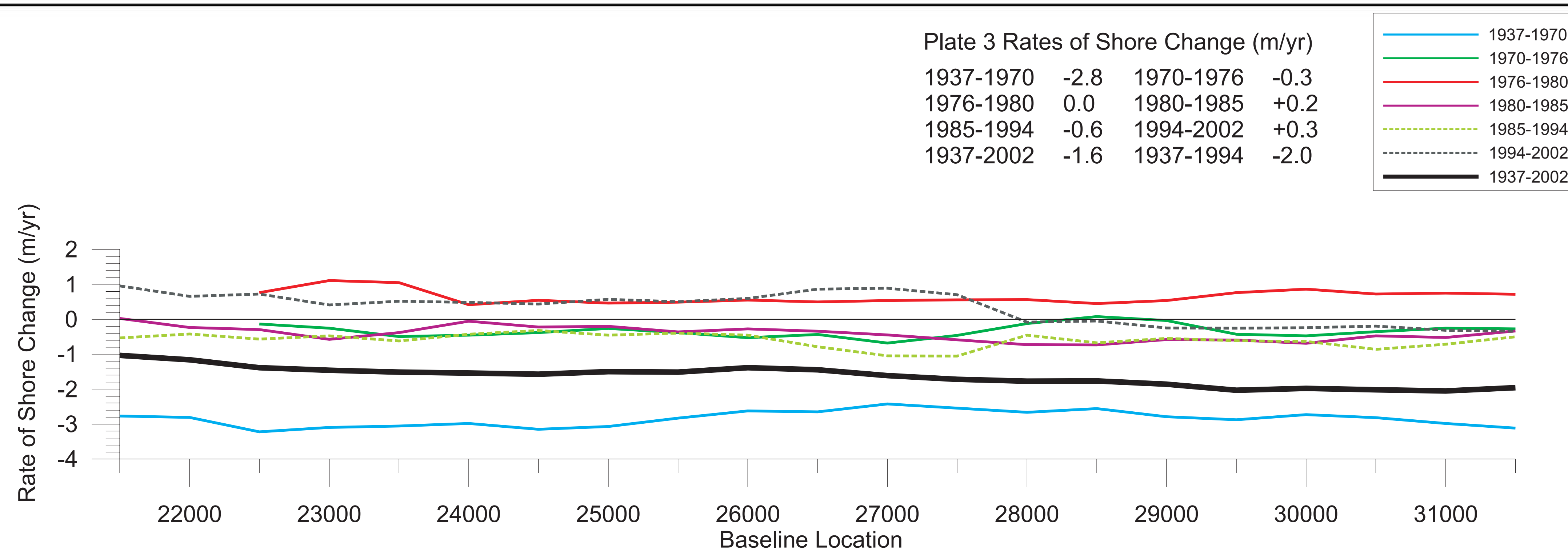
Virginia Beach
Plate 3
Atlantic Ocean
1985
Sandbridge
20500 21000 21500 22000 22500 23000 23500 24000 24500 25000 25500 26000 26500 27000 27500 28000 28500 29000 29500 30000 30500 31000 31500 32000
Sandbridge Road
Black Gut
Atlantic Ocean
1994
Sandbridge
20500 21000 21500 22000 22500 23000 23500 24000 24500 25000 25500 26000 26500 27000 27500 28000 28500 29000 29500 30000 30500 31000 31500
Sandbridge Road
Black Gut
Legend
Transect Points
Baseline
Shoreline 1985
Shoreline 1994
Shoreline Studies Program
VIMS
250 125 0 250 Meters
1,000 0 1,000 Feet

Virginia Beach

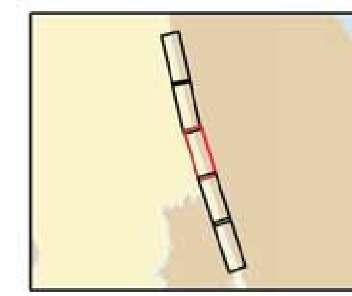
Plate 3

Legend

- Transect Points
- Baseline
- Shoreline 1937
- Shoreline 1970
- Shoreline 1976
- Shoreline 1980
- Shoreline 1985
- Shoreline 1994
- Shoreline 2002



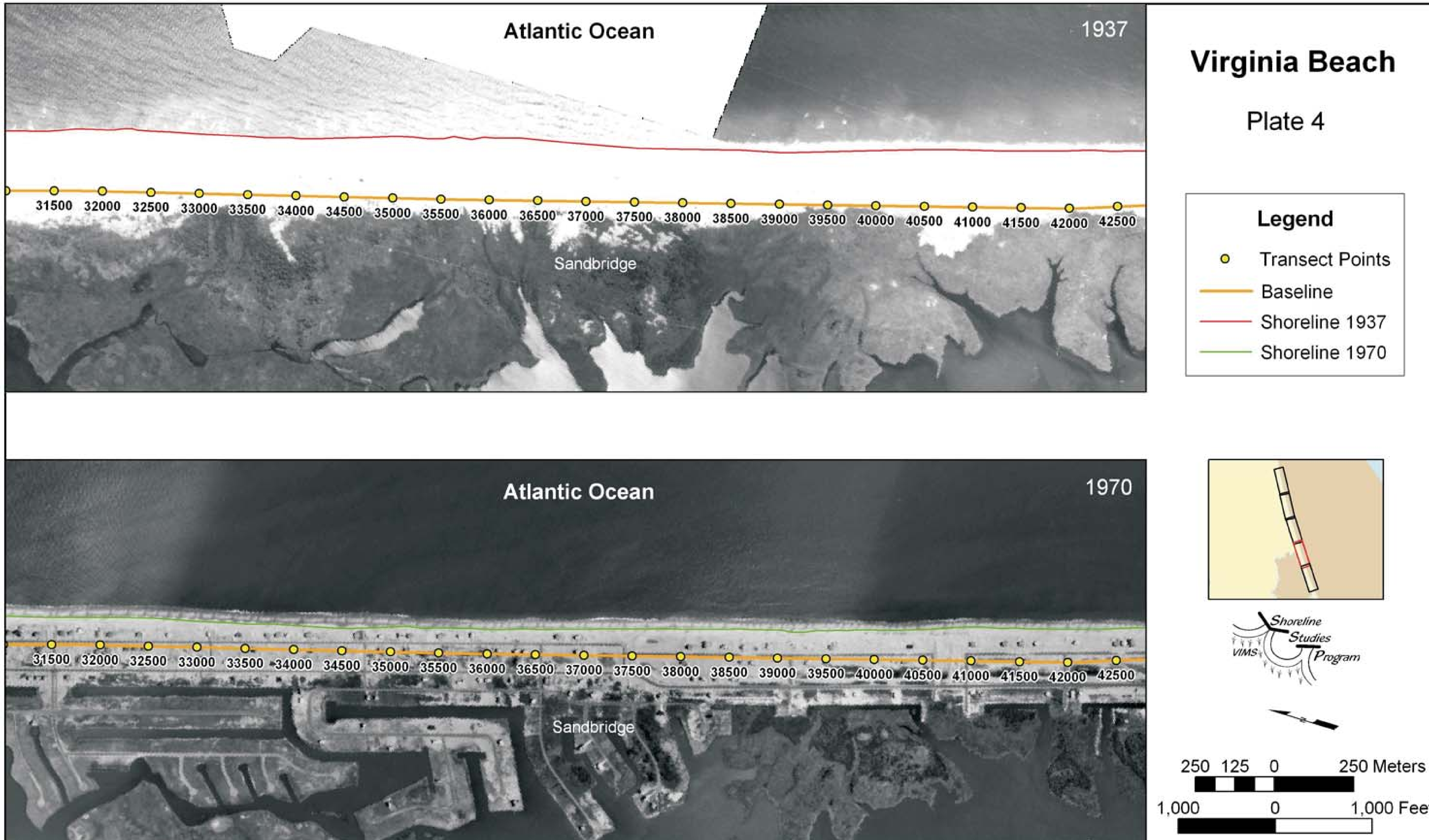
1937-1970	-2.8	1970-1976	-0.3
1976-1980	0.0	1980-1985	+0.2
1985-1994	-0.6	1994-2002	+0.3
1937-2002	-1.6	1937-1994	-2.0

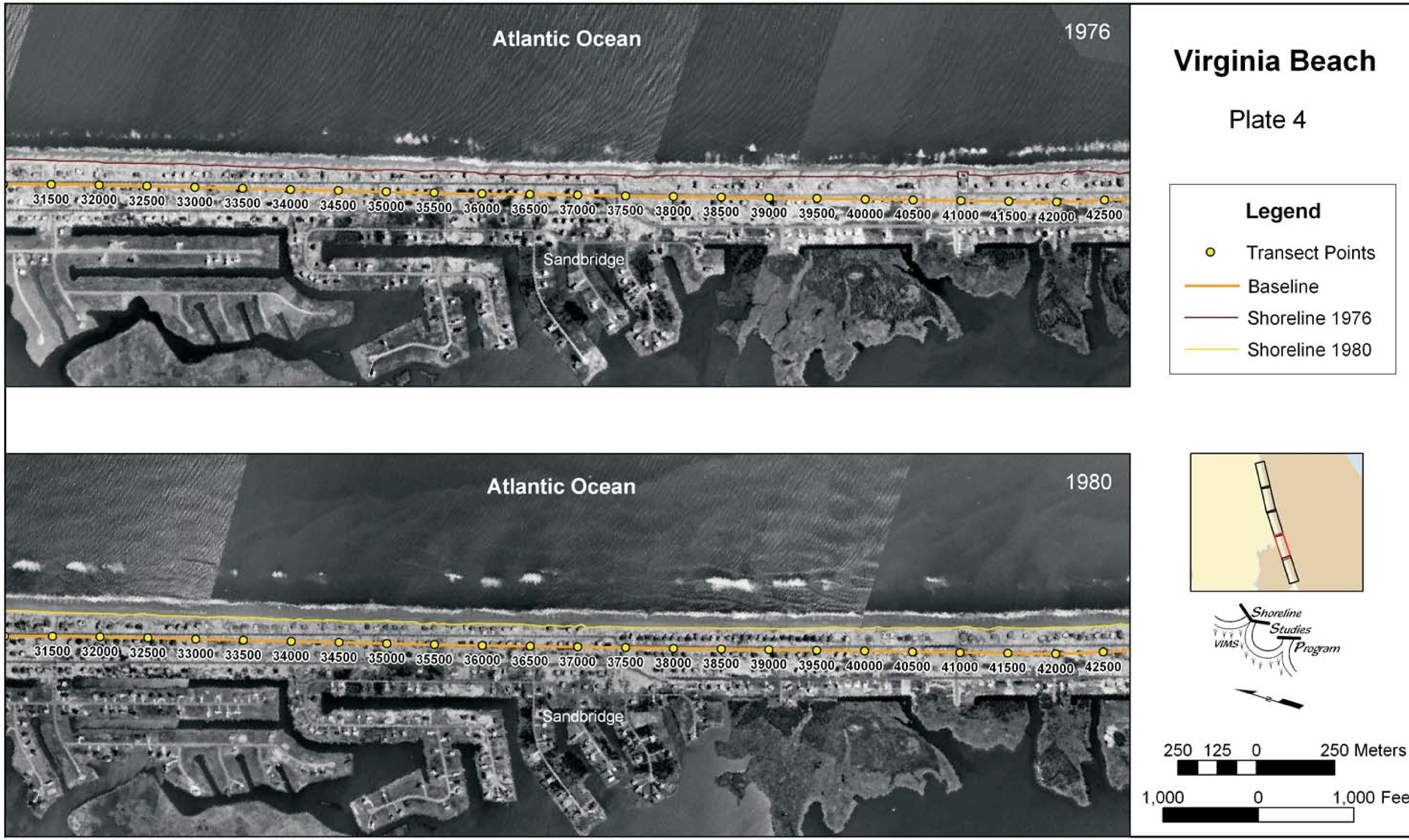


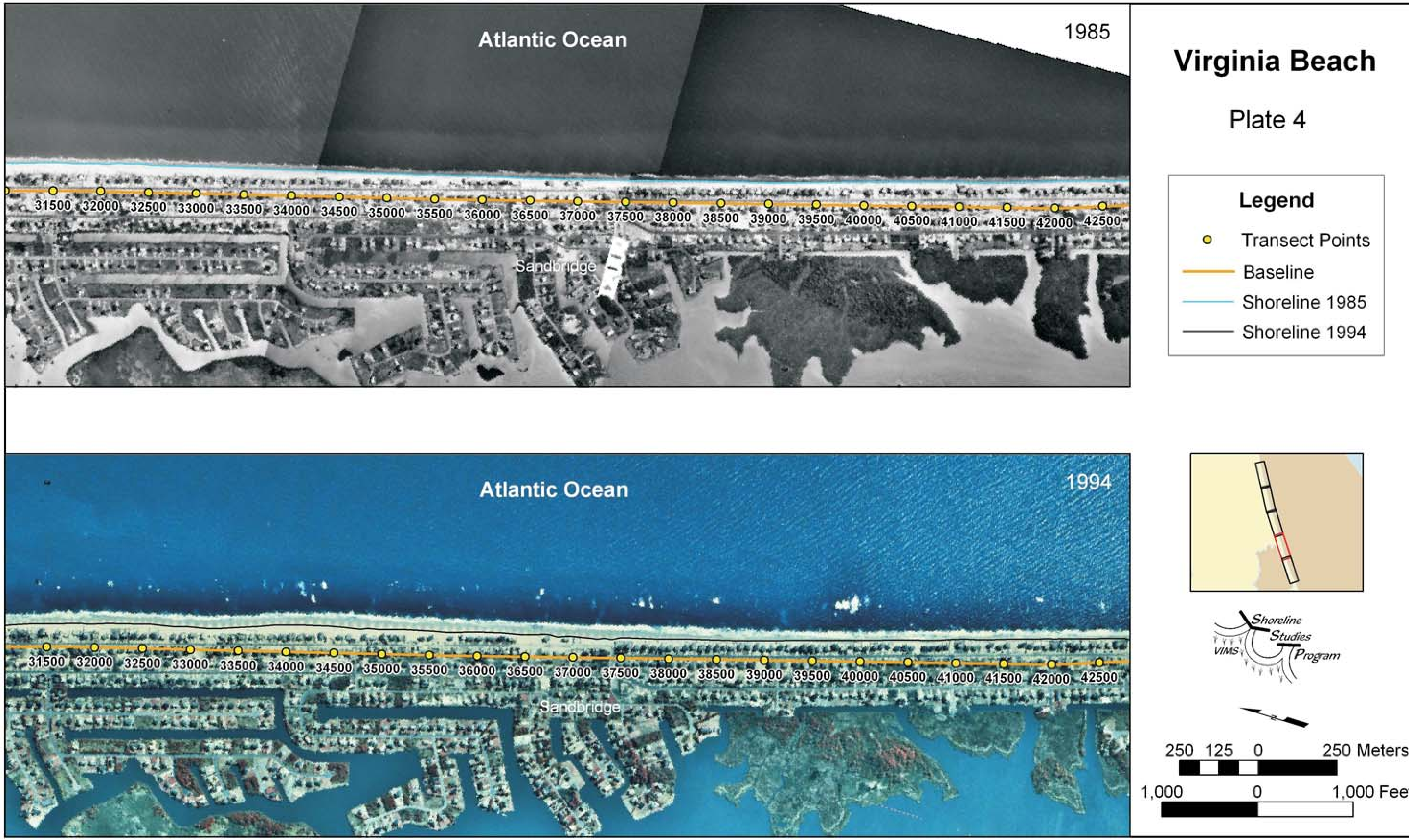
Shoreline Studies Program VIMS

250 125 0 250 Meters

1,000 0 1,000 Feet


Virginia Beach
Plate 4
Atlantic Ocean
1937
31500 32000 32500 33000 33500 34000 34500 35000 35500 36000 36500 37000 37500 38000 38500 39000 39500 40000 40500 41000 41500 42000 42500
Sandbridge
Atlantic Ocean
1970
31500 32000 32500 33000 33500 34000 34500 35000 35500 36000 36500 37000 37500 38000 38500 39000 39500 40000 40500 41000 41500 42000 42500
Sandbridge
Legend
Transect Points
Baseline
Shoreline 1937
Shoreline 1970
Shoreline Studies Program
VIMS
250 125 0 250 Meters
1,000 0 1,000 Feet


Virginia Beach
Plate 4
Atlantic Ocean
1976
Sandbridge
31500 32000 32500 33000 33500 34000 34500 35000 35500 36000 36500 37000 37500 38000 38500 39000 39500 40000 40500 41000 41500 42000 42500
Atlantic Ocean
1980
Sandbridge
31500 32000 32500 33000 33500 34000 34500 35000 35500 36000 36500 37000 37500 38000 38500 39000 39500 40000 40500 41000 41500 42000 42500
Legend
Transect Points
Baseline
Shoreline 1976
Shoreline 1980
Shoreline Studies Program
VIMS
250 125 0 250 Meters
1,000 0 1,000 Feet


Virginia Beach
Plate 4
Legend
Transect Points
Baseline
Shoreline 1985
Shoreline 1994
Atlantic Ocean
1985
Sandbridge
31500 32000 32500 33000 33500 34000 34500 35000 35500 36000 36500 37000 37500 38000 38500 39000 39500 40000 40500 41000 41500 42000 42500
Atlantic Ocean
1994
Sandbridge
31500 32000 32500 33000 33500 34000 34500 35000 35500 36000 36500 37000 37500 38000 38500 39000 39500 40000 40500 41000 41500 42000 42500
Shoreline Studies Program
VIMS
250 125 0 250 Meters
1,000 0 1,000 Feet

