APPENDIX L

BORROW AREA REPORTS AND PROJECT PLANS

Biological and Environmental Services Related to Marine and Navigable Waterways Civil Works Activities in the New York District

Contract: W912BU-13-D-0010, Task Order CE01

Fire Island to Moriches Inlet (FIMI) Borrow Area Study for the Atlantic Coast Long Island, New York, Storm Damage Reduction Projects

Final Report
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FOREWORD

This report entitled “Fire Island to Moriches Inlet (FIMI) Borrow Area Study for the Atlantic Coast Long Island, New York, Storm Damage Reduction Projects” was prepared by Tetra Tech, Inc., for Mr. Robert Smith, Environmental Branch, U.S. Army Corps of Engineers, New York District, under Contract No. W912BU-13-D-0010; Task Order: CE01.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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LIST OF ABBREVIATIONS

°C	degrees Celsius
cm	centimeter
DO	dissolved oxygen
EFH	Essential Fish Habitat
ft.	feet
GPS	global positioning system
in.	inch
m^2	square meter
mg/L	milligrams per liter
NAVD	North American Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NTU	nephelometric turbidity units
ppt	parts per thousand
QC	quality control
sp.	species
USACE	United States Army Corps of Engineers

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1.0 INTRODUCTION

The U.S. Army Corps of Engineers (USACE), New York District is conducting a comprehensive feasibility-level reformulation of shore protection and storm damage reduction for the Atlantic Coast of Long Island, New York, FIMI Storm Damage Reduction Project (the Project). The habitats within the borrow area of the project must be assessed in order to monitor conditions before and after dredge activities. Tetra Tech, Inc. (Tetra Tech) conducted the benthic and fisheries assessment surveys as part of this program. Field work conducted between July and October 2015 included the collection of water quality data, benthic grab sampling, sediment characterization, and fish trawling at the FIMI Borrow Areas 2C and 5B.

There are potential impacts to fish from the dredging of sand for beach nourishment along the New York coast. Dredge activities affect the top portion of the seabed, creating a shallow depression in the borrow area. Impacts are generally localized and restricted to the dredge project footprint and the immediately surrounding area. Larger and more mobile organisms, such as crustaceans, finfish, and marine mammals, are not similarly confined to one area and will largely be able to avoid most of the dredging activity, though this is not universal, especially for bottom-dwelling animals and early life history stages. Additionally, many fisheries resources depend on benthos as a prey resource. Since benthic invertebrates are expected to experience 100% mortality if residing within dredged material removed from the borrow area, finfish abundance within the borrow area following dredging may be influenced by recovery of benthic resources within the borrow area.

Of particular interest to this fish study are commercially important species, as New York waters support a diversity of valuable fisheries. For the purposes of this report the commercially important species in New York waters are the eleven species that generated over $1 million of revenue individually in 2014 (Table 1; NOAA 2015a). Of these, five were finfish, five were bivalves, and one was a cephalopod. Northern quahogs (*Mercenaria mercenaria*) were the most valuable fishery, worth over $11.6 million. The most abundant species landed by weight was longfin squid (*Doryteuthis pealeii*), which brought in almost $5.5 million. In total, 107 different species were landed in New York State, grossing $53.9 million.

Table 1. Commercial Fisheries Landings from 2014 in New York that Generated Over $1 Million in Revenue

Commercial Fisheries Landings from 2014 in New York that Generated Over $1 Million in Revenue		
Species	**Pounds**	**Value**
Northern quahog	1,779,364	$11,605,093
Eastern oyster	418,782	$9,309,230
Longfin squid	5,141,198	$5,450,985
Golden tilefish	1,378,600	$4,247,077
Summer flounder	833,587	$2,999,627
Sea scallop	261,383	$2,965,019
Scup	3,190,441	$2,330,558
Silver hake	2,312,770	$1,927,415
Bay scallop	12,160	$1,452,886
Atlantic surf clam	1,982,642	$1,395,135
Goosefish	1,118,461	$1,312,200