Virginia Beach

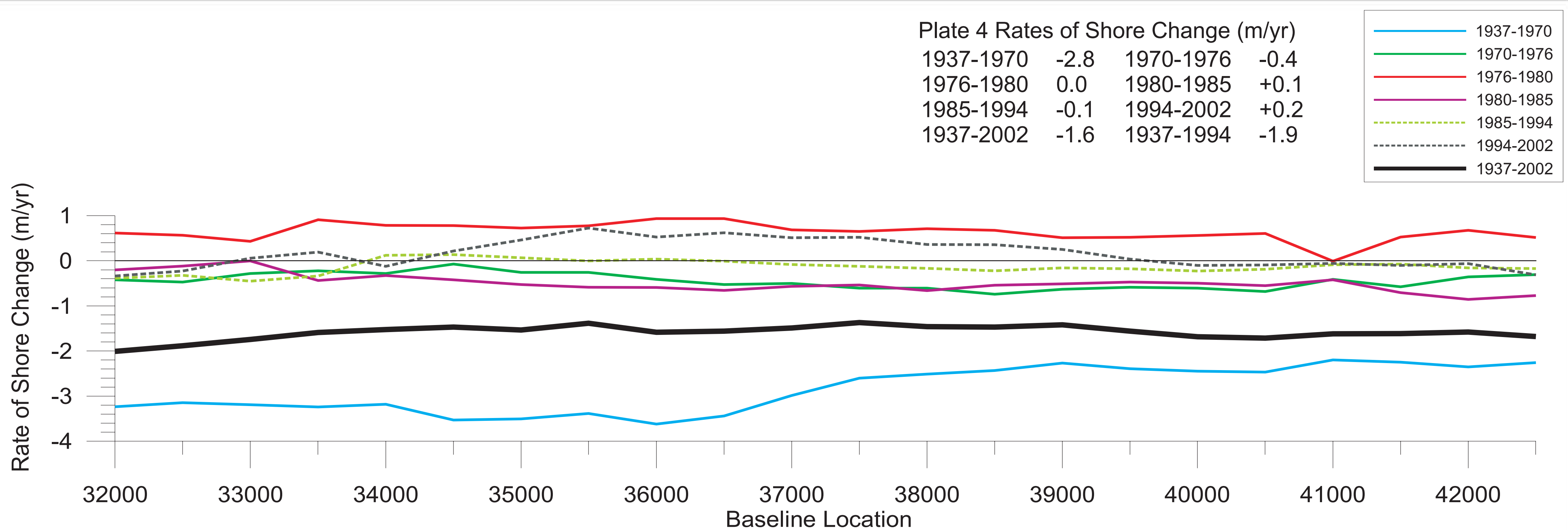
Plate 4

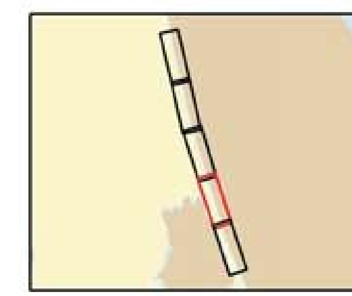
Legend

- Transect Points
- Baseline
- Shoreline 1937
- Shoreline 1970
- Shoreline 1976
- Shoreline 1980
- Shoreline 1985
- Shoreline 1994
- Shoreline 2002

Plate 4 Rates of Shore Change (m/yr)

1937-1970	-2.8	1970-1976	-0.4
1976-1980	0.0	1980-1985	+0.1
1985-1994	-0.1	1994-2002	+0.2
1937-2002	-1.6	1937-1994	-1.9





Shoreline Studies Program
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250 125 0 250 Meters

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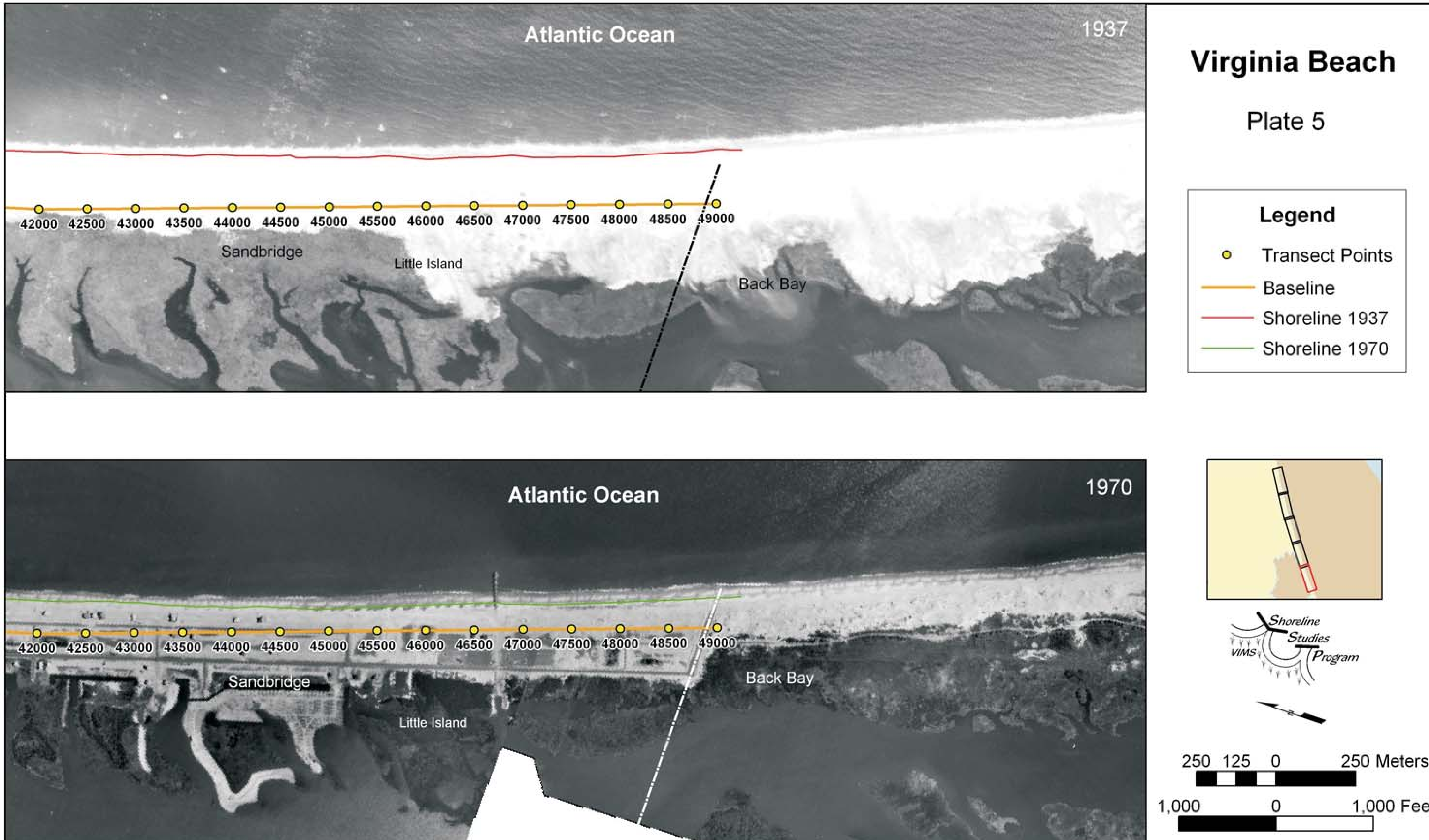
Virginia Beach
Plate 5
Atlantic Ocean
1937
42000 42500 43000 43500 44000 44500 45000 45500 46000 46500 47000 47500 48000 48500 49000
Sandbridge
Little Island
Back Bay
Atlantic Ocean
1970
42000 42500 43000 43500 44000 44500 45000 45500 46000 46500 47000 47500 48000 48500 49000
Sandbridge
Little Island
Back Bay
Legend
Transect Points
Baseline
Shoreline 1937
Shoreline 1970
Shoreline Studies Program
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250 125 0 250 Meters
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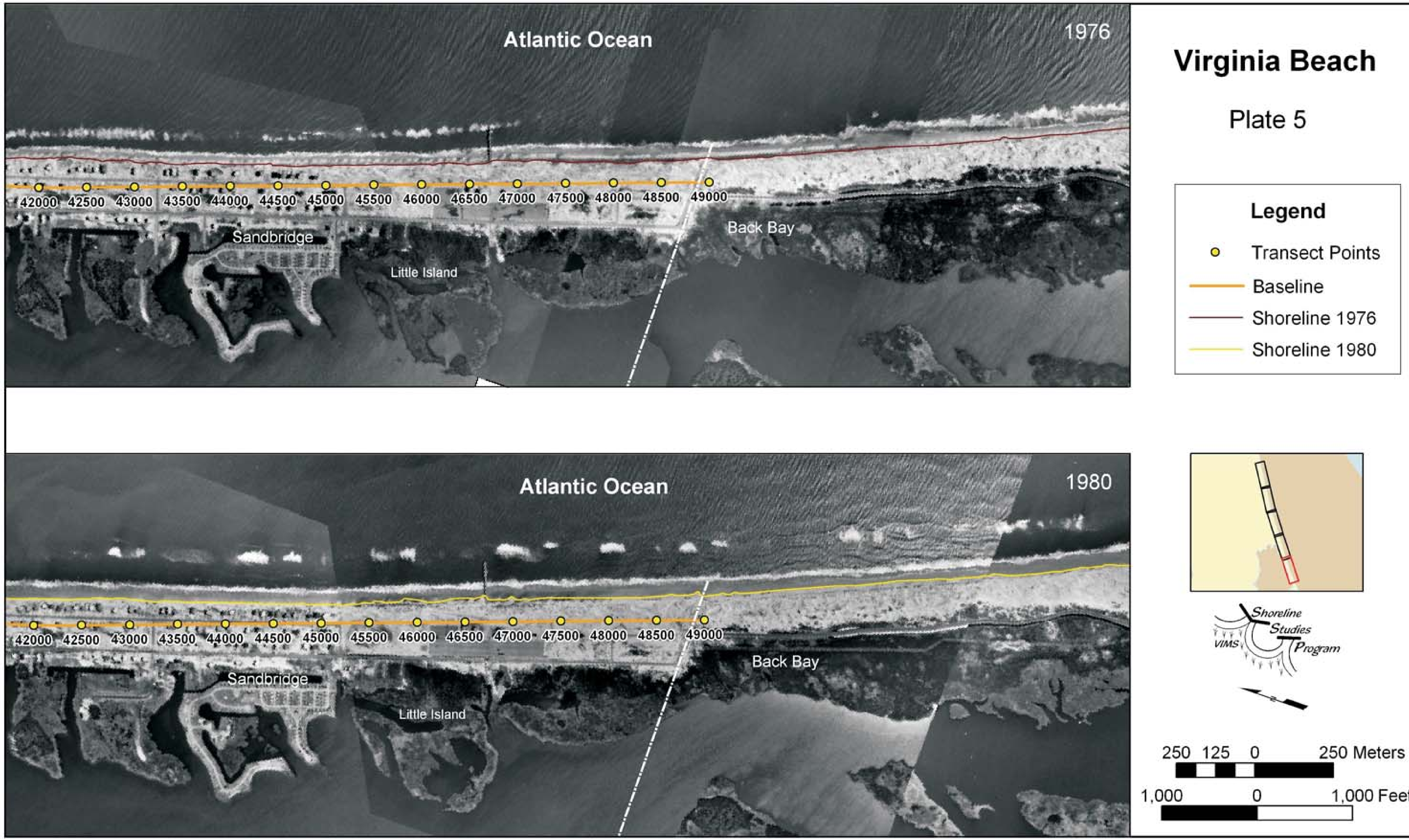
Atlantic Ocean
1976
42000
42500
43000
43500
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45000
45500
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46500
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Sandbridge
Little Island
Back Bay
Atlantic Ocean
1980
42000
42500
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43500
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44500
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46500
47000
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48500
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Sandbridge
Little Island
Back Bay
Virginia Beach
Plate 5
Legend
Transect Points
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Shoreline 1976
Shoreline 1980
Shoreline
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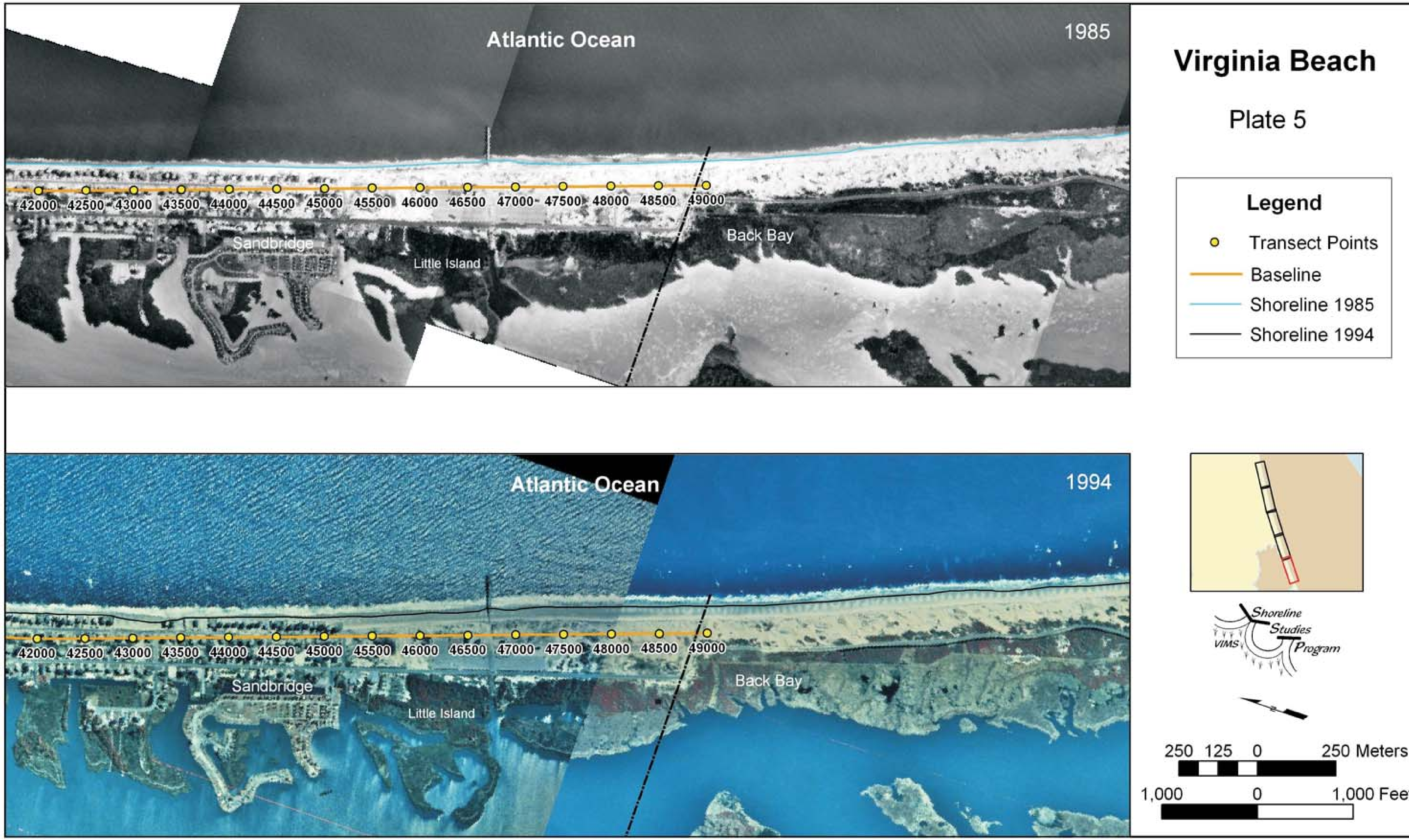
Virginia Beach
Plate 5
Atlantic Ocean
1985
42000 42500 43000 43500 44000 44500 45000 45500 46000 46500 47000 47500 48000 48500 49000
Sandbridge
Little Island
Back Bay
Atlantic Ocean
1994
42000 42500 43000 43500 44000 44500 45000 45500 46000 46500 47000 47500 48000 48500 49000
Sandbridge
Little Island
Back Bay
Legend
Transect Points
Baseline
Shoreline 1985
Shoreline 1994
Shoreline Studies Program
VIMS
250 125 0 250 Meters
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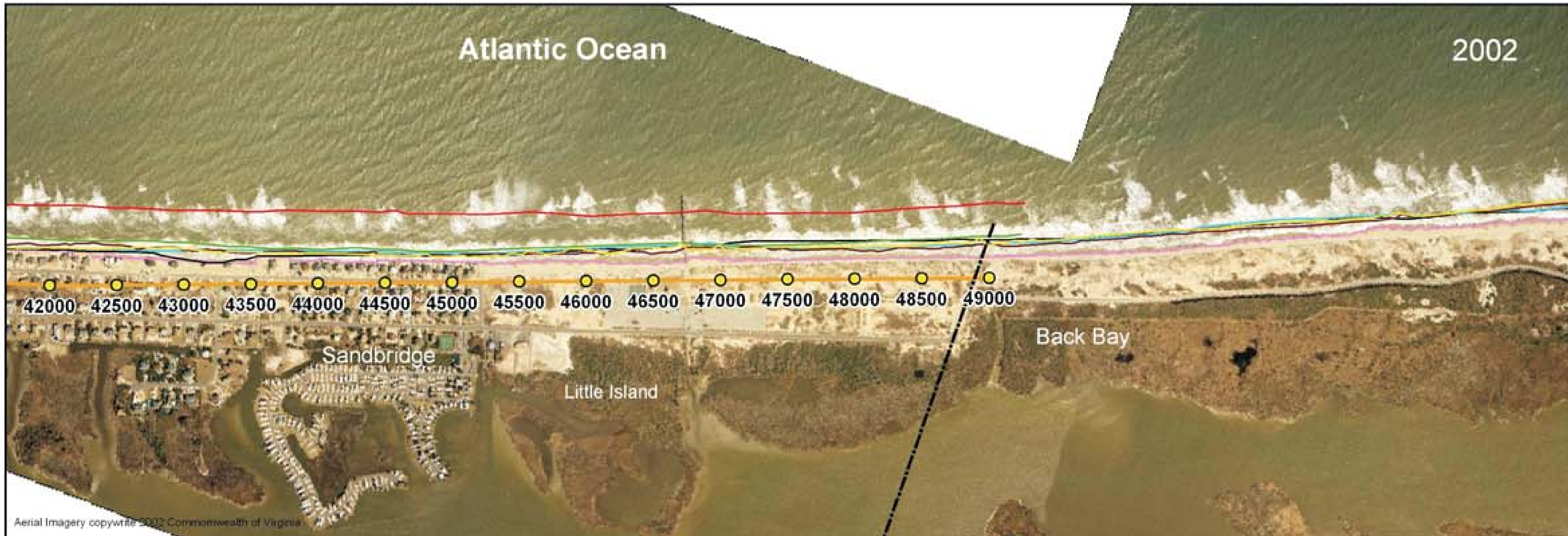
Virginia Beach