Source: NOAA 2015a

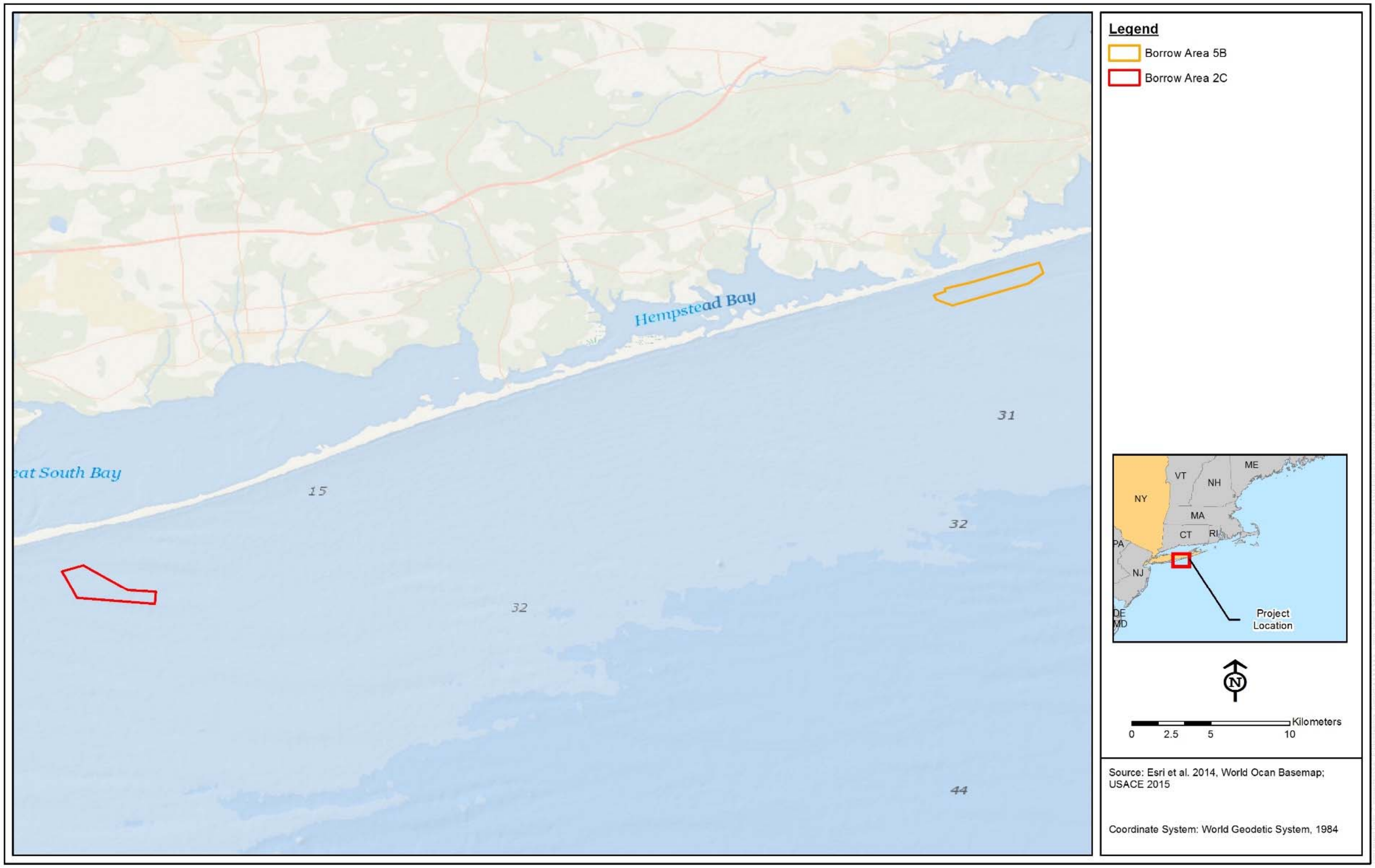
1.1 PROJECT DESCRIPTION AND LOCATION

The USACE identified the FIMI Borrow Areas, 2C and 5B, for this benthic and finfish survey (Figure 1). The borrow areas surveyed for this study are both located on the Atlantic shore of Long Island, NY. Borrow Area 2C is located about 2 miles off of Cherry Grove, Fire Island, NY; and 5B is approximately 2 miles off of the coast from Quogue, NY. Borrow Area 2C is approximately 2 square miles, about 2.4 miles long on its longest side, and 1.1 miles wide at its widest, with depths of 51 to 78 feet (Figure 2). Borrow Area 5B is approximately 2 square miles, about 3 miles long on its longest side, and 0.7 miles wide, with depths of 24 to 64 feet. Borrow Area 5B, an area which is approximately 0.45 square miles, was dredged previous to the commencement of this study and is depicted in Figure 3. The coordinates of the borrow areas are defined according to the New York State Plane Coordinate System, Long Island Zone, NAD 83 coordinate system in Table 2.

Table 2: Coordinates of the FIMI Borrow Areas

Coordinates of the FIMI Borrow Areas 2C and 5B Coordinates in North American Datum 83		
Borrow Area	**Latitude**	**Longitude**
2C	1243159.377292	165921.860011
	1243032.973039	163393.751821
	1230663.283129	164477.228057
	1228250.353280	169996.990027
	1231600.352311	171296.988408
	1238735.182801	166210.790037
	1381679.707375	236208.585700
5B	1382350.323684	234053.971574
	1380000.323147	231846.973505
	1368150.325307	227146.973302
	1365580.327525	228234.974465
	1365190.326414	229200.973004
	1367020.325938	230031.973331
	1366900.327457	230596.974439
	1371143.855008	231980.882888

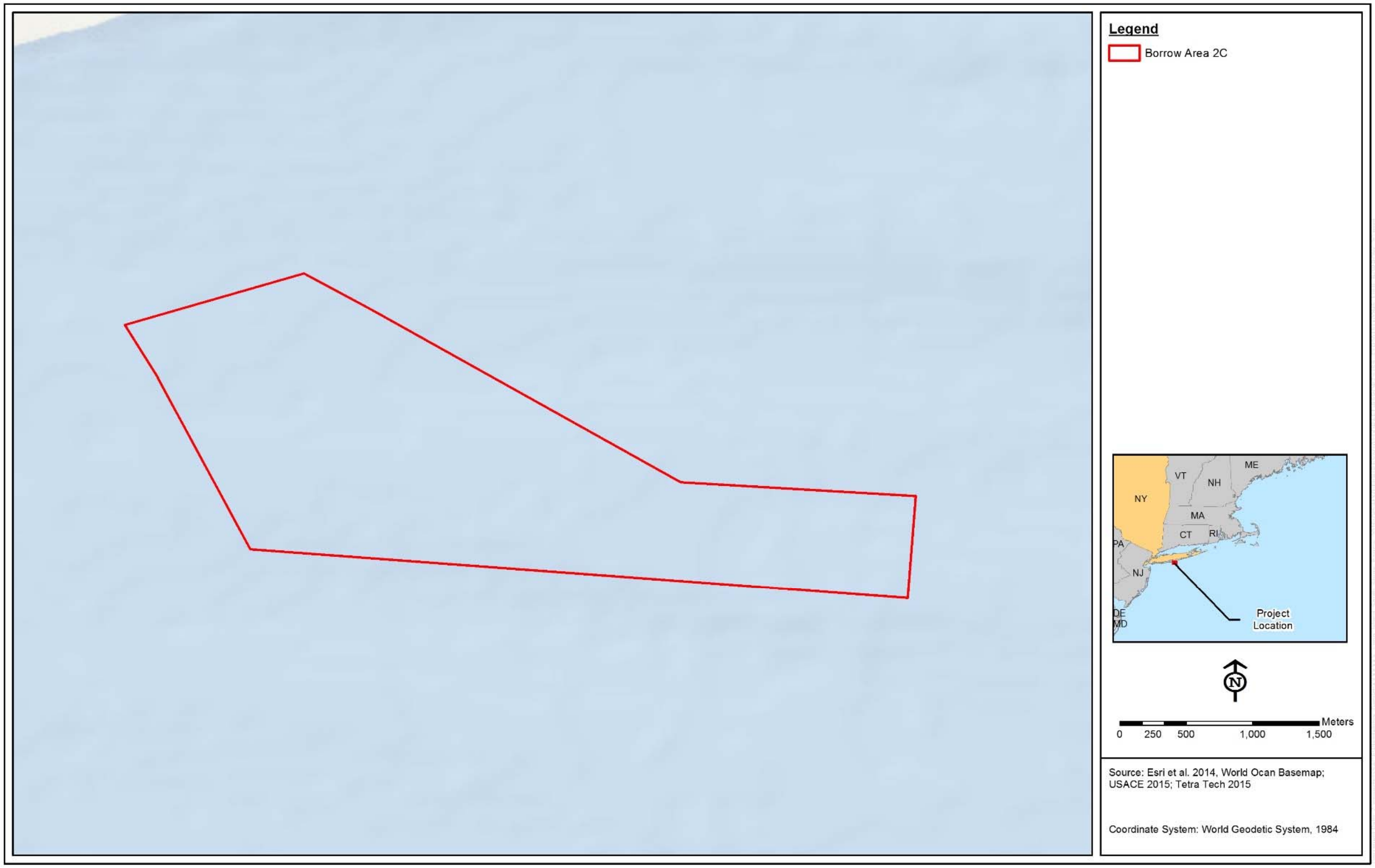
Tetra Tech completed the benthic and finfish survey of this site as described below. Sampling sites were targeted and identified using the vessel's onboard global positioning system (GPS) navigation system. Positioning data were recorded manually or electronically using a Trimble® Juno SB handheld GPS system with differential capability, or with the ESRI Collector application in an Apple iPad along with a mapping grade Bluetooth GPS receiver, at each of the sites identified for sampling. GPS points followed the WGS 84 coordinate system. Sampling locations were mapped using ESRI ArcGIS® Release 10.



Source: Esri et al. 2014, World Ocan Basemap; USACE 2015

Coordinate System: World Geodetic System, 1984

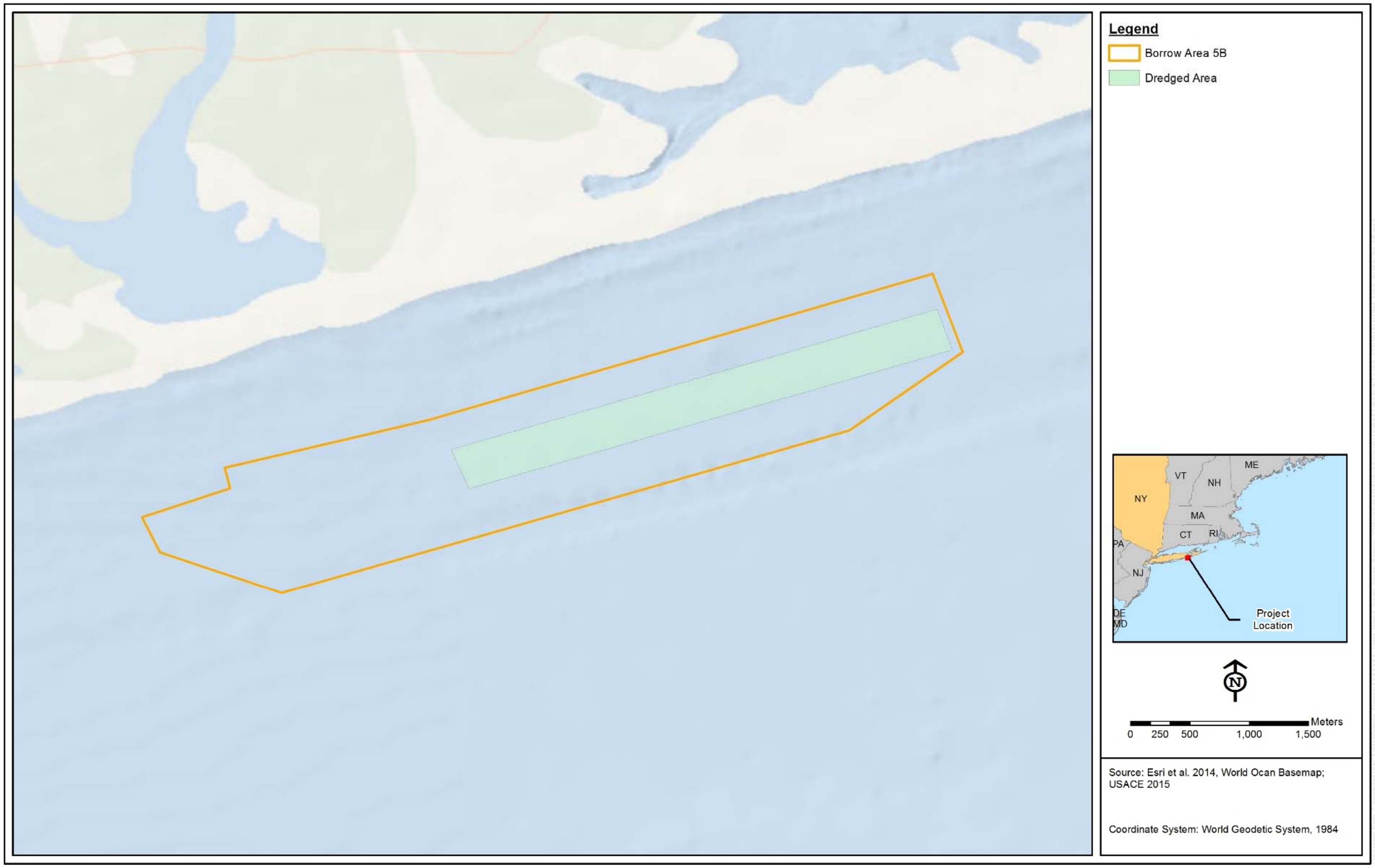
Figure 1: FIMI Borrow Areas for Long Island, New York Storm Damage Reduction Projects