Plate 5

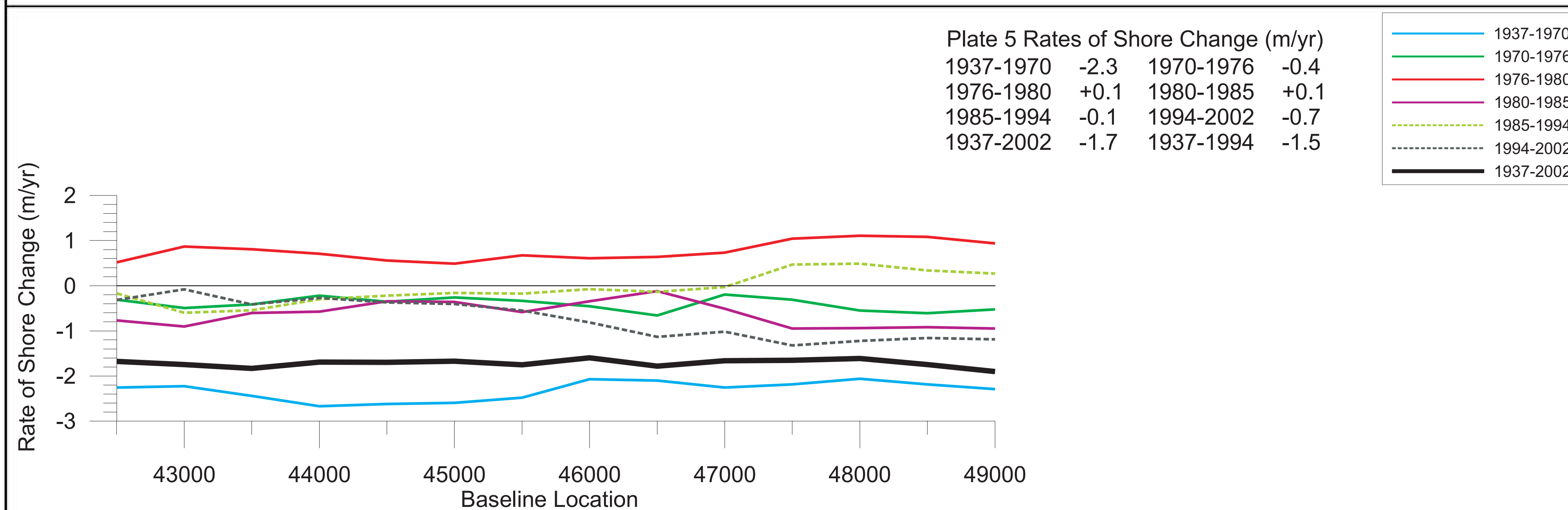


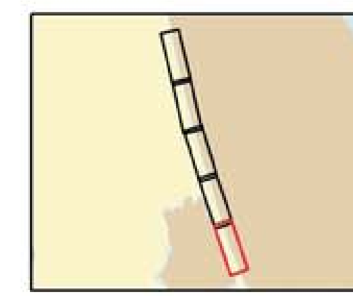
Legend

- Transect Points
- Baseline
- Shoreline 1937
- Shoreline 1970
- Shoreline 1976
- Shoreline 1980
- Shoreline 1985
- Shoreline 1994
- Shoreline 2002

Plate 5 Rates of Shore Change (m/yr)

1937-1970	-2.3	1970-1976	-0.4
1976-1980	+0.1	1980-1985	+0.1
1985-1994	-0.1	1994-2002	-0.7
1937-2002	-1.7	1937-1994	-1.5





Shoreline Studies Program
VIMS

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APPENDIX C

Manuscript submitted to

International Journal of Marine Geology, Geochemistry and Geophysics

In Review

LINKING FRAMEWORK GEOLOGY AND NEARSHORE MORPHOLOGY: CORRELATION OF PALEO-CHANNELS WITH SHORE-OBLIQUE SANDBARS AND GRAVEL OUTCROPS

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Abstract

This work describes a newly discovered spatial correlation between paleo-channels and nearshore morphology along the barrier islands of northeastern North Carolina and southeastern Virginia, U.S. mid-Atlantic coast. These nearshore morphological features include regions of shore-oblique sandbars and coincident gravel outcrops that previously have been linked to shoreline hotspots. The importance of these new findings has direct bearing on both nearshore morphodynamics and shoreline management. Paleo-channels were identified in the chirp seismic record and compared to shore-oblique sandbar locations discerned from bathymetric data and corroborated by gravel outcrops depicted in the side scan record. Both graphical correlation and statistical cross-correlation analyses revealed a significant spatial relationship between these features, with higher statistical correlation for channels >500 m wide. Seismic records also indicate that the gravel outcrops seen on the updrift flanks of the shore-oblique bars are surface expressions of the underlying geology. We hypothesize that these outcrops are composed of relict channel fill sediments that interact with the hydrodynamic regime to produce sorted bedforms. The bathymetric anomalies then serve to alter incident wave energy and affect shoreline behavior. The spatial and temporal stability of these features over several years and through a variety of wave conditions suggests some degree of underlying geologic control. While the mechanisms responsible for this relationship remain speculative, these results may bridge the gap between studies focusing on framework geology and its influence on shoreline change and those that investigate bar morphodynamics and the initiation of sorted bedforms.

Keywords: paleo-channels, shore-oblique sandbars, hotspots, beach erosion, framework geology, nearshore morphodynamics

1. Introduction

This paper addresses the strong spatial correlation between paleo-channels buried beneath the modern shoreface and morphologic anomalies, shore-oblique bars and outcropping gravel patches, seen in the surf zone and nearshore. This correlation holds major implications for shoreline management, since the aforementioned anomalies have been linked to areas of excessive shoreline erosion (McNinch, 2004). In addition, the correlation provides further evidence supporting the growing consensus of a link between underlying geology and shoreline behavior. Throughout this study, the terms underlying geology, framework geology and antecedent geology are used interchangeably to refer to the sediments which underlie the modern deposits, to a depth of ~10 m. We believe that one of the more exciting aspects of this research is that it bridges the gap between two prominent but separate current research endeavors: influence of framework geology on shoreline behavior (Demarest and Leatherman, 1985; Gayes, 1998; Honeycutt and Krantz, 2003; Kraft et al., 1987; McNinch, 2004; Pilkey et al., 1993; Riggs et al., 1995; Schupp et al., 2002; Schwab et al., 2000) and nearshore sorted bedforms (Green et al., 2004; Gutierrez et al., 2005; Murray and Thieler, 2004; Trembanis et al., 2004). We will present the varied natures of the channels seen in the seismic record and highlight what appear to be the most important parameters in determining potential influence on seabed morphological characteristics. We will also propose several hypotheses that address how a buried relict feature might have an effect on the modern nearshore environment.

A reconnaissance survey undertaken in the summer of 2002 brought to light an apparent spatial relationship between shore-oblique sandbars in the nearshore and shoreline erosion (McNinch, 2004). The purpose of the survey was to investigate the previously unmapped framework geology of the nearshore (McNinch et al., 2002). This study utilized chirp seismic and interferometric swath bathymetry to provide a three-dimensional view along 56 km of the nearshore of southeastern Virginia and the northern Outer Banks of North Carolina. This survey further revealed a vertical and horizontal heterogeneity in sediment size and composition across the study area. The layer of modern sand was relatively thin (from 0 to 1.5 m thick) and was concentrated in several locations in clusters of shore-oblique sandbars. In all cases, these sandbars were flanked by gravel patches that were shown to be surface expressions of the underlying substrate. Repeat surveys in March 2003 and November 2003 (only six weeks after Hurricane Isabel) of one of the largest of these clusters showed remarkable spatial stability (Figure 1). More interesting still is the apparent spatial alignment between these larger shore oblique bar/outcrop regions and the locations of long-term erosional hotspots (Schupp, 2005).

Erosional hotspots are problematic regions of coastline that display great variability and resist classification and prediction (Fenster and Dolan, 1993). These areas exhibit anomalously high erosion or accretion, as well as spatial and temporal variability (Benton et al., 1997; Hobbs et al., 1999; List and Farris, 1999). Shoreline hotspots challenge our knowledge and understanding of alongshore transport and cross-shore sediment exchange and for this reason have been the subject of much study in recent years (McNinch, 2004). Specifically, they raise the question of why we see localized variation in shoreline behavior when longshore transport of sediment is such a dominant process. While some hotspots may be explained by their proximity to coastal engineering projects (Dean et al., 1999; Kraus and Galgano, 2001) and inlets (Fenster and Dolan, 1996), it has become evident that in order to explain many of these features, shoreline prediction models need to look beyond the principle variables of waves and bathymetry to other possible controlling factors.

The findings of the 2002 reconnaissance study challenge the existing paradigm of a dynamic shoreface morphology that is strictly controlled by waves, currents and mean grain size (McNinch, 2004). Specifically, they raise the questions of why shore-oblique sandbars persist through storms, why outcrops remain exposed and what dictates their location. This persistence is noteworthy given the high energy environment of the nearshore. The present study explores the possibility that the location of the shore-oblique bar and outcrop clusters are influenced by the framework geology of the nearshore. The notion that a buried feature could have any communication with the modern substrate is not immediately intuitive, but this paper introduces some mechanisms that might explain this phenomenon.

1.1 Framework geology and shoreline behavior

There is a steadily growing body of literature exploring the effect that framework geology may have on beach and nearshore behavior (Belknap and Kraft, 1985; Demarest and Leatherman, 1985; Honeycutt and Krantz, 2003; McNinch, 2004; McNinch and Drake, 2001; Pilkey et al., 1993; Rice et al., 1998; Riggs et al., 1995). Some framework geology studies have looked at the implications of underlying and outcropping relict sediments on shoreline change (Honeycutt and Krantz, 2003; McNinch, 2004; Riggs et al., 1995; Schupp, 2005). Honeycutt and Krantz (2003) found that the character (lithology and degree of compaction) of underlying relict units in the nearshore of Bethany Beach, Delaware, was a controlling factor in the rate of shoreline erosion. In one cited example, an early Holocene unit slowed the rate of shoreline erosion by acting as a sediment source. In another, an erosion-resistant Pleistocene headland also slowed erosion rates, but as a result of greater compaction relative to nearby Holocene sediments.

Riggs and others (1995) found that increased shoreline erosion occurred in areas of the northern Outer Banks where relict channels could be traced in the stratigraphic record. They attributed this to the characteristics of the type of fill within the channels. The most rapid shoreline recession was associated with sandy sediments (typical of relict inlet channels). Erosion of these sediments resulted in steeper shoreface profiles and the eventual supply of these materials (similar in composition to the modern sands) to adjacent beaches. Shorefaces underlain by estuarine sediments (typical of relict fluvial channels) eroded more slowly and produced profiles that were less steep than those underlain by predominantly sandy sediments. Once eroded, the fine-grained sediments were suspended and transported offshore. Riggs et al. (1995) did find coarser-grained material in the cores from relict fluvial channels but did not consider these in the shoreline change question since they generally are buried beneath the estuarine sediments. We have found gravel sediments cropping out near buried fluvial channels in the nearshore and believe that they might play an important role in influencing shoreline behavior.

Other studies have focused on the contribution of relict sediments to the modern sediment budget, a concept known as shoreface bypassing (Swift, 1976). Demarest and Leatherman (1985) found relict sediments to be a significant source of sand for modern beaches along the Delmarva Peninsula. Schwab et al. (2000) traced an offshore source of relict sediment near Long Island, New York to a pre-Holocene subaerial headland that had been eroded during the Holocene transgression. The eroded sediment was reworked into shoreface-attached sand ridges that now appear to be significant contributors to the modern littoral system. In large part, these studies demonstrate that there is a connection between the framework geology and shoreline change but do not provide mechanisms to explain this connection. Honeycutt and Krantz (2003) presented three ways in which framework geology may influence shoreline-change rates: 1) the differential erosion of underlying sediments causes discontinuity in erosion rates, 2) shoreline retreat is slowed by relict topographic highs and hastened by relict topographic lows, and 3) relict sediments (if they are similar in size and composition to modern sediments) may supply local beaches. One important possibility they do not address is how the outcropping of relict sediments might affect the hydrodynamic regime and nearshore bedforms.

Cox et al. (1995) found that a consolidated Pleistocene submarine headland near Rodanthe, NC dramatically influenced the distribution of nearshore wave energy, thus acting as a major control on shoreline behavior. Bender and Dean (2003) used both field studies and modeling efforts to examine how changes in offshore bathymetry modified local wave fields and shoreline. These and other modeling efforts have consistently shown that bathymetric irregularities on the shelf, which are often a product of antecedent geology, are a major influence on incident waves (Maa and Hobbs, 1998; O'Reilly and Guza, 1993) and, thus, shoreline behavior.

There is also a growing body of work exploring how bedform morphology can be influenced by different sediment types exposed on the seafloor. Trembanis et al. (2004) examined bottom boundary layers over a smooth sandy bed and a rough bed of coarse sand on New Zealand’s inner shelf. Results from that study and others like it (Green et al., 2004; Gutierrez et al., 2005) show that during storm conditions, turbulence increases over the rough beds, inhibiting settling of finer material, effectively enhancing the partitioning effect between the two types of sediment. These results support the positive feed-back loop suggested by Murray and Thieler (2004) as a sustaining mechanism for sorted bedforms. The present study combines all of these concepts and looks at how framework geology might influence nearshore bedforms, tying into earlier studies linking these bedforms to shoreline change (Schupp, 2005; McNinch, 2004).

1.2 Paleo-channels

Earlier seismic investigations in the study area show that the framework geology of the Northern Outer Banks and southern Virginia is not homogeneous but rather laced with ancient fluvial and tidal inlet channels (Boss et al., 2002; Chen, 1992; Chen et al., 1995; Colman et al., 1990; Dame, 1990; Kimball and Dame, 1989; Riggs et al., 1995). Throughout Quaternary history, major glaciations have led to large-scale oscillations in global sea level (Boss et al., 2002; Fairbanks, 1989; Shackleton, 1987). The resulting regressions and transgressions have left their marks on the stratigraphic record in this area. During regressive episodes, when sea level was much lower than it is presently, fluvial systems cut across previously laid coastal plain and continental shelf strata, reworking older sediments and disrupting the normal horizontal pattern of bedforms (Belknap and Kraft, 1981; Chen, 1992; Hobbs, 2004; Rice et al., 1998; Riggs et al., 1995; Riggs et al., 1992; Roberts and Snyder, 2001), and making stratigraphic interpretation all the more challenging. When sea level rose again, the fluvial channels were inundated and backfilled with first fluvial, then estuarine and coastal sediments (Riggs and Belknap, 1988).

Riggs et al. (1992) described the paleo-Roanoke-Albemarle system as a superposition of multiple channels with various degrees of preservation. The fluvial channels they mapped under the barrier island system and back bay area are filled first in their lower narrow reaches with fluvial sediments as sea level rises. This type of infill creates "chaotic depositional patterns" as displayed in the seismograms. The upper portions of the channels tend to be broader and the change to estuarine fill is evident by the more horizontal deposition patterns (Figure 2). Holocene tidal inlet channels may also be preserved in the framework geology and exhibit specific geometries and fill patterns in the seismic record that may help distinguish them from Pleistocene fluvial channels. Moslow and Heron (1978) described a distinct cross-sectional profile associated with preserved Holocene tidal inlets, a direct result of its lateral migration (Figure 3).

This study explores the possible link between paleo-channels in the framework geology and overlying bathymetry and surface sediment characteristics in the nearshore. Objectives of this study are 1) mapping the underlying geology and surface sediment characteristics of the nearshore in several sites in northern North Carolina and southern Virginia, 2) using these data to identify the locations of relict channels, shore-oblique bars and gravel outcrops, 3) quantifying the spatial relationship between these features and 4) identifying characteristics of buried channels that may play an important role in controlling the presence of shore-oblique bars and gravel outcrops.

2. Study area

2.1 Physical setting

135 line-kilometers were surveyed among four sites in southeastern Virginia and northeastern North Carolina (Figure 4) during the summer of 2003. The sites encompass portions of the nearshore regions of Sandbridge, Virginia and Duck, Kitty Hawk and Nags Head, North Carolina. These study sites vary in alongshore length but generally span the nearshore region between the 4m and 15m isobaths.

This section of the Virginia and North Carolina coastline is microtidal (Hayes, 1979) and storm dominated (Wright and Short, 1984). Tides are semidiurnal with a mean tidal range of 0.97 m (Birkemeier et al., 1985) and a mean spring range of 1.25 m (Wright and Short, 1984). The period of greatest storm activity occurs in fall and winter, and the majority of storms are extratropical with northeast winds. Most of the wave energy is from the east-northeast and northeast. The lowest waves, occurring in summer, average 0.88 m. During the winter months, deep water wave heights are often greater than 4 m (Wright and Short, 1984).

2.2 Geologic setting

The study sites are located within the submerged extension of the coastal plain provinces of Virginia and North Carolina. While stratigraphic relationships can be difficult to reconstruct due to the low relief and low gradient of regional geomorphology (Boss et al., 2002), Riggs and others (1992) identified seven distinct Quaternary stratigraphic sequences in the back barrier region of northeastern North Carolina. The five upper sequences appear to correspond with those identified by Boss et al. (2002) offshore, absent any direct tying data in the nearshore. Studies in southeastern Virginia, however, identify only three to four major Quaternary sequences (Chen et al., 1995; Dame, 1990; Hobbs, 1990; Hobbs, 2004; Shideler et al., 1972). This difference may be attributable to the tectonic framework of the Atlantic Coastal Plain, which consists of a series of embayments and topographic highs. Southeastern Virginia is located on the Norfolk or Fort Monroe High and northeastern North Carolina is underlain by the Albemarle Embayment. Thinner sedimentary sections are typically associated with the highs, whereas sediment thicknesses are greater and the stratigraphic record usually more complete, in the embayments (Owens and Gohn, 1985). Alternatively, the difference in number of reported sequences may simply be the result of interpretation or equipment resolution (Hobbs, 2004).

The North Carolina study area is underlain by a series of tabular Quaternary strata sloping to the east-southeast (Boss et al., 2002; Riggs et al., 1992), which, in some locations, outcrop on the seafloor (Boss et al., 2002; McNinch, 2004; Rice et al., 1998; Riggs et al., 1992; Roberts and Snyder, 2001). The region is overlain by a thin layer of Holocene sand which thins in the seaward and southward direction (Rice et al., 1998; Riggs et al., 1995). Cutting through the Quaternary strata is a series of Pleistocene paleo-fluvial systems that have since been back-filled with Pleistocene and Holocene sediments following rising sea level. Boss et al. (2002) mapped multiple channels of the Roanoke Albemarle paleo-fluvial complex on the continental shelf and managed to correlate them, with some degree of confidence (despite the lack of nearshore data), with those identified by Riggs and colleagues in the back barrier. In southeastern Virginia, two potentially separate major paleo-fluvial drainage networks have been mapped in the Chesapeake Bay and offshore (Chen et al., 1995; Colman et al., 1990; Dame, 1990; Hobbs, 1997; Oertel and Foyle, 1995). Beneath the Delmarva Peninsula and the modern Bay mouth, at least four distinct iterations of the paleo-Susquehanna have been identified (Colman et al., 1990; Hobbs, 1997; Hobbs, 2004; Oertel and Foyle, 1995). Exmore Channel, the oldest (~200-400 ka) and northernmost, lies beneath the Delmarva Peninsula, approximately 50 km north of Cape Charles, VA. The progressively younger channels (Belle Haven, Eastville and Cape Charles) cut paths farther to the south, in succession. This southward migration of the paleo-Susquehanna is attributed to the barrier spit formation process of the Delmarva Peninsula during periods of interglacial sea-level high-stands. The resultant southward progradation of the peninsula forced the southward migration of the river's course (Colman et al., 1990; Hobbs, 2004; Mixon, 1985).

Offshore of Sandbridge, VA, in the vicinity of a documented long-term erosional hotspot (Hobbs et al., 1999), a separate paleo-fluvial system has been mapped (Chen, 1992; Dame, 1990; Hobbs, 1990; Kimball and Dame, 1989). This might be associated with the paleo-James River (or possibly the paleo-Elizabeth River) (Harrison et al., 1965; Meisburger, 1972; Swift, 1975) and there is speculation that it links up with the paleo-Roanoke-Albemarle system farther offshore (Boss et al., 2002, Chen et al., 1995). Chen et al. (1995) identified three temporally-distinct paleo-channel systems (I-III), which presumably developed during the same lowstands as the Exmore, Eastville and Cape Charles Channels of the paleo-Susquehanna system. The youngest of these, System III, consists of channels oriented generally shore-normal and is most likely associated with features of the modern shoreline. The two older systems run more shore parallel and suggest analogs to the modern northeastern North Carolina sounds and southeastern Virginia's Back Bay, which are bounded by Pleistocene shorelines.

3. Methods

3.1 Data collection and processing

Surface sediment characteristics were mapped during June of 2003 using a 600kHz Marine Sonics side scan sonar. These data were used to identify the locations of outcropping gravel patches. An Edgetech 512I Chirp sub-bottom profiler was used to map the underlying geology of the study areas. A range of frequencies (0.5-6kHz) allowed penetration of the nearshore Holocene sand layer, while resolving the acoustic layers to within ~10 cm. This allowed the identification of paleo-channels to depths of ~20 m below the seafloor, as well as finer details of the infilled layers. Both the side scan and seismic data were processed with SonarWeb Pro software, developed by Chesapeake Technologies.

Interferometric swath bathymetry data collected in 2002 were used to identify the locations of the shore-oblique bars. During that survey, outcropping gravel patches were found on the northern flanks of the bars. The side scan data for this study (collected in 2003) were used to identify gravel patches and the locations of these were plotted on the bathymetric maps to compare the locations of the bar and outcrop fields. Using previously collected bathymetry data corroborated with current gravel outcrop data is justifiable given the recent findings of extremely high correlation between shore-oblique sandbars and gravel outcrops in the northern Outer Banks (Schupp, 2005; McNinch, 2004). Chirp seismic data also highlighted the bar locations, but only as a complement to the bathymetry and side scan data, since seismic data collected with a towfish are not a reliable indicator of bathymetry. Channel locations were then plotted on the same map to give a visual indication of the spatial relationships between the various features.

3.2 Statistical analysis

A chi square test was used to determine if a spatial relationship between the occurrence of shore-oblique bars and buried channels exists. An arbitrary baseline was drawn parallel to shore and the endpoints of bar fields and channels were traced in perpendicular to this line. Approximately every ten meters along this line, a simple presence / absence test was performed for bars and channels. The results were put into a 2x2 contingency table and analyzed by the chi square method.

Cross-correlation analyses were performed in Matlab to quantify the spatial relationship between shore-oblique bars and paleo-channels. Bar metrics were created to allow the assignment of a numerical value to each bar based on certain dimensions. Bar area, B_x, was determined by the product of the length of each shore-oblique bar and its width. In all cases, the index for each bar metric was the northing (spaced every 10m) from a "bar baseline" traced in Surfer at approximately the 5m isobath (Figure 5). The bar metric was associated with the midpoint of each bar and values were interpolated between each bar midpoint.

Each channel was digitized in the seismic record and the resultant depths were referenced to both the seafloor and the top of the channel (Figure 6). This was done to try to capture the importance of the depth of channel burial beneath the seafloor. A channel baseline was drawn in Surfer at approximately the 7m isobath. Channel endpoints were plotted (coordinates taken from the cross-sections in the seismic record) and lines were drawn from these to the channel baseline (Figure 5). The channel depths (referenced to either the seafloor or the top of channel, depending on the test being run) were inserted at the appropriate northing along the channel baseline.

Three separate correlation analyses were run for each study site. The first two were run using the digitized channel depths referenced either to the overlying seafloor or the top of the channel (Figure 6). In the third analysis, we subtracted the depth of burial beneath the seafloor (DBSF) from the actual channel depth to investigate the effect of channel burial (Figure 6). A conservative approach was taken in determining sample independence and degrees of freedom for statistical significance assessments. Sample size (n) was based on the total number of channels plus the non-channel, or interfluve, areas on either side of each channel. Each channel and interfluve was assigned a sample size of n=1, regardless of channel width. For example, there were four channels in the Sandbridge region, so n=9; Kitty Hawk had 1 channel, so n=3; and Nags Head had 3 channels, so n=7. The same correlation analyses were also run for combined study sites, providing a sample size of n=17.

4. Results

4.1 Correlation of buried channels and nearshore outcrops / shore-oblique bars

4.1.1 Spatial correlation using mapped bathymetry and channel locations

The shore-oblique bar and outcrop clusters were interpreted from the seismic record and side scan data from the June 2003 data collection period and found to be consistent with the 2002 bathymetry. The 2002 bathymetry data were then overlain with the 2003 outcrop and channel locations. Figures 7-9 reveal a strong correlation between the bar and outcrop locations, further increasing the confidence in comparing the channel locations with bathymetry collected at a previous time. Graphical correlation can also be made between the bar and outcrop clusters and wide (>500 m) channels (Figures 7-9).

At the Duck study site there were no distinct channels or evidence of shore-oblique bars in the seismic record and no gravel outcrops in the side scan record. The bathymetric survey of May 2002 did not cover this region, but a reconnaissance study in 2001 that did cover this area did not reveal any bars or outcrops.

4.1.2 Differences in sub-bottom cross-sections

Shore-normal and –oblique, sub-bottom profiles reveal a trend that supports the correlation seen on the surface between larger channels and bar/outcrop regions. Figure 10 shows a plan view of the Sandbridge region with the bar cluster highlighted. The strike lines represent the locations of the sub-bottom cross-sections shown in Figure 11. Results from the other study sites are shown in Figures 12-15. Sub-bottom cross-sections that lie outside of the bar fields show low relief, horizontal beds, a typical stratigraphic signature for an undisturbed, transgressive barrier island. Those that lie within, or partially within the bar fields, however, have a vastly different look: chaotic, truncated reflectors and evidence of channel meandering and down-cutting.

4.1.3 Statistical correlation

Figure 16 is a graph of paleo-channels and bar metrics plotted against location (northing, UTM). Since the plotted channel data show sub-bottom topography and the bar data reflect the metric (bar length x width at center point and interpolated to edges), magnitudes cannot be compared directly. However, a spatial relationship between the two features is immediately apparent. The results of the chi square test reveal a strong spatial relationship between shore-oblique bars and channel location. Table 1 shows the 2x2 contingency table that was analyzed. For 1 degree of freedom, the significant chi square value at the 0.1% confidence level is 10.83, meaning that for 1 degree of freedom, the probability that chi square is greater than 10.83 is 0.001. In other words, fewer than 0.1% of trials would give a value greater than 10.83 if the sample is truly from a uniform distribution. Our chi square value was 949.98, indicating that the result is highly significant.

Cross-correlation analyses comparing the locations of the bar/outcrop areas with the channel locations resulted in the correlation coefficients presented in Table 2. For the most part, correlations are comparable whether the channel depth is referenced to the seafloor or the top of the channel. An exception is Sandbridge, which had one of the most deeply buried channels. In all cases, correlations were lowest when the effect of channel burial depth was considered.

5. Discussion

5.1 Correlation of shore-oblique bars/outcrops with paleo-channels

Shore-oblique bars and gravel outcrops in the nearshore correlate strongly with paleo-channels buried beneath the nearshore Holocene sands. This finding is notable because the same bathymetric features have been previously linked to shoreline hotspots. Whether there is a causal relationship involved (between bars and shoreline change, between paleo-channels and bars, etc.) or all phenomena are the result of some other common mechanism remains unclear. Nevertheless, the contribution of this finding lies in the establishment of a connection between relict framework geology and nearshore bedforms in a wave-dominated, energetic setting. Shore-oblique bars and gravel outcrops in the Outer Banks study sites appear to be relatively stable, wherein the overall position of the bars remain in a fixed position with small-scale movement (wagging) in the shallowest portions (Schupp, 2005; McNinch, 2004). This is noteworthy because acoustic profiles and vibracores (McNinch et al., 2001) indicate that the bars are composed of unconsolidated sand with the same characteristics as the surrounding nearshore and beach, and yet they persist in the same locations despite the high wave energy. We suspect this stability, as well as their origin, may be linked to the underlying geology of the nearshore. This study was designed simply to investigate the potential spatial correlation between shore-oblique bar fields and channel locations. Although a statistically significant relationship between the bar/outcrop regions and underlying paleo-channels was demonstrated, we understand that the nature of a potential causal relationship is not addressable from these data. We believe, nonetheless, that the fact that they are spatially related may give insight into the mechanisms responsible for their existence.

The spatial relationships were assessed both visually and quantitatively. A plan view of each study site overlain by the locations of the bar/outcrop regions as well as the buried channels (Figures 7-9) demonstrates that all of the gravel outcrops and most of the channels were found in close proximity to the shore-oblique bars, suggesting high spatial correlation. This relationship is further strengthened by the nature of the seismic reflection profiles that fall within and outside of the bar areas. In all cases, there is a distinct difference between the sub-bottom cross-sections lying within the bar/outcrop region. The seismic lines which lie well outside these regions show a typical onshore-offshore sub-bottom profile: gently sloping, low relief, horizontal strata (Figures 10-15). The seismic lines which cross through and seaward of the bar/outcrop regions, however, display very distinct chaotic reflector patterns, likely indicating reworking of older strata by the meandering and down-cutting of Pleistocene rivers or relict tidal inlets. Simply put, evidence of prior reworking by a relict channel is found in all of the bar/outcrop regions. For example, in the Kitty Hawk site, there is a tie line which lies outside of the bar region in the northern half of the study site and falls seaward of the bar region at its southern end (Figure 12). Interestingly, the reflectors on the northern end of the line are parallel and gently sloping, while the reflectors at the southern end show no such order (Figure 13), once again strengthening the connection between channel location and the shore-oblique bars and outcrops.

A chi square test was used to determine whether a significant quantitative relationship exists between the locations of the bar clusters and underlying channels. The results of this test revealed a strong relationship between the locations of the two types of features. Our chi square value of 949.98 was orders of magnitude higher than the significant value of 10.83 at the 0.1% confidence level. In order to quantify this spatial relationship, a cross correlation analysis was used to compare the bars and channels at each study site individually, and across the study sites as a whole. The correlations were statistically significant at the 1% confidence interval for the collective study sites and the Sandbridge site. While the correlation coefficients were relatively high at the Kitty Hawk and Nags Head sites, our conservative method of determining sampling size (total of interfluve and channel areas) did not render them statistically significant.

Following the establishment of a spatial correlation, we scrutinized the channels to determine distinguishing features of those that appear to correlate more closely with the bar regions. Figures 7-9 reveal that the channels that lie closest to the bar/outcrop areas tend to have the widest cross-sections. Further, where channels are better defined acoustically with distinctive reflectors indicating downcutting and back-filling (e.g. Kitty Hawk and Sandbridge sites), bar fields are larger. In contrast, Nags Head, which has large areas of chaotic reflectors, but less definition, has the smallest bar fields. This suggests that while channel width seems to be the most important parameter in determining bar location, the size of a bar field might be related to the level of definition of the channel reflectors. We believe that this level of definition might be due to lithologic differences between fluvial channel fill and migrating tidal inlet fill. Greater density differences between fluvial channel fill types would result in higher reflection coefficients and more pronounced seismic reflectors. Our major channels follow this trend with those at Sandbridge and Kitty Hawk potentially tied to the paleo-James and paleo-Roanoke-Albemarle, respectively and that at Nags Head perhaps associated with the historic Roanoke Inlet, which was open between 1585 and 1817 and migrated at least 4 km during that span (Fisher, 1962; Riggs et al., 1995).

An attempt was made to determine the influence of the depth of burial of a channel on its correlation with the shore-oblique bars. Since it seems intuitive that, all other things being equal, a channel that is more deeply buried will have less of an influence on overlying sediments, another cross correlation comparison was performed after subtracting the amount of burial (DBSF) from the real channel depth (Figure 6). While this was done at the scale of an entire site, rather than that of individual channels, it might yet prove to be a useful indicator since the site with the most deeply buried channel (Sandbridge) showed the lowest correlation for this comparison (Table 2). The depth at which a channel is buried beneath the seafloor cannot itself be used as a diagnostic, since it is dependent in part on sampling location; closer to shore, the Holocene sand is thicker so the same channel will be more deeply buried than it is farther seaward. It could be used for a relative comparison, however, for perhaps looking at two different channel cross-sections that lie along the same isobath. Even though some channels are more deeply buried and may not directly influence the overlying bathymetry, they may still provide insight. If they are older iterations of overlying paleo-fluvial systems, they will most likely correlate spatially, so width still seems to be the most important parameter in determining influence on surface expression.

5.2 Prospective field and management applications

The larger paleo-channels in the seismic record showed high spatial correlation with the locations of nearshore bar/outcrop fields. While the processes that might cause or influence such a relationship are still unknown, the importance of this connection is immediately applicable in shoreline management practices. For example, Boss et al. (2002) provide a map of paleo-channels on the inner shelf of northern North Carolina. We mapped the nearshore portion of one of these thalwegs at our site in Kitty Hawk, NC. This is the location of the largest bar/outcrop region and best-defined channel (presumably the paleo-Roanoke-Albemarle River), as well as a long-term erosional hotspot. We also mapped the nearshore region of Sandbridge, VA, where a large channel complex has been identified offshore (Chen et al., 1995; Dame, 1990; Hobbs, 1997; Kimball and Dame, 1989). Like the previous example, this site is characterized by a well-defined channel, large bar region and shoreline hotspot. If the shoreline erosion at these locations is attributable to the underlying channels, then it stands to reason that in similar environments, one might be able to trace channels mapped on the inner shelf into shore to predict areas susceptible to erosion. In other words, it might be possible to make educated guesses about shoreline erosion using data that already exist in the literature.