Source: Esri et al. 2014, World Ocan Basemap; USACE 2015; Tetra Tech 2015

Coordinate System: World Geodetic System, 1984

Figure 2: FIMI Borrow Area 2C



Source: Esri et al. 2014, World Ocan Basemap; USACE 2015

Coordinate System: World Geodetic System, 1984

Figure 3: FIMI Borrow Area 5B

1.2 OBJECTIVES

The objectives of this study were to characterize and compare seasonal demersal fishes and benthic community structures, and to assess Project impacts on these communities and their related marine habitats, based on the Project Scope of Work. This report describes field and laboratory methods that were used for the collection of benthic grab samples and offshore fishing trawls. Results are presented in graphs and tables, and are discussed in the context of other relevant studies. The benthic sample collection and bottom trawl methods are described in Section 2.0. Benthic grabs were collected in the summer and fall of 2015. From these, infauna identification, biomass, and sediment size were determined. Monthly trawl data was analyzed for species composition, abundance, and size data to characterize the finfish community of the FIMI Borrow Areas.

1.3 SUMMARY OF FINDINGS

1.3.1 BORROW AREA 2C

Based on the benthic grabs collected in Borrow Areas 2C in the summer and fall, the average dominant sediment type was coarse sand for whole and top samples in both seasons. The most abundant benthic infauna phylum in Borrow Area 2C was Arthropoda in the summer and Annelida in the fall. At the species level, an amphipod (phylum Arthropoda) was the most abundant species in the summer and Nematoda spp. were the most abundant in the fall in Borrow Area 2C. Species richness and individuals per grab were both significantly greater in the summer relative to the fall. During monthly fish sampling both within the borrow area (on-site) and at reference sites, 36 distinct species were captured. Of these, 28 support a commercial industry and 10 have Essential Fish Habitat (EFH) in the study area. Overall, the most abundant species was longfin squid; winter skate (*Leucoraja ocellata*) had the greatest biomass. Based on catch per unit effort (CPUE), which is a standardized unit of abundance, there was greater variation month-to-month than between on-site and reference trawls within a given month.

1.3.2 BORROW AREA 5B

Based on the benthic grabs collected in Borrow Areas 5B, the dominant sediment type was medium sand in the summer for whole and top samples, and coarse sand in the fall for whole and top samples. The most abundant benthic infauna phylum in Borrow Area 5B was Arthropoda in the summer and Nematoda in the fall. At the species level, an amphipod (phylum Arthropoda) was the most abundant in the summer and Nematoda spp. were the most abundant in the fall in Borrow Area 5B. Species richness, individuals per grab, and the dominance index were all significantly greater in the summer relative to the fall; and the diversity index and evenness index were significantly greater in the fall. During monthly fish sampling both within the borrow area (on-site) and at reference sites, 47 distinct species were captured. Of these, 28 support a commercial industry and 10 have Essential Fish Habitat (EFH) in the study area. Overall, the most abundant species was longfin squid; winter skate had the greatest biomass. Based on catch per unit effort (CPUE), which is a standardized unit of abundance, there was greater variation month-to-month than between on-site and reference trawls within a given month.

2.0 METHODS

Sample collection in the field is summarized in Table 3. The benthic surveys and finfish trawls were conducted aboard the fishing vessel *(F/V) Sea Scout.* Sampling details are provided in each subsection below. Blank data sheets used in the field are provided in Appendix A.

Table 3: Summary of Sample Collection Methods in the FIMI Borrow Areas

Summary of Sample Collection Methods in the FIMI Borrow Areas				
Type of sampling	**Gear**	**Number of sites**	**Frequency of sampling**	**Samples collected**
***In situ* water quality**	YSI 6920 sonde	Surface, middle, and bottom readings at each site	Every site	Readings of pH, water temperature, turbidity, dissolved oxygen, and salinity
Benthic grab	0.1 m^2 Smith-McIntyre grab	90 randomly selected sites (45 sites per borrow area)	Seasonally, summer and fall	Assessment of subsamples: macroinvertebrates, and sediment size. Two samples from each grab: a) from top 1 in. of sample, 2) vertical sample of the whole grab
Finfish trawl	30-ft. headrope bottom otter trawl with 1-in. mesh and ¼-in. codend liner	Average of 17 trawl transects per month	Monthly (or bi-monthly), July through October	Species identification, length, and weight; all animals released

Notes: m^2 = square meters; ft. = foot; in. = inch

2.1 PHYSICAL DATA AND WATER QUALITY

Physical data and water parameters were taken at all sampling sites. In the field, date and time of collection, and latitude/longitude coordinates (by dual-range global positioning system) for all samples were recorded. Weather was also recorded for each sampling day.