A simple test of this method was done with Hine and Snyder's (1985) map of paleo-channels in Onslow Bay, NC. Figure 17 shows the locations of their mapped channels coupled with North Carolina shoreline change rates from 1998 (more recent rates were not used due to substantial beach nourishment.) The shoreline change rates for Bogue Banks show four main areas of erosion. Hine and Snyder (1985) mapped two major channels on the inner shelf that can be traced inshore. The westernmost channel corresponds well with the area of erosion just east of Bogue Inlet. The easternmost channel appears to have several iterations closer to shore, two of which are still seen in their innermost seismic line. There is a smaller channel that lies in the vicinity of Beaufort Inlet, but the erosion here is more likely attributable to inlet dynamics. Overall, there are four channels discernible landward of the 10 m isobath, all of which lie near one of the four main areas of beach erosion.

We are not suggesting that such associations between paleo-channels and erosion-prone regions of shoreline will always apply. Nor are we suggesting that paleo-channels will always be associated with shore-oblique sandbars and vice versa; indeed, this was not always the case in our data. However, the established spatial relationship between buried channels with nearshore bedforms and shoreline erosion in the northern Outer Banks and southern Virginia, and the apparent similar association found in Onslow Bay suggest sub-bottom mapping of inner-shelf paleo-channels may prove to be a useful guide for predicting the location of future erosion-prone areas. Ultimately, the primary scientific goal is to illuminate the mechanisms involved in this relationship, but the potential applications that have resulted thus far are compelling.

5.3 Prospective mechanisms

The idea that a buried feature could possibly have any influence on nearshore morphodynamics is contrary to the widely accepted concept of shoreface slope and bedforms responding simply to wave energy and mean sediment size (Komar, 1998; Pilkey et al., 1993). The spatial association suggests a more complex picture, one in which other variables such as sediment heterogeneity (vertical and horizontal), and seabed roughness gradients (which, in turn, may be dictated by paleo-channels), may play an important role in bar morphodynamics and beach erosion.

One possible explanation for the spatial relationship between buried channels and shore-oblique bars in the nearshore is submarine groundwater discharge (SGD) (Corbett et al., 2001). A lens of freshwater accumulated from rainwater underlies barrier islands. It is well known that these freshwater reservoirs can seep into the marine environment where the fresh groundwater first encounters interstitial saline water in the nearshore (Valiela et al., 1990). Ongoing studies are investigating the effect of this discharge in terms of contaminants (Corbett et al., 2002). It is possible that channel fill sediments might act as an aquitard (compact estuarine muds) or as a conduit (coarse-grained fluvial gravel) for groundwater. Inspection of channel cross-sections in the seismic record reveals definite lateral heterogeneity. While it is only speculation until coring has occurred, perhaps some of this heterogeneity is due to alternating coarse and fine sediments. Coarser sediment could have been left near the top of the channel at the initial cut-bank or at a point bar after the river continued to migrate. Finer sediments would have back-filled the available accommodation space during transgression (Belknap and Kraft, 1985). If freshwater discharge is higher at the locations of the more porous, coarse-grained sediments, perhaps it could alter sediment transport potential. The overlying Holocene sediments at these locations would have increased interstitial water content and thus increased porosity, making them more easily erodible, perhaps resulting in the formation of irregular bathymetric features.

Another possible explanation for the correlation between paleo-channels and shore-oblique bars is the exposure of channels farther offshore where the overlying sediment is thinner. The various lithologies exposed, ranging from fine-grained, compact estuarine muds to coarse fluvial gravels, could create roughness gradients and/or bathymetric irregularities leading to an influence on waves. Ardhuin et al. (2003) showed that heterogeneity of surficial sediments could, in fact, impact waves as they propagate across the shelf, and many have shown the influence of holes (Bender and Dean, 2003) or highs (Cox et al., 1995) on wave direction near the beach. Presumably, alteration of the incident wave energy could result in alongshore gradients in nearshore sediment transport (Ashton et al., 2003). This may possibly explain different bar formations and spatial variations in beach erosion, but the presence of persistant outcropping gravel patches in the nearshore remains unexplained. Furthermore, nearshore sand volume calculations in this region, indicate that such gradients have not resulted in significant alongshore sand volume variations (Miselis and McNinch, 2002; 2003)

A more plausible scenario, we feel, also involves exposure of channel fill, but in the nearshore region rather than farther out on the shelf. During high energy conditions, upper layers of Holocene sand get stripped away in the nearshore, exposing underlying surfaces of differing lithology (Pearson, 1979; Thieler et al., 2001). Where these surfaces are composed primarily of coarse gravel (such as from relict riverine point bars), larger turbulent eddies form, inhibiting the settling of finer-grained material, as was described by Green et al. (2004). The exposure thus initiates a self-sustaining feed-back mechanism as described by Murray and Thieler (2004) such that coarse rippled beds inhibit settling of fine material, thereby sustaining and increasing the partitioning effect between the two grain sizes. Unlike the previous hypothesis, this one explains both the location of the bar fields, and the gravel exposures on the updrift flanks of the bars. This could be initially tested with densely-spaced cores across the width of a channel. The close spacing would capture cross-channel heterogeneity and determine if channel-fill gravels can be found close to the seafloor, and are thus a plausible source material for this mechanism. A combined hydrodynamic and sediment transport study would be necessary, however, to thoroughly test this hypothesis.

6. Conclusions

Results from this study show the following:

1) Underlying, relict channels in the nearshore correlate spatially with regions of shore-oblique bars and gravel outcrops. Because the bar and outcrop regions have been previously linked to erosional hotspots, this finding has direct bearing on shoreline management.
2) Underlying channel size (width) is the most important factor in determining presence of a shore-oblique bar field.
3) Size of a bar region may be dictated by lithology of fill material; larger bar fields may form over relict fluvial channels while smaller bar regions may be associated with tidal inlet channels.

In the region investigated in this study (southeastern Virginia and the northern Outer Banks of North Carolina) we identified three shore-oblique bar/outcrop clusters with associated erosional hotspots. Each bar region was underlain by a large paleo-channel. From this, it was surmised that a first-order approach to identifying potential erosional hotspots would be to trace previously mapped channels into shore. A cursory test of this method was performed with published data from Onslow Bay, NC. Comparing channels mapped on the inner shelf with shoreline change data revealed that all four channels discernible landward of the 10 m isobath lie near the four main areas of beach erosion on Bogue Banks.

Several possible mechanisms were proposed to explain the correlation between shore-oblique bars fields and paleo-channels, including submarine groundwater discharge modifying the hydrodynamic environment, and the exposure of coarse channel fill and resultant self-organization of bedforms. While illuminating the precise mechanism will require further study and coring efforts, the results thus far may provide immediate and important management applications.

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Figure 10. Sandbridge cross-shore seismic line locations for sub-bottom data shown in the following figure.

Figure 11. Sandbridge sub-bottom cross-sections. A-A' lies outside the bar area and exhibits gently sloping reflectors. B-B' falls within the bar area and shows chaotic and truncated reflectors, evidence of channel meandering and downcutting.

Figure 12. Kitty Hawk cross-shore seismic line locations for sub-bottom data shown in the following figure.

Figure 13. Kitty Hawk sub-bottom cross-sections. As in Sandbridge (Figure 10), only those cross-sections underlying the bar area show evidence of buried paleo-channels.

Figure 14. Nags Head cross-shore seismic line locations for sub-bottom data shown in the following figure.

Figure 15. Nags Head sub-bottom cross-sections. Neither line falls near the shore-oblique bar/gravel outcrop region and neither line reveals relict channels.

Figure 16. Graph of paleo-channel depths and bar metrics plotted against location (northing, UTM) every 10 meters in the alongshore direction.

Figure 17. Locations of relict channels in Onslow Bay identifiable in the seismic record at the 10 m isobath (from Hine and Snyder, 1985) and superposition of 1998 shoreline change rates (from NC Division of Coastal Management). Shaded areas show where elevated erosion rates shown on the graph correspond with the shoreline.

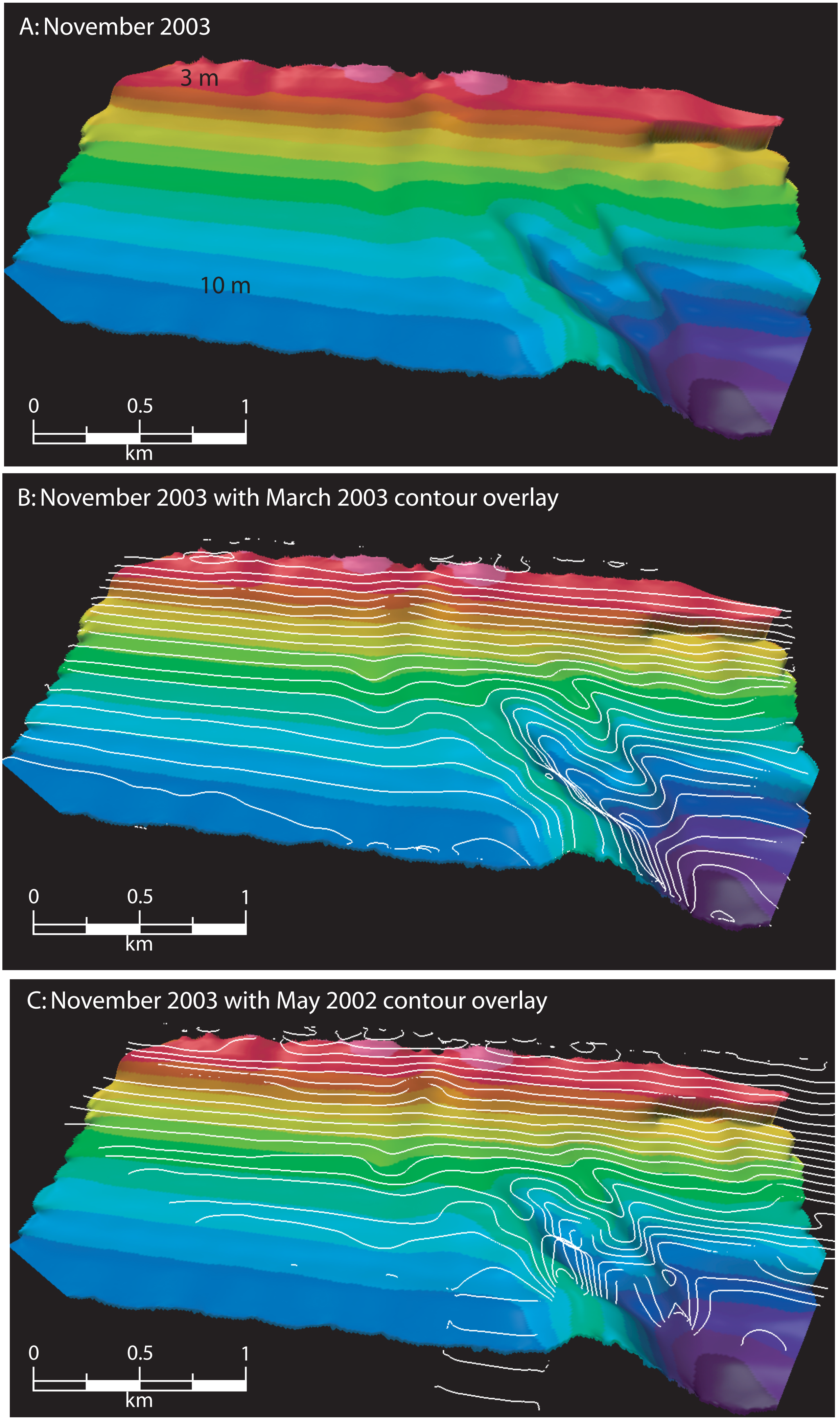
	Channels	No Channels	Total
Bars	1281	397	1678
No Bars	336	1198	1534
Total	1617	1595	3212

Degrees of freedom = 1
$\chi 2$ = 949.98
$p < 0.001$

Table 1

Study Site	Channel depth referenced to seafloor	Channel depth referenced to top of channel	Incorporating importance of channel burial
Sandbridge	0.7991	0.494	0.4374
Kitty Hawk	0.7413	0.7029	0.639
Nags Head	0.6621	0.6679	0.551
All Sites	0.6359	0.7124	0.6082

Table 2



A: November 2003
3 m
10 m
0
0.5
1
km
B: November 2003 with March 2003 contour overlay
0
0.5
1
km
C: November 2003 with May 2002 contour overlay
0
0.5
1
km

Figure 1

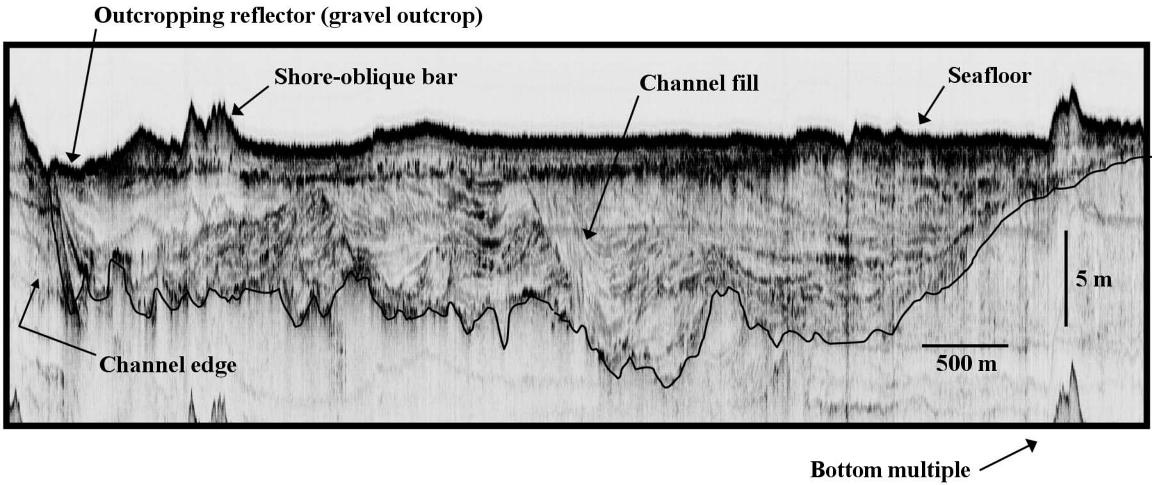

Outcropping reflector (gravel outcrop)
Shore-oblique bar
Channel fill
Seafloor
5 m
500 m
Channel edge
Bottom multiple

Figure 2

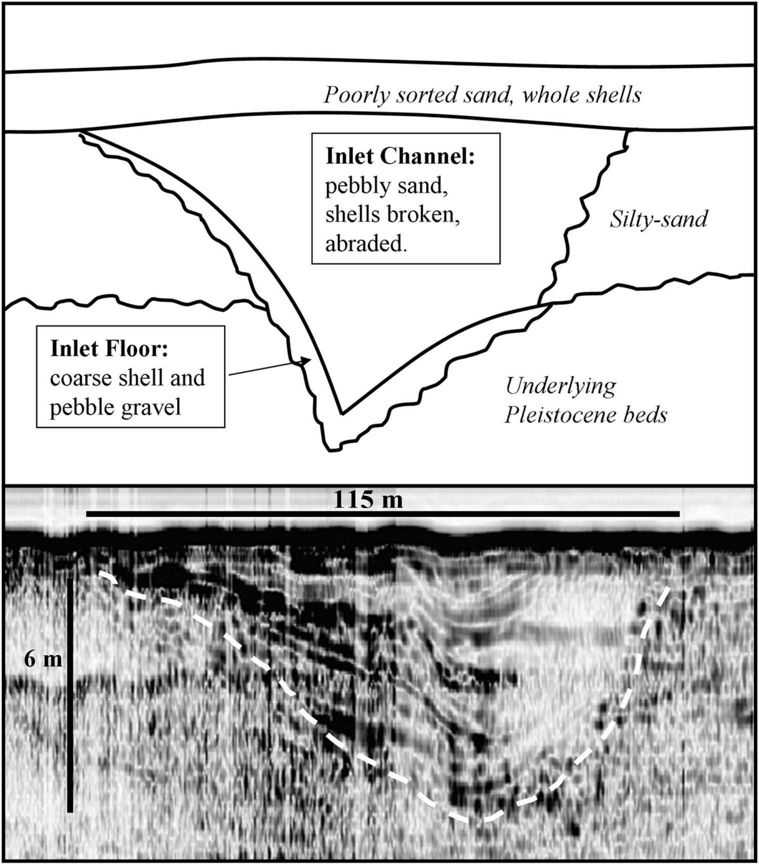
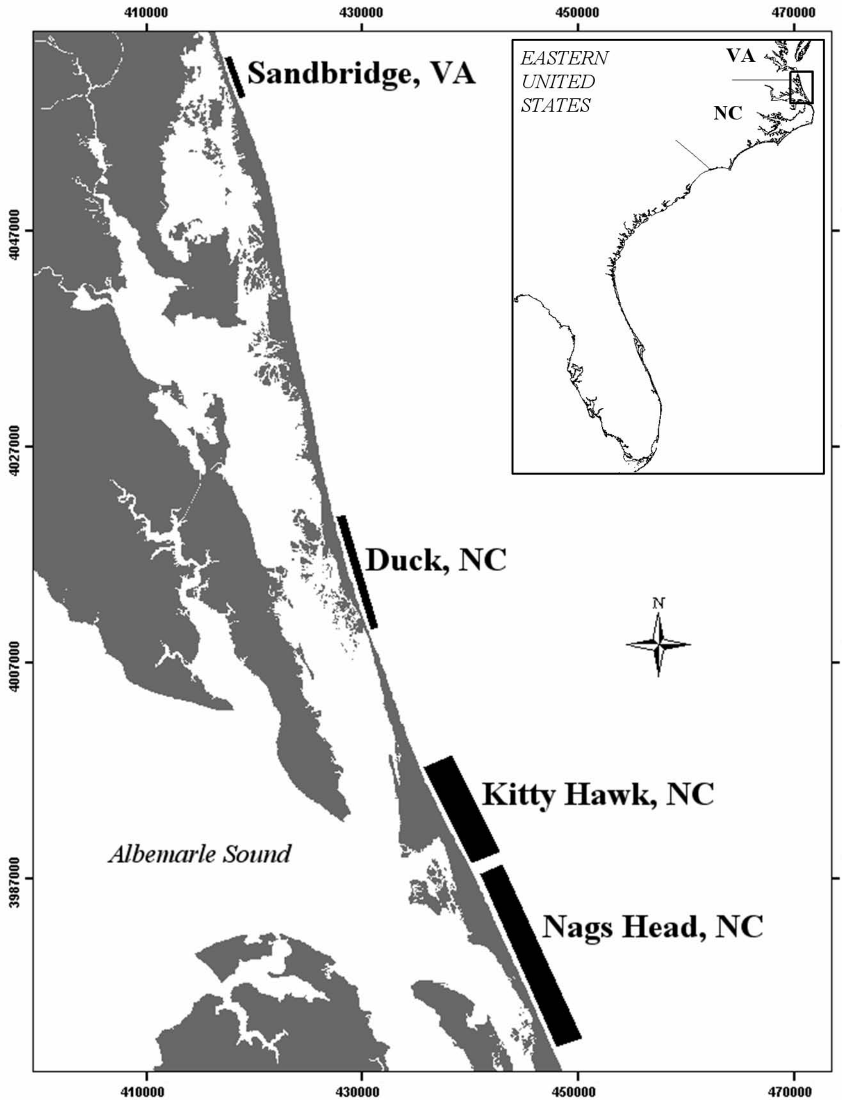
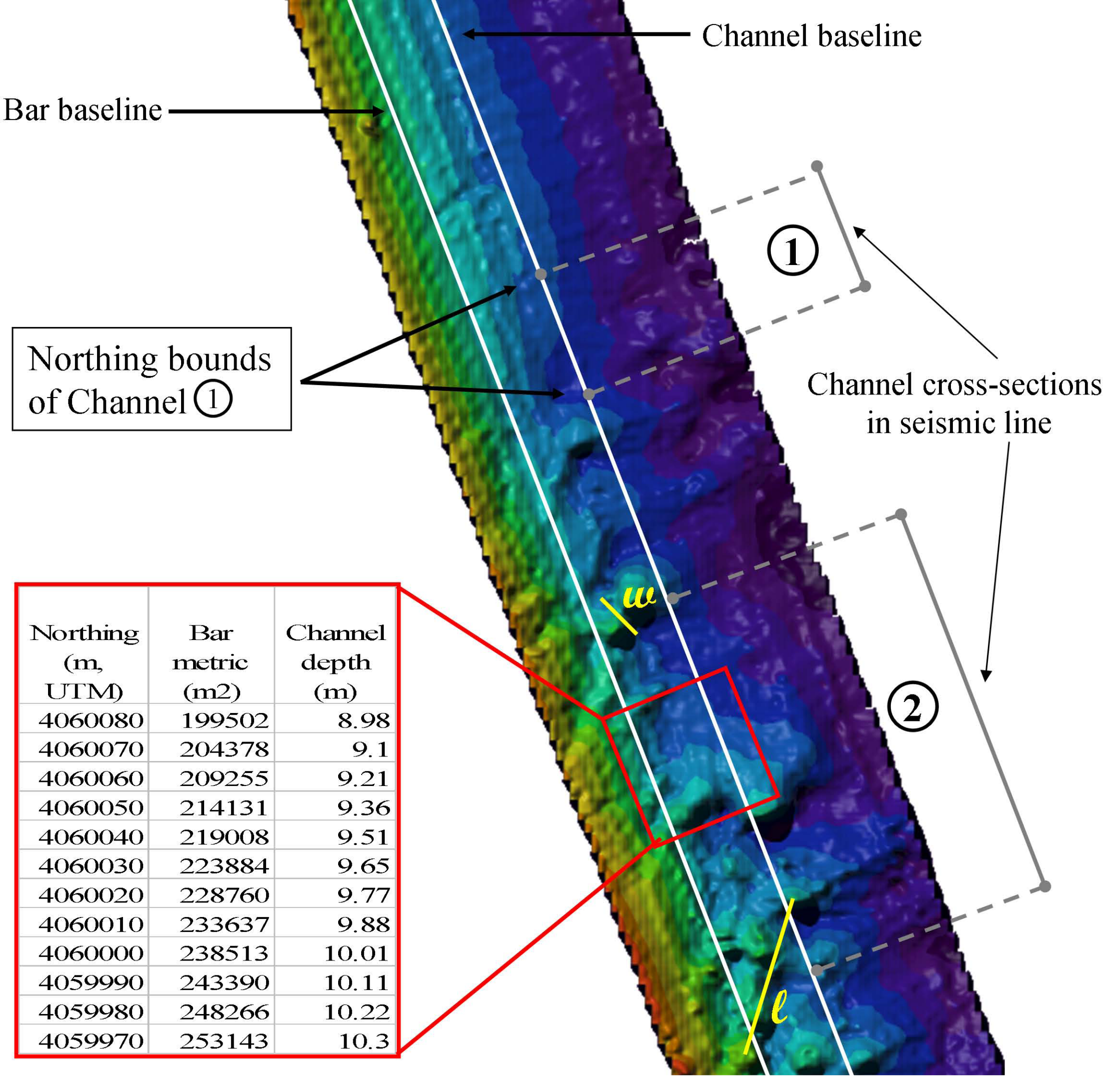

Poorly sorted sand, whole shells
Inlet Channel: pebbly sand, shells broken, abraded.
Silty-sand
Inlet Floor: coarse shell and pebble gravel
Underlying Pleistocene beds
115 m
6 m

Figure 3



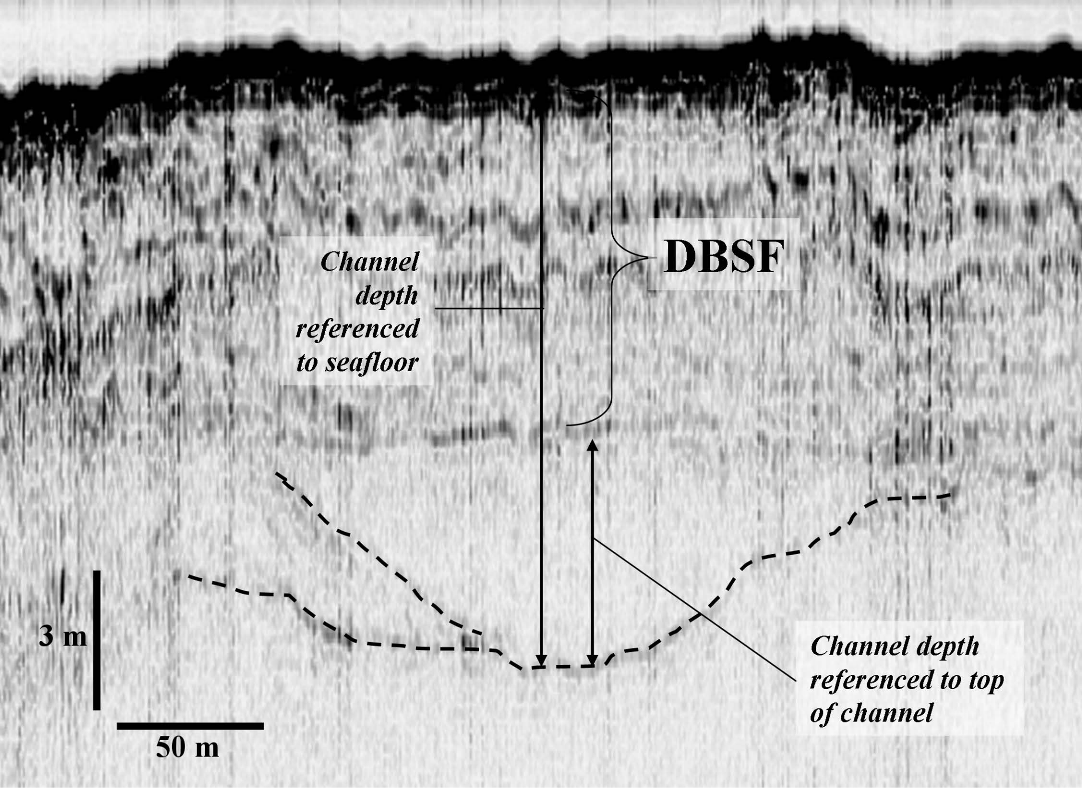
410000
430000
450000
470000
4047000
4027000
4007000
3987000
Sandbridge, VA
Duck, NC
Kitty Hawk, NC
Nags Head, NC
Albemarle Sound
EASTERN UNITED STATES
VA
NC
N

Figure 4



Northing (m, UTM)	Bar metric (m2)	Channel depth (m)
4060080	199502	8.98
4060070	204378	9.1
4060060	209255	9.21
4060050	214131	9.36
4060040	219008	9.51
4060030	223884	9.65
4060020	228760	9.77
4060010	233637	9.88
4060000	238513	10.01
4059990	243390	10.11
4059980	248266	10.22
4059970	253143	10.3

Figure 5



Channel depth referenced to seafloor
DBSF
Channel depth referenced to top of channel
3 m
50 m