Water quality data were collected at each of the benthic and finfish sample sites, at the end of each grab or tow. The following parameters were measured at the surface, middle, and bottom: pH, water temperature (degrees Celsius [°C]), turbidity (nephelometric turbidity units [NTU]), dissolved oxygen (DO) (milligrams per liter [mg/L] and percent [%]), and salinity (parts per thousand [ppt]), using a YSI 6920. Depth was also reported relative to tide state. The time of the latest high and low tide at the nearest tide station is included in Appendix B.

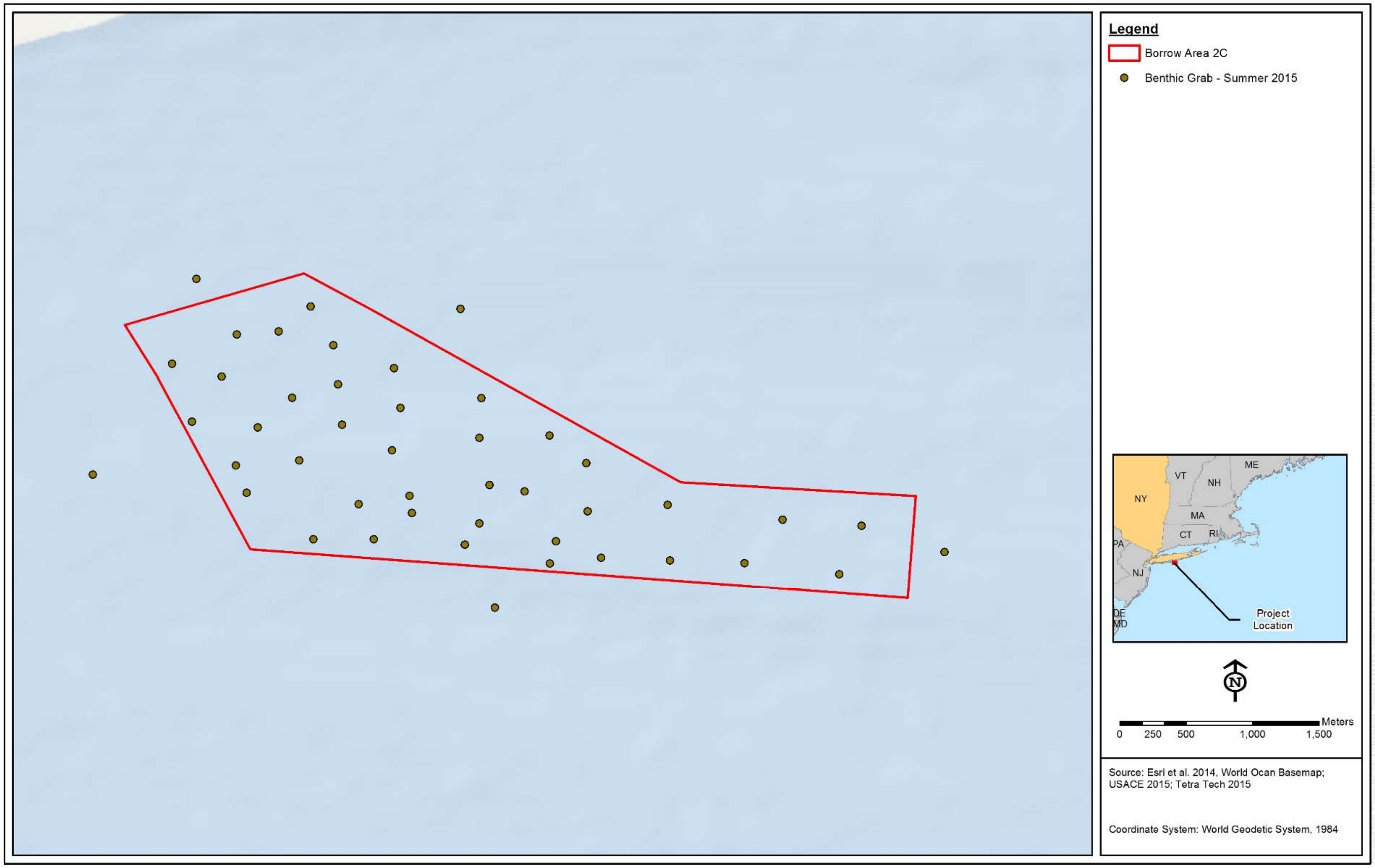
2.2 BENTHIC GRABS

To characterize the benthic environment, a total of 90 benthic grabs were completed. Benthic grabs were collected from pre-selected sites in the FIMI Borrow Areas in the summer and fall of 2015 aboard the *F/V Sea Scout*, which are summarized in Table 4. Benthic grabs for the Borrow Area 2C summer and fall surveys are depicted in Figure 4 and Figure 5, and the Borrow Area 5B summer and fall benthic grabs are depicted in Figure 6 and Figure 7. Coordinates of each grab location are provided in Appendix C. Sites within the borrow areas were labeled as "2C" and "5B" with the site number following each borrow area name, while reference sites were labeled "R" at the end the site name. At each site, the 0.1 m^2 stainless steel Smith-McIntyre grab sampler was thoroughly rinsed with ambient sea water prior to each grab. Each grab was at least 50% full and showed no evidence of surface washout. A 2-liter subsample of each grab was collected and sieved through a clean 0.5 millimeter sieve bucket. The filtered samples were placed in a sediment bag and preserved in 10% buffered Formalin with rose bengal stain. Every sample was analyzed in a laboratory for macroinvertebrate composition and grain size.