Figure 6

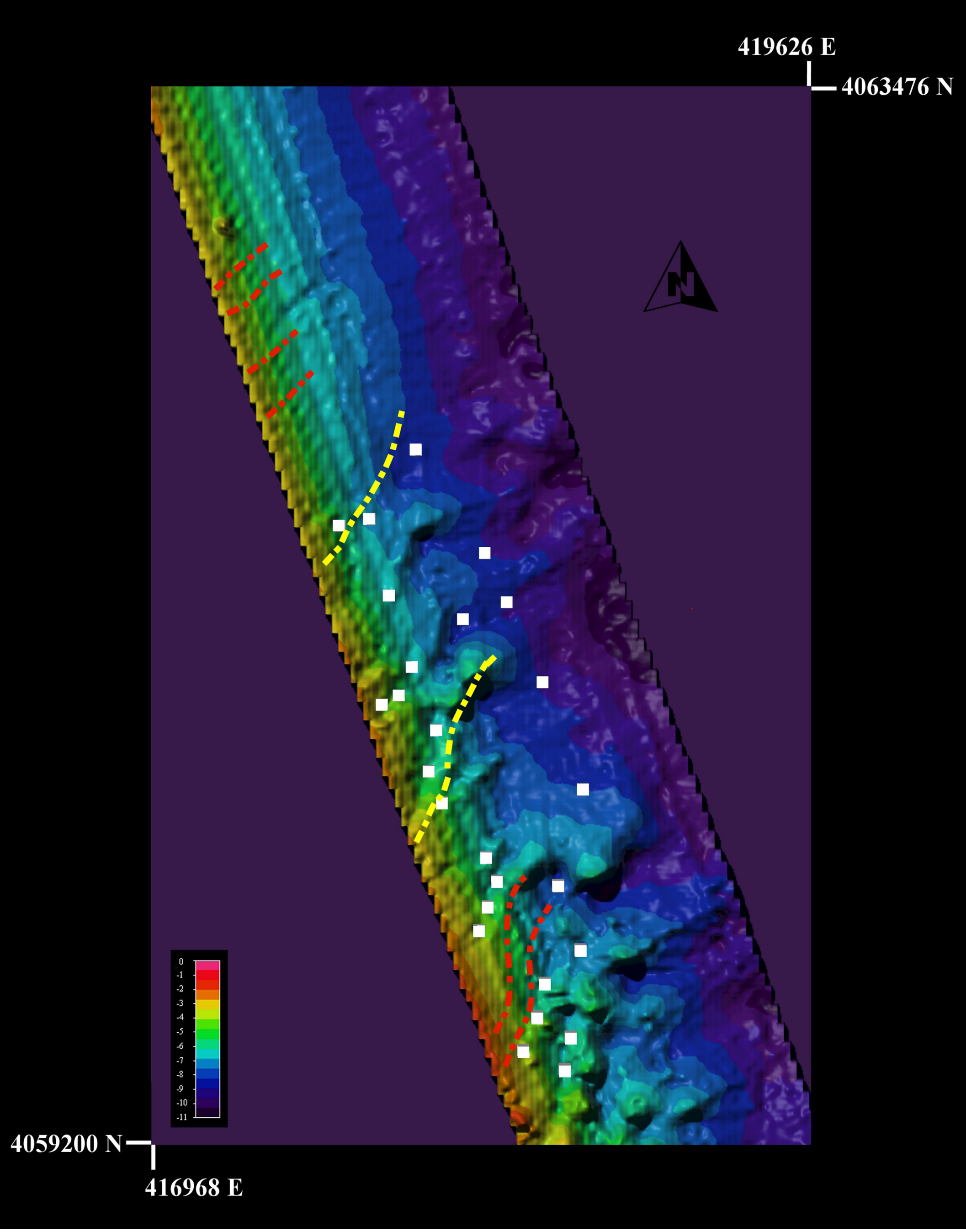


Figure 7

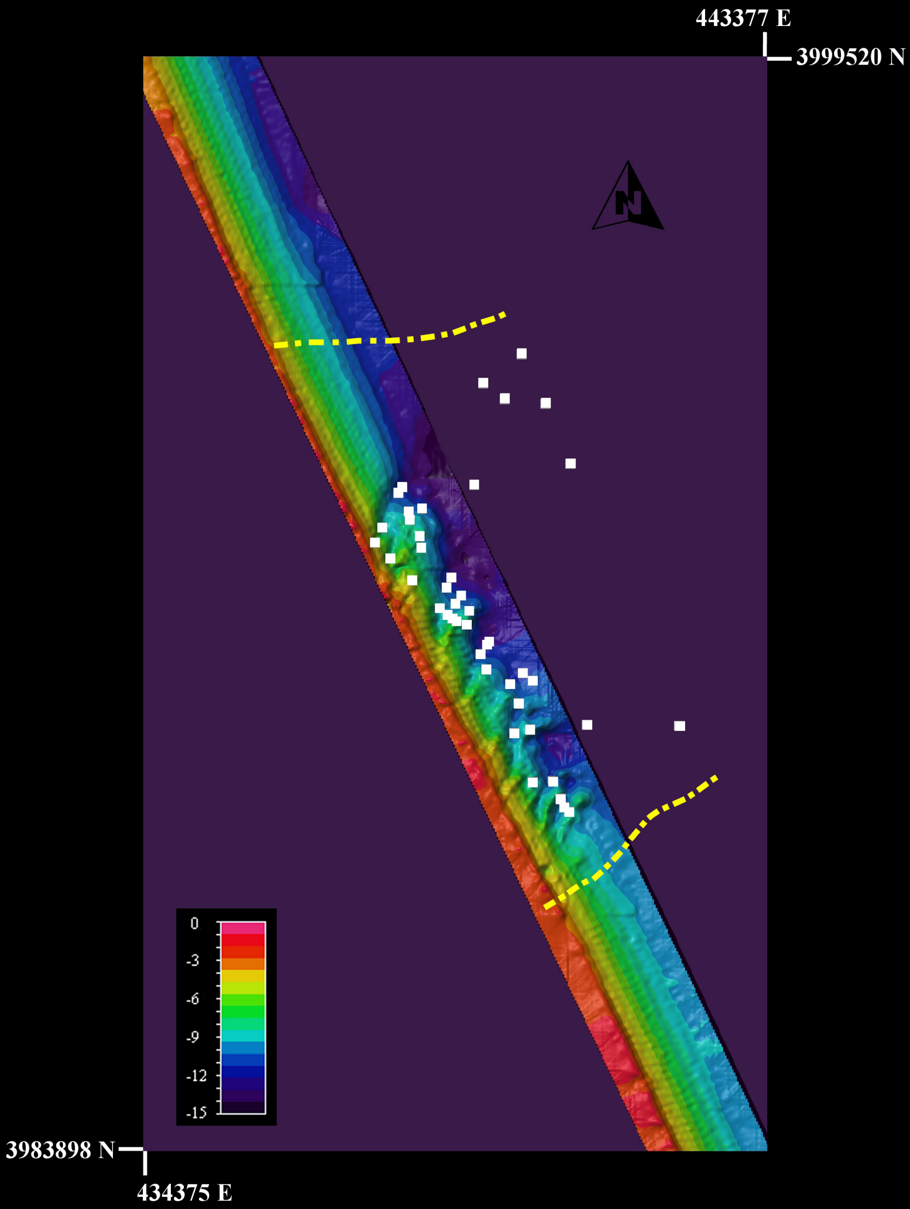


Figure 8

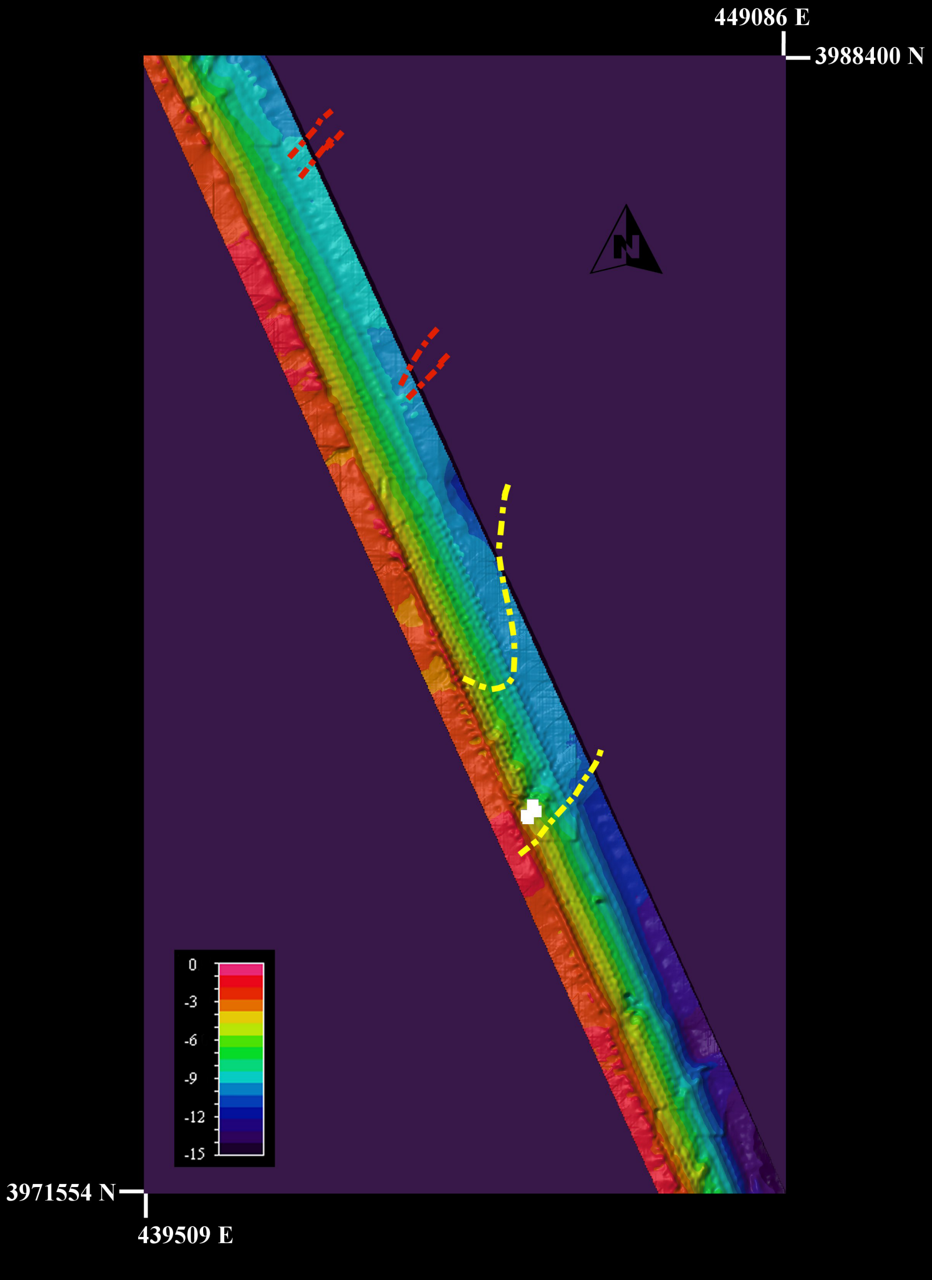


Figure 9

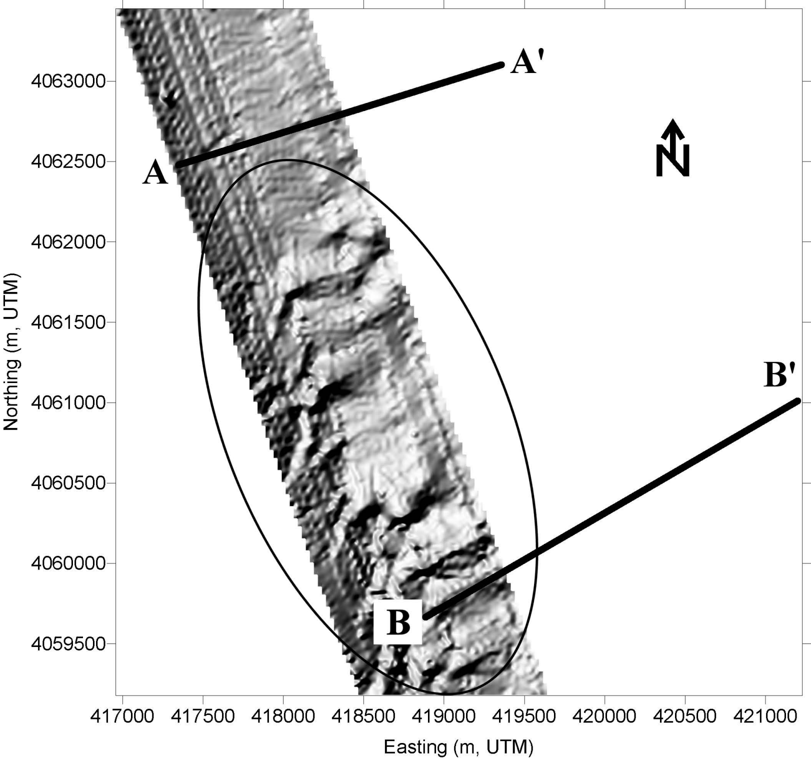

A'
A
N
B'
B
4063000
4062500
4062000
4061500
4061000
4060500
4060000
4059500
Northing (m, UTM)
417000
417500
418000
418500
419000
419500
420000
420500
421000
Easting (m, UTM)

Figure 10

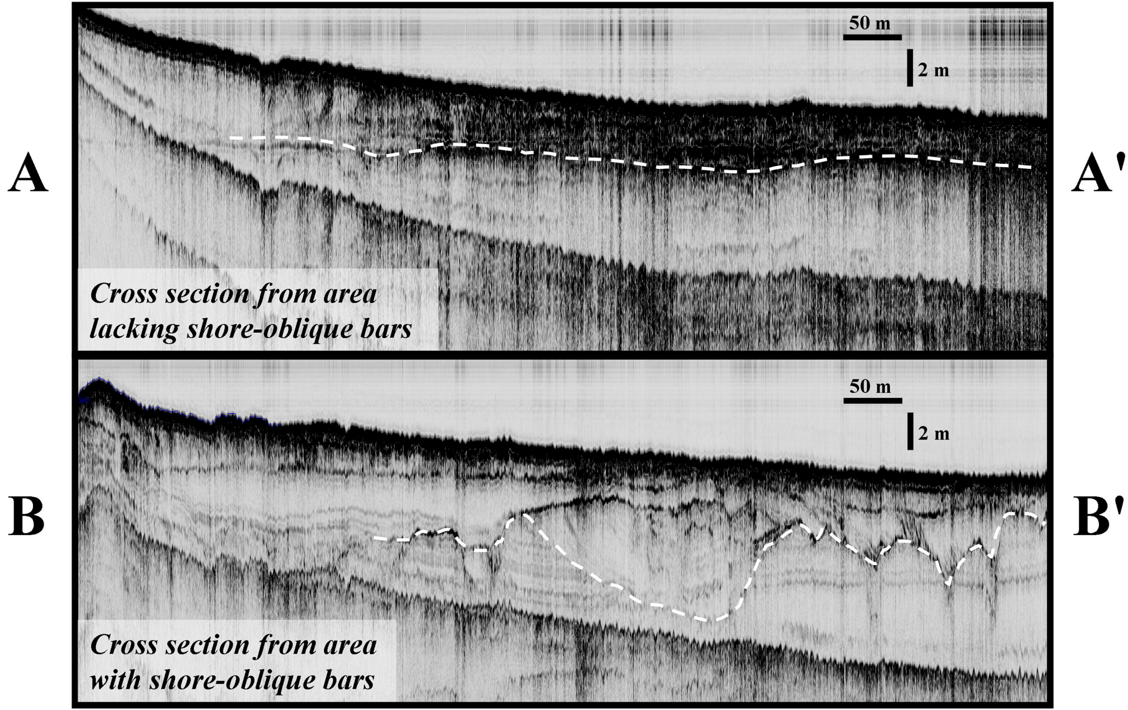
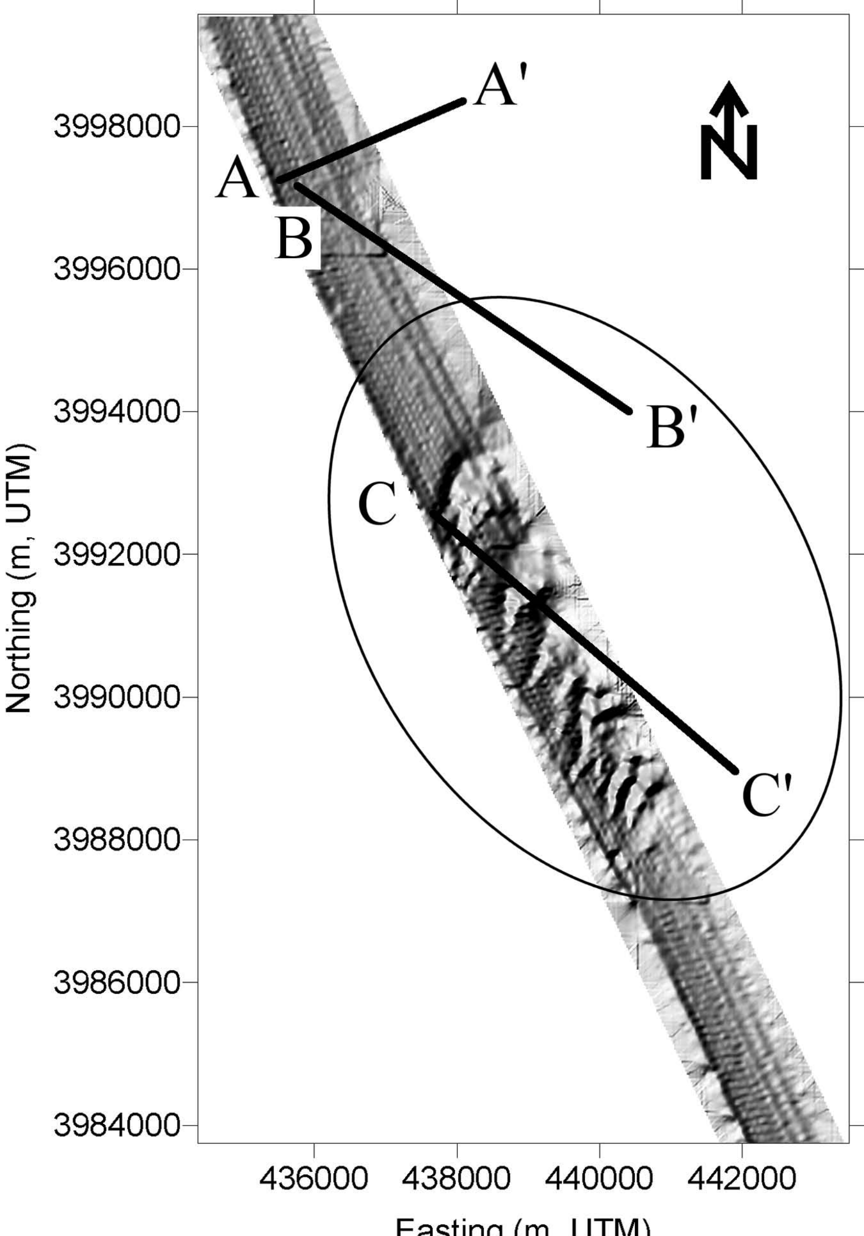

A
A'
50 m
2 m
Cross section from area lacking shore-oblique bars
B
B'
50 m
2 m
Cross section from area with shore-oblique bars

Figure 11



A'
A
B
B'
C
C'
N
3998000
3996000
3994000
3992000
3990000
3988000
3986000
3984000
Northing (m, UTM)
436000
438000
440000
442000
Easting (m, UTM)

Figure 12

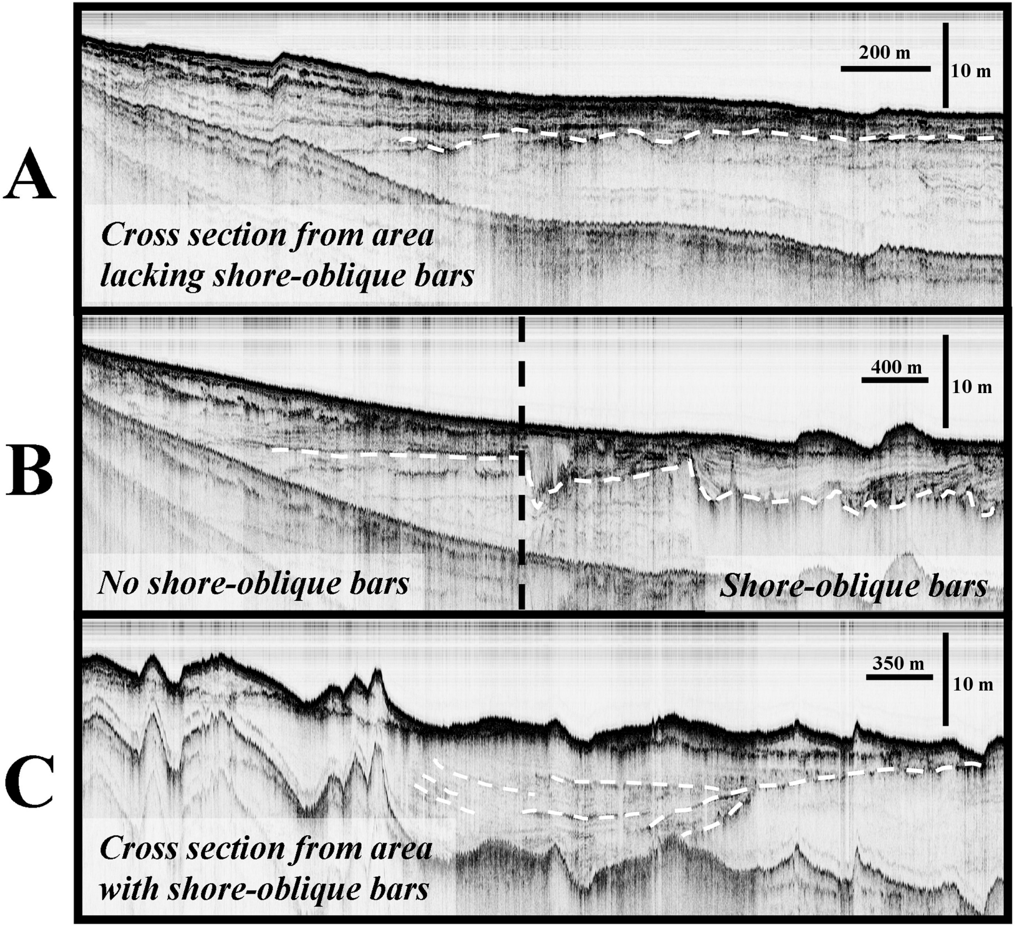

A
A'
200 m
10 m
Cross section from area
lacking shore-oblique bars
B
B'
400 m
10 m
No shore-oblique bars
Shore-oblique bars
C
C'
350 m
10 m
Cross section from area
with shore-oblique bars

Figure 13

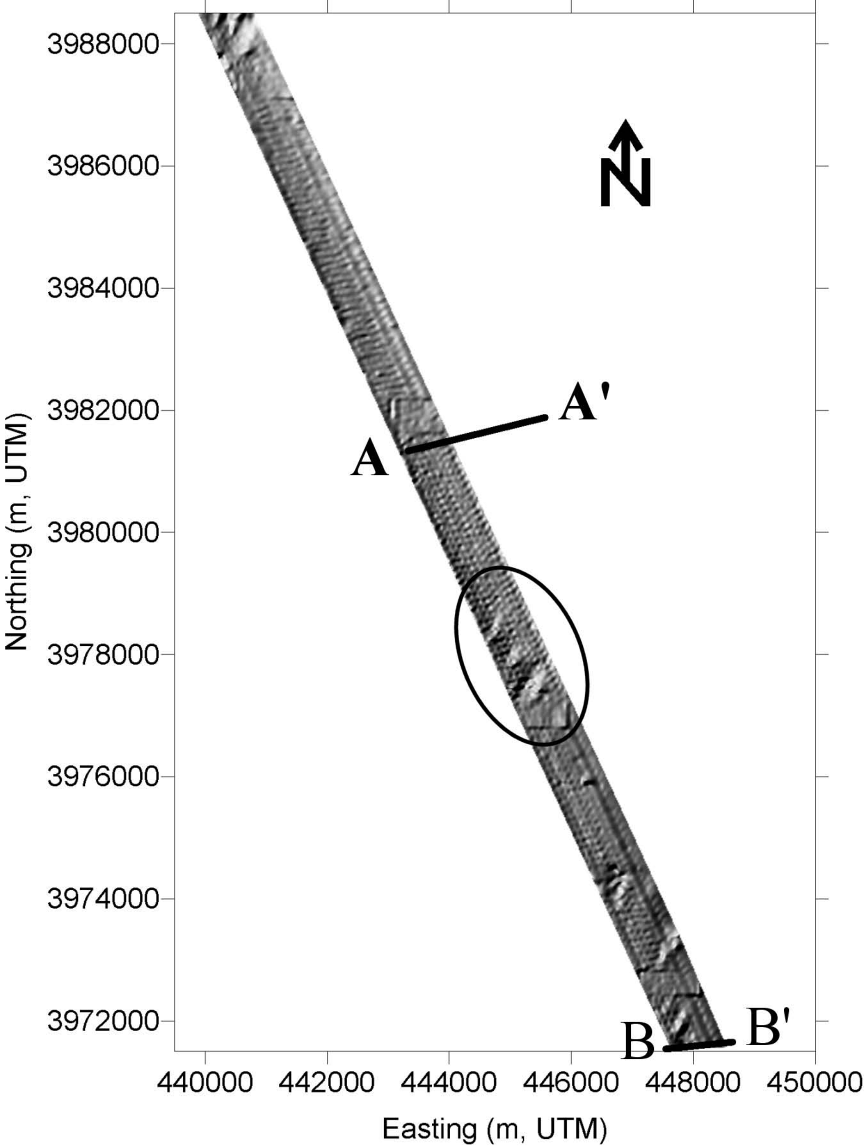

3988000
3986000
3984000
3982000
3980000
3978000
3976000
3974000
3972000
Northing (m, UTM)
440000
442000
444000
446000
448000
450000
Easting (m, UTM)
N
A
A'
B
B'