Table 4: Benthic Sampling Effort within the FIMI Borrow Areas

Benthic Sampling Effort within the FIMI Borrow Areas							
Borrow area	**Collection date (2015)**	**Weather conditions**	**Number of samples in borrow area**	**Number of reference samples**	**Benthic infauna samples**	**Grain size: top samples**	**Grain size: vertical samples**
Summer 2015							
2C	30 July	Cloudy, 75-85°F, 6 knot winds	26	2	28	28	28
2C	31 July	Sunny, 73-82°F, 2.6 knot winds	14	3	17	17	17
5B	5 August	Sunny, 80°F, 10-15 knot winds	40	5	45	45	45
Fall 2015							
2C	07 Oct	Sunny, high of 70°F, 5-10 knot winds	26	4	30	30	30
2C	08 Oct	Partly cloudy, 55-68°F, 5-10 knot winds	14	1	15	15	15
5B	09 Oct	Cloudy, 65°F, strong winds	9	1	10	10	10
5B	10 Oct	Sunny, 52-57°F, 5-20 knot winds	31	4	35	35	35

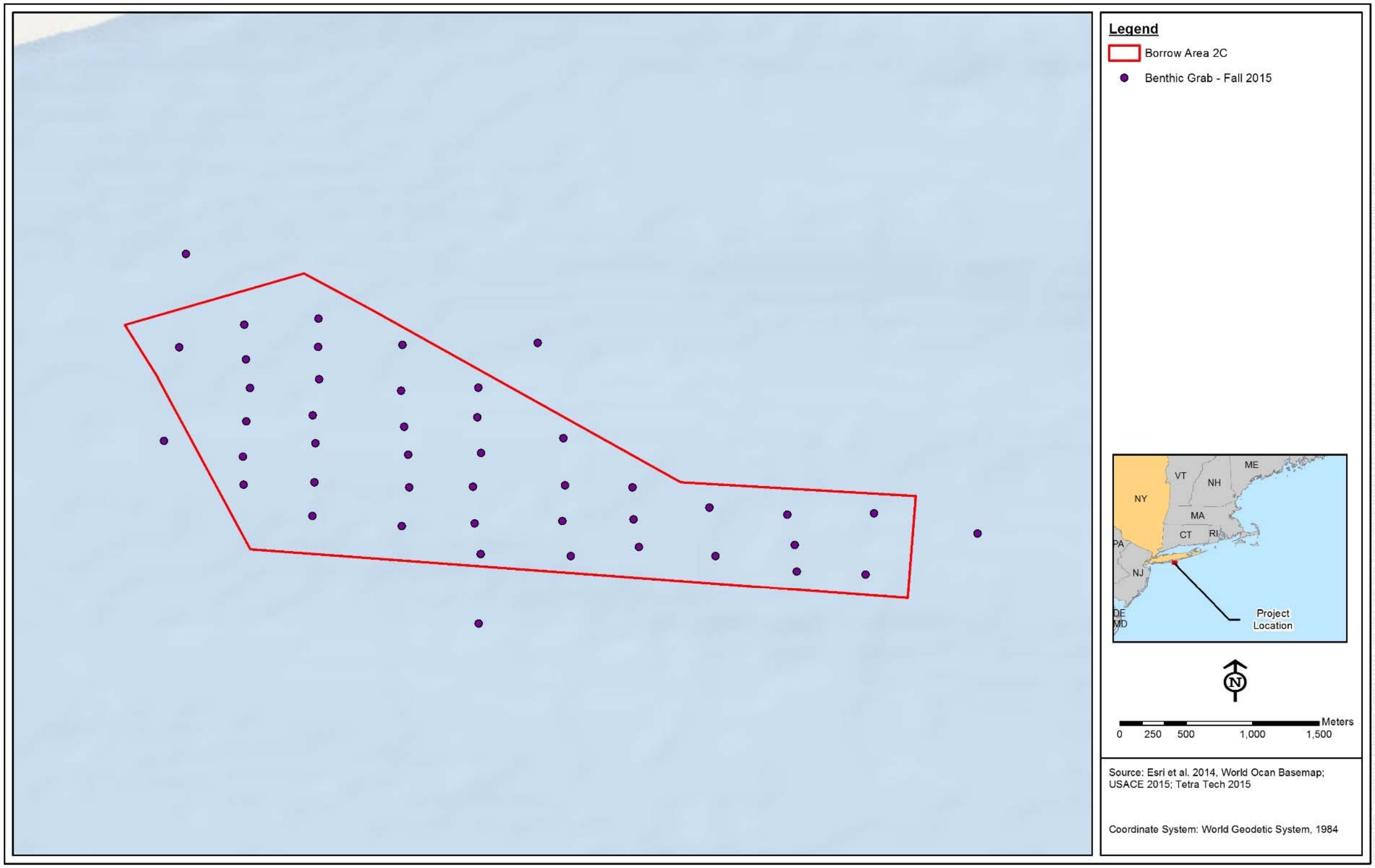
Note: Summer benthic grabs for 5B were conducted in one day due to weather delays.



Source: Esri et al. 2014, World Ocan Basemap; USACE 2015; Tetra Tech 2015

Coordinate System: World Geodetic System, 1984

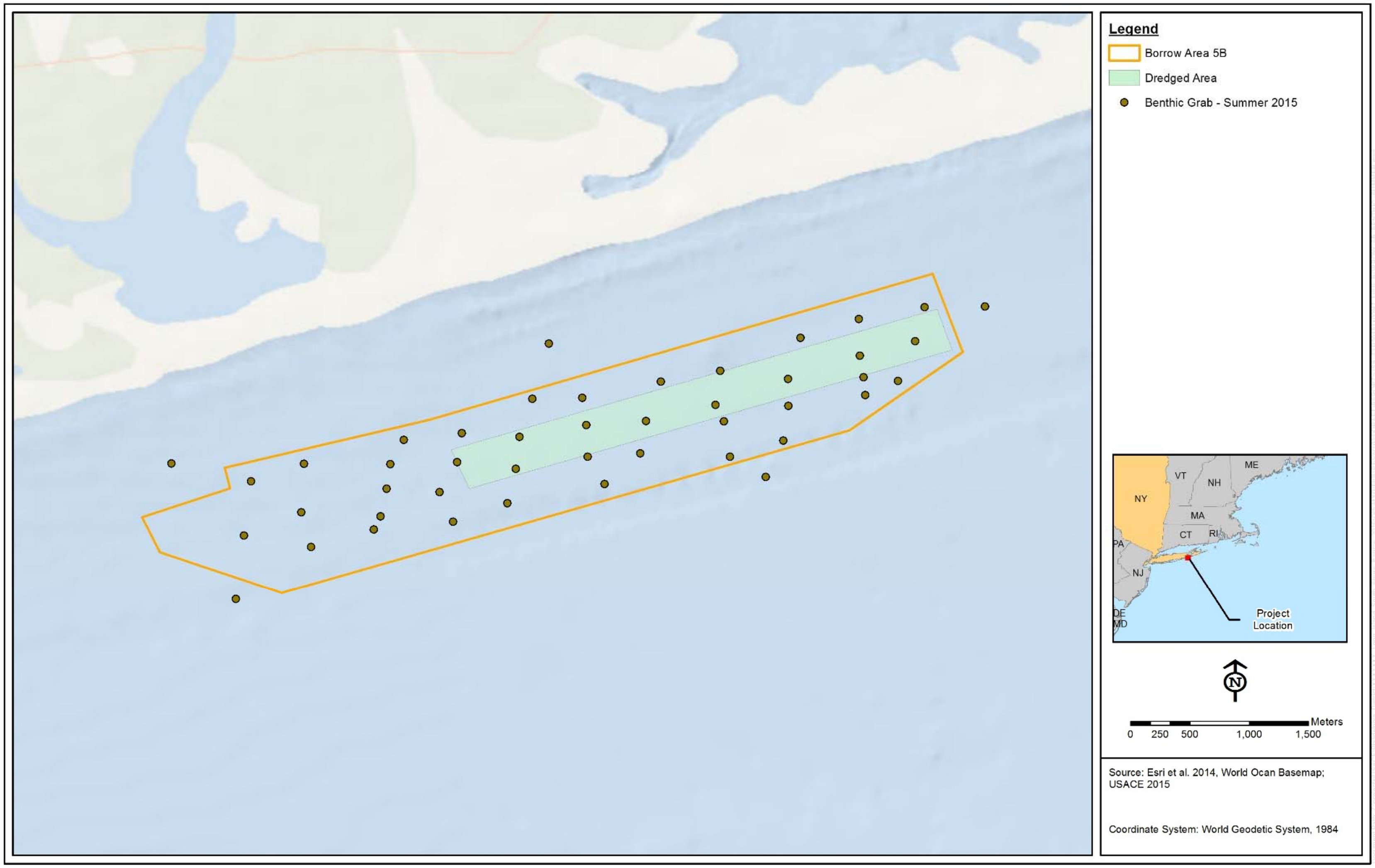
Figure 4: Benthic Grab Sampling Sites in FIMI Borrow Area 2C Collected in the Summer