Figure 14

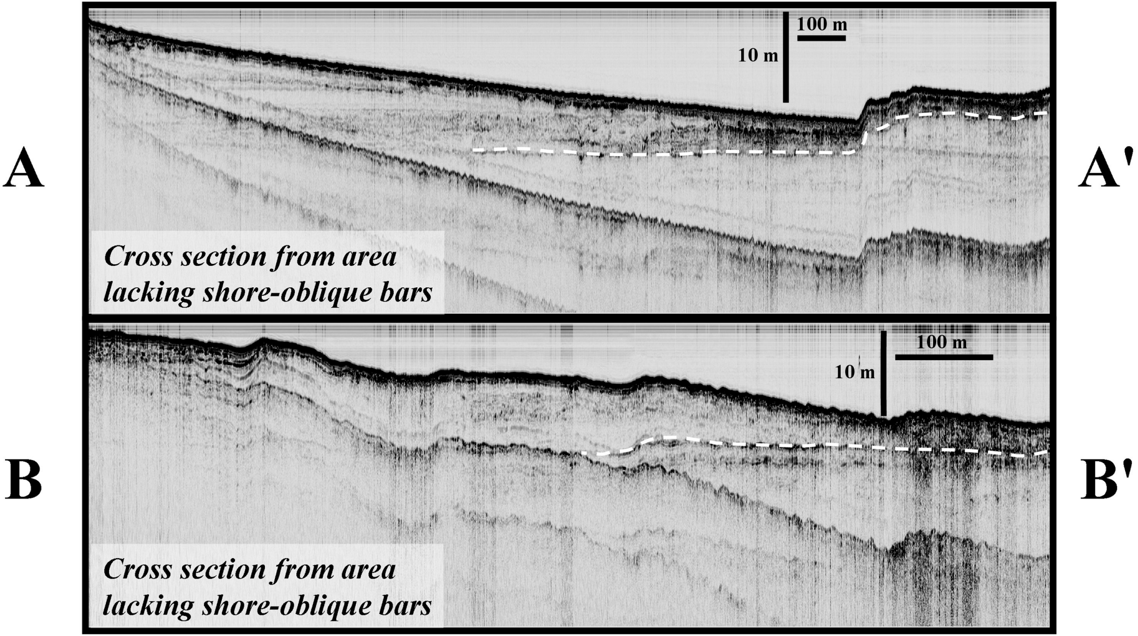

A
A'
100 m
10 m
Cross section from area
lacking shore-oblique bars
B
B'
100 m
10 m
Cross section from area
lacking shore-oblique bars

Figure 15

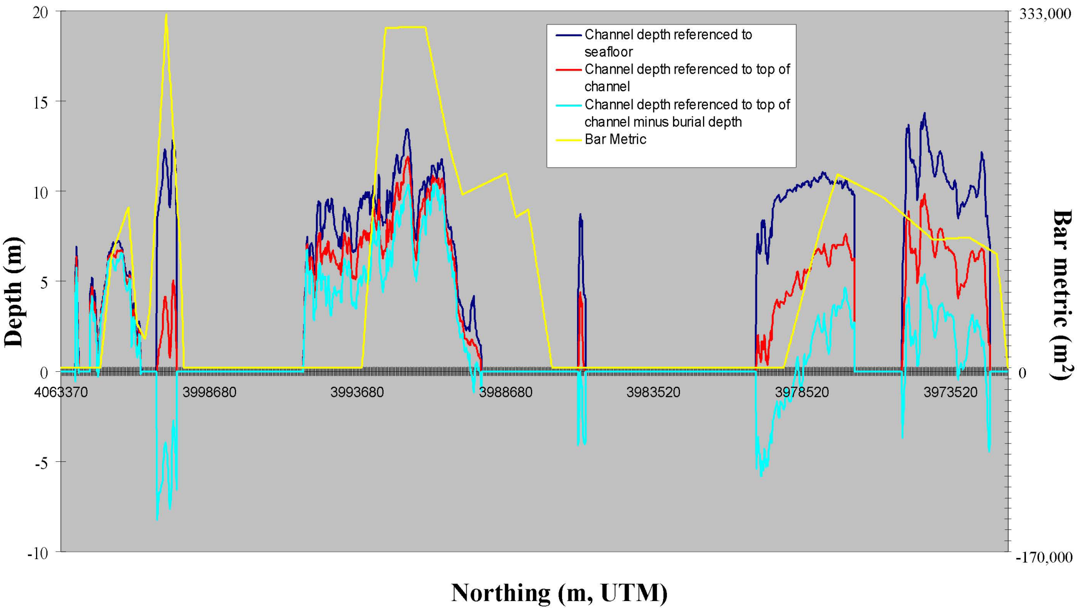

Channel depth referenced to seafloor
Channel depth referenced to top of channel
Channel depth referenced to top of channel minus burial depth
Bar Metric
Depth (m)
20
15
10
5
0
-5
-10
333,000
0
-170,000
Bar metric (m²)
4063370
3998680
3993680
3988680
3983520
3978520
3973520
Northing (m, UTM)

Figure 16

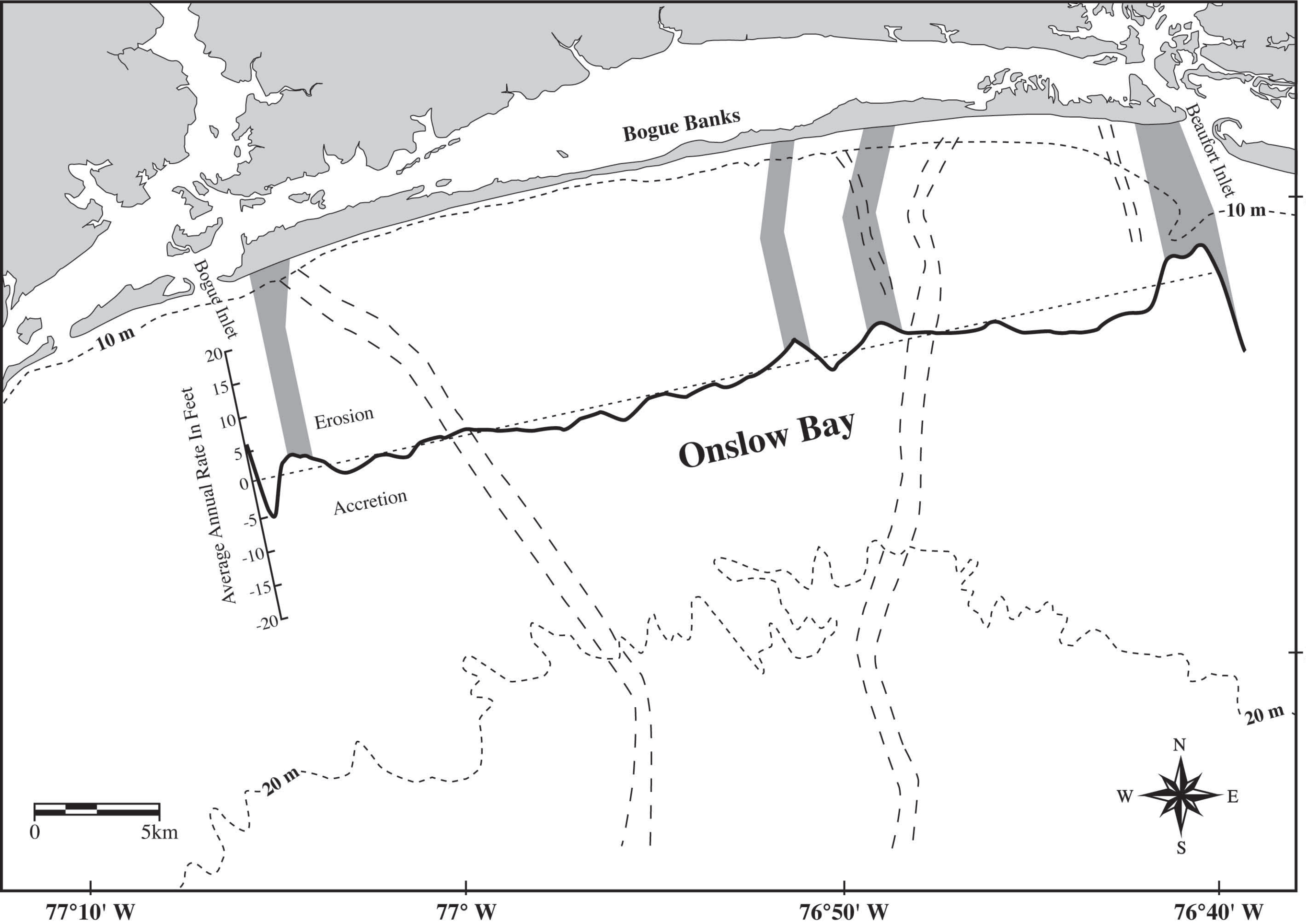

Bogue Banks
Beaufort Inlet
Bogue Inlet
10 m
10 m
34°40' W
34°30' W
20 m
20 m
Onslow Bay
Erosion
Accretion
Average Annual Rate In Feet
20
15
10
5
0
-5
-10
-15
-20
0
5km
N
W
E
S
77°10' W
77° W
76°50' W
76°40' W

Figure 17

CONCLUDING THOUGHTS

The concept of a monitoring protocol for the environmentally sound management of federal offshore borrow areas along the U.S. east and Gulf of Mexico coasts is complex. In 2001 Research Planning, Inc. et al. developed such a protocol for the Minerals Management Service (MMS). The proposed protocol addresses six issues:

1: Bathymetric and Substrate Surveys
2: Sediment Sampling and Analysis
3: Wave Monitoring and Modeling
4: Shoreline Monitoring and Modeling
5: Benthic Communities and Their Trophic Relationships to Fish, and
6: Marine Mammal and Wildlife Interactions During Dredging.

The procedures, techniques, and tools advanced to examine these issues are fully appropriate for use in the study of each of the issues at specific sites and, if adopted as a mandatory element of dredging projects, should provide robust datasets.

However the concept of a monitoring protocol is substantially more difficult than the mechanics of the protocol. In order for the protocol to be accepted and effective, several questions need be answered. Why is the monitoring being performed? Who, as in what agency, will supervise the work? Who pays the bills? Where will the data be housed?

Why should an offshore borrow area be monitored? There are two, somewhat interconnected, underlying reasons. The practical reason is to assess the accuracy of the predictions that were used in the design and consideration of the dredging process. The scholarly reason is to learn about the “recovery” process. And the tie between these two is the desire to improve the models used during the planning process so that predictions made for subsequent dredging projects will be more accurate.

The predictions and the models used in developing them are concerned with assessing and quantifying the changes to the ambient or natural environment resulting from the dredging project. And these changes relate to the six issues noted above. How will the dredging operation alter the bathymetry and how will those alterations lead to changes in the (sedimentological) character of the sea floor? What is the nature of the “recovery” of the sea floor? Do the trenches or pits that result from the excavation fill in; if they do, how quickly and with what? As wave transformation, primarily refraction, is a function of the bathymetry and , to a lesser extent, character of the sea floor, how and in what circumstances will the modifications of the sea floor change wave transformation? Hence the need for wave monitoring.

For many reviewers, the biological monitoring is of the highest importance, given broad societal concerns for the living portions of the environment. However the significance may vary from region to region. In the Sandbridge study area no negative environmental impacts were observed for macrobenthos or demersal fishes. This might not be true for all regions, especially if the preferred dredged material is beneath a muddy overburden. Also with its reliance on extensive field sampling and labor intensive analyses, each element of a biological monitoring program must be considered in the light of the local situation.

In some respects, monitoring and modeling the shoreline is the key issue. As at present the vast majority of the offshore dredging projects in the U.S. are for beach nourishment, there can be a strong case for tracking changes in the shoreline. Other than the obvious, gross, and acute act of placing sand on the beach, most shoreline changes are the result of wave action. Thus monitoring the shoreline can provide direct evidence with which to assess changes in wave transformation. Have sites of chronic erosion or deposition shifted? Monitoring the rate of shoreline changes can indicate the level of success of the nourishment project and provide data to predict the timing of renourishment efforts.

The biological issues also are interrelated. The usual assumption is that all of the benthic infauna and sessile epifauna within the dredged sediment or at the nourishment site die as a consequence of the mechanical disturbance. And as other marine organisms such as fish, marine mammals, and turtles, often feed upon the benthic fauna, there is valid reason for concern with the secondary impacts of a dredging project. How quickly do benthic fauna recolonize the disturbed area? How closely does the biological community of the recolonized area resemble that which existed before dredging? What is the extent and duration of the impacts upon the mobile and transitory species? And, of course, how closely do the post-dredging conditions approach those predicted by the pre-project estimates and models?

The preceding sentence emphasizes another aspect of any such monitoring program: in order to understand the rates of change of conditions resulting from dredging, there must be a thorough knowledge of the predredging conditions; in order to assess the accuracy of models predicting change, it is necessary to know what the initial conditions were so that the intensity of the changes can be measured.

The answer to the question of who supervises the work likely will influence the thoroughness and duration of the monitoring project. The MMS is one potential supervisor or sponsor. The agency is designated as the “steward” of resources beneath federal waters and is the agency that would grant the permit allowing the dredging. Another potential federal supervisor is the National Oceanographic and Atmospheric Administration (NOAA), part of the Department of Commerce. Though not a specific party to the dredging operation or beach nourishment, NOAA and its subagencies have both broad and specific concerns and authority concerning marine fisheries and other aspects pertaining to a dredging project. The U.S. Geological Survey, like MMS an agency of the Department of the Interior, also would have the ability and expertise to supervise a monitoring project. At the other end of the spectrum of potential supervising agencies are the local agency sponsoring or responsible for the nourishment project and the organization actually performing the monitoring activity.

In the broadest sense there are two classes of potential supervisors: one representing the sand source, the other representing the end user. And there might be a parallel division of approach wherein the agencies representing the sand source might advocate a more thorough program with a longer duration, in order to learn how to best manage the resource while agencies representing the end user might be more interested in a simpler, more pragmatic program.

The deciding factor might be the answer to the question, "who pays?" The real answer to that question is the taxpayer, as long as the dredging is for a public purpose. Should the marine mining of sand ever become a commercial concern, as in mining sand for construction aggregate, the business sponsoring the project likely would bear the costs of monitoring and would pass those costs along to the end user.

The preceding discussion of the funding and supervision of the monitoring project does not address who actually performs the work. It is assumed that the supervising agency would contract with consulting firms, academic research groups, or federal or state agencies to do the work.

The final major question (where will the data be stored?) is intimately tied to the first (why monitor?). If the data, having been collected solely to satisfy a requirement that there be a monitoring program, are just to be stuck in a file cabinet to take up space and gather dust, the entire effort would be a total waste and should not be undertaken. If, however, the data are intended for honest use, they should be stored in some form that facilitates access. Clearly there should be some on-line access to at least some of the data. In this circumstance, data storage becomes an active function with the needs to set up and maintain the web-site and associated mechanics, to update the site as new data become available, and to migrate the data to progressively more modern software and systems. The issue of data storage also asks the question as to whether there should be one central repository for the data from all locations or whether there should be local repositories that are linked to one another and are equally accessible.

Finally, monitoring is not a new concept. Indeed there are several program for monitoring or observing various aspects of the beach and nearshore including borrow areas. Thus any new monitoring protocol imposed upon a region must consider both existing programs and historical datasets. Both the new and old data will be more useful if they are compatible. Thus the monitoring data need to be compatible across time and among locations.

Extending beyond the specifics of a monitoring protocol targeted for offshore mining, MMS and other agencies involved in data collection from the coastal zone must be cognizant of the growing network of coastal ocean observation systems. The online, realtime and archived data that potentially will be available from these systems will be beneficial to studies of dredging sites, especially if the observation system data collection sites are appropriately cited. As an example, the ability to tie measured offshore wave conditions to inshore observations obtained by the monitoring program would provide ongoing tests of the wave refraction models and predictions employed in the monitoring program.

Reference Cited

Research Planning, Inc, W.F.Baird & Associated, Ltd, and Applied Marine Sciences, Inc, 2001. Development and Design of Biological and Physical Monitoring Protocols to Evaluate the Long-Term Impacts of Offshore Dredging Operations in the Marine Environment. Minerals Management Service, U.S. Department of the Interior, OCS Report MMS 2001-089. 116 p.

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the nation's Outer Continental Shelf (OCS), collect revenue from Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialog with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.