Source: Esri et al. 2014, World Ocan Basemap; USACE 2015; Tetra Tech 2015

Coordinate System: World Geodetic System, 1984

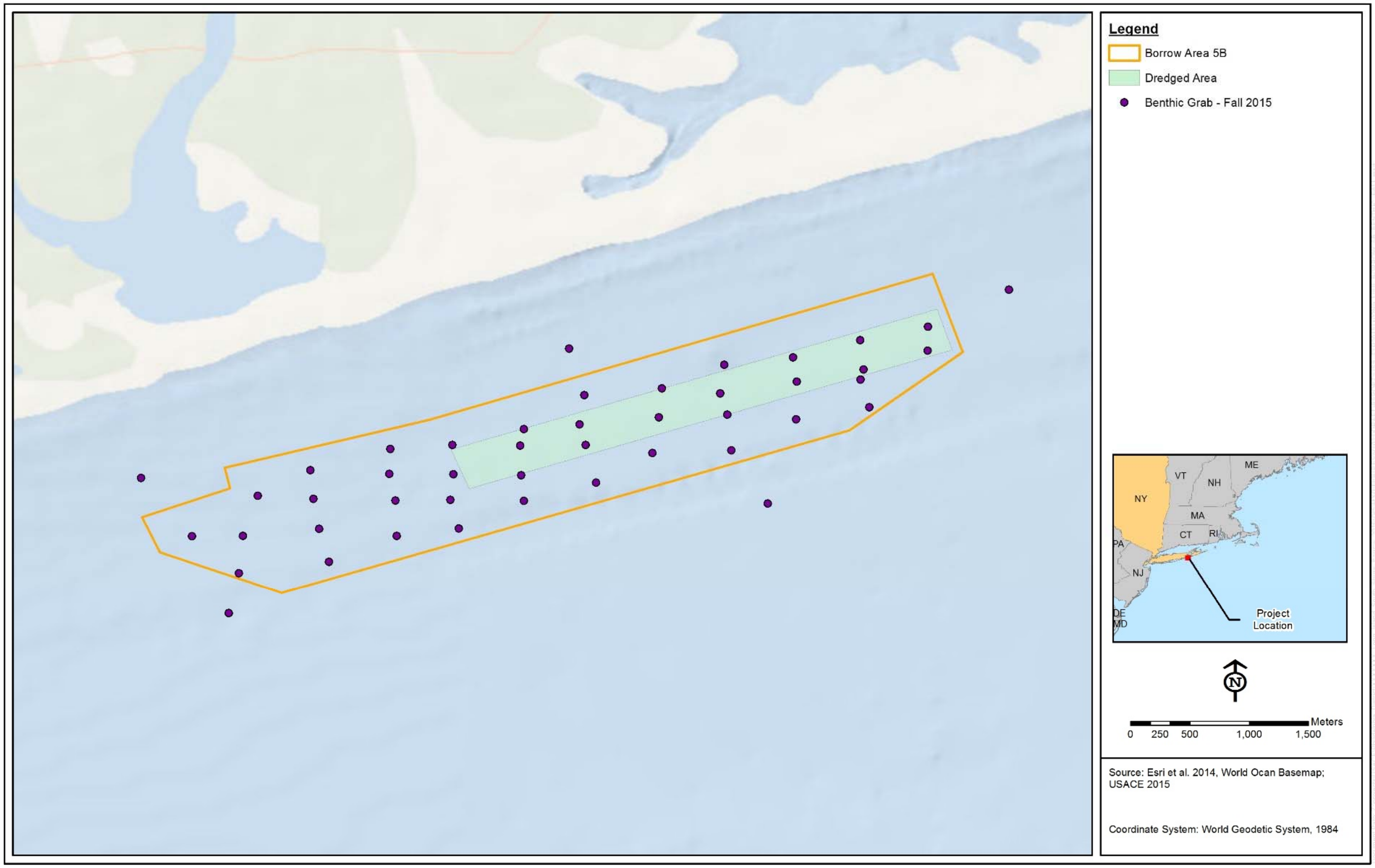
Figure 5: Benthic Grab Sampling Sites in FIMI Borrow Area 2C Collected in the Fall



Source: Esri et al. 2014, World Ocan Basemap; USACE 2015

Coordinate System: World Geodetic System, 1984

Figure 6: Benthic Grab Sampling Sites in FIMI Borrow Area 5B Collected in the Summer



Source: Esri et al. 2014, World Ocan Basemap; USACE 2015

Coordinate System: World Geodetic System, 1984

Figure 7: Benthic Grab Sampling Sites in FIMI Borrow Area 5B Collected in the Fall

All sampling containers were pre-labeled for sieved benthic organisms and grain size. No samples were composited; all samples were handled individually. For the grain size sample, two types of samples were collected, a whole sample and a top sample. Whole samples were collected to represent the composition of the whole sample by taking a vertical portion of the material from the sediment grab. For the top samples, surface sediments were removed from the top 1 in. (2.54 cm) of each sediment grab. Both types of samples were placed in quart-sized bags, double bagged, and kept in a cooler until transfer for laboratory processing (Appendix D). Within 1-2 days of collection, the samples were picked up by or delivered to the lab for analysis. In the field, grab samples were then processed for laboratory analysis of benthic infauna identification (Figure 8; see Appendix E for details). After sieving and preserving, the benthic organism samples were packed securely in sealed 5-gallon buckets and shrink-wrapped.

Figure 8: Benthic Sample Processing

2.3 LABORATORY ANALYSIS

2.3.1 GRAIN SIZE

Grain size analysis was performed in a laboratory using the ASTM Standard D422-63, Particle-Size Analysis of Soils (ASTM International 2007). In this method, sediment was sifted through progressively smaller, nested sieves. After the sample was dried, the weight retained in each sieve was then divided by the total sample weight. Cobble gravel was sediment greater than 2.5000 inches (in.). Pebble gravel was retained in US sieve Number (No.) 5 (0.1570-in.). Granule gravel was retained in the No. 10 sieve (0.0787-in.). Very coarse and coarse sand passed through the No. 10 sieve and was retained in the No. 35 sieve (0.0197-in.). Medium sand was retained in the No. 60 sieve (0.0098-in.). Very fine and fine sand passed through the No. 60 sieve and was retained in the No. 230 sieve (0.0025-in.). Silt and clay passed through all sieves and were collected in the bottom tray, with no further differentiation.

2.3.2 INVERTEBRATE ANALYSIS

Benthic invertebrates, preserved in the field, remained in 10% buffered formalin and rose bengal stain until laboratory sorting by taxonomists. To remove preservative and any sediment, samples were gently rinsed with water over a 0.020-in. (0.5 mm) mesh sieve. If not processed immediately, samples were kept in alcohol for longer-term storage. All species were identified on a sorting tray using a stereoscope. Each individual was identified to the lowest practical taxonomic level and counted.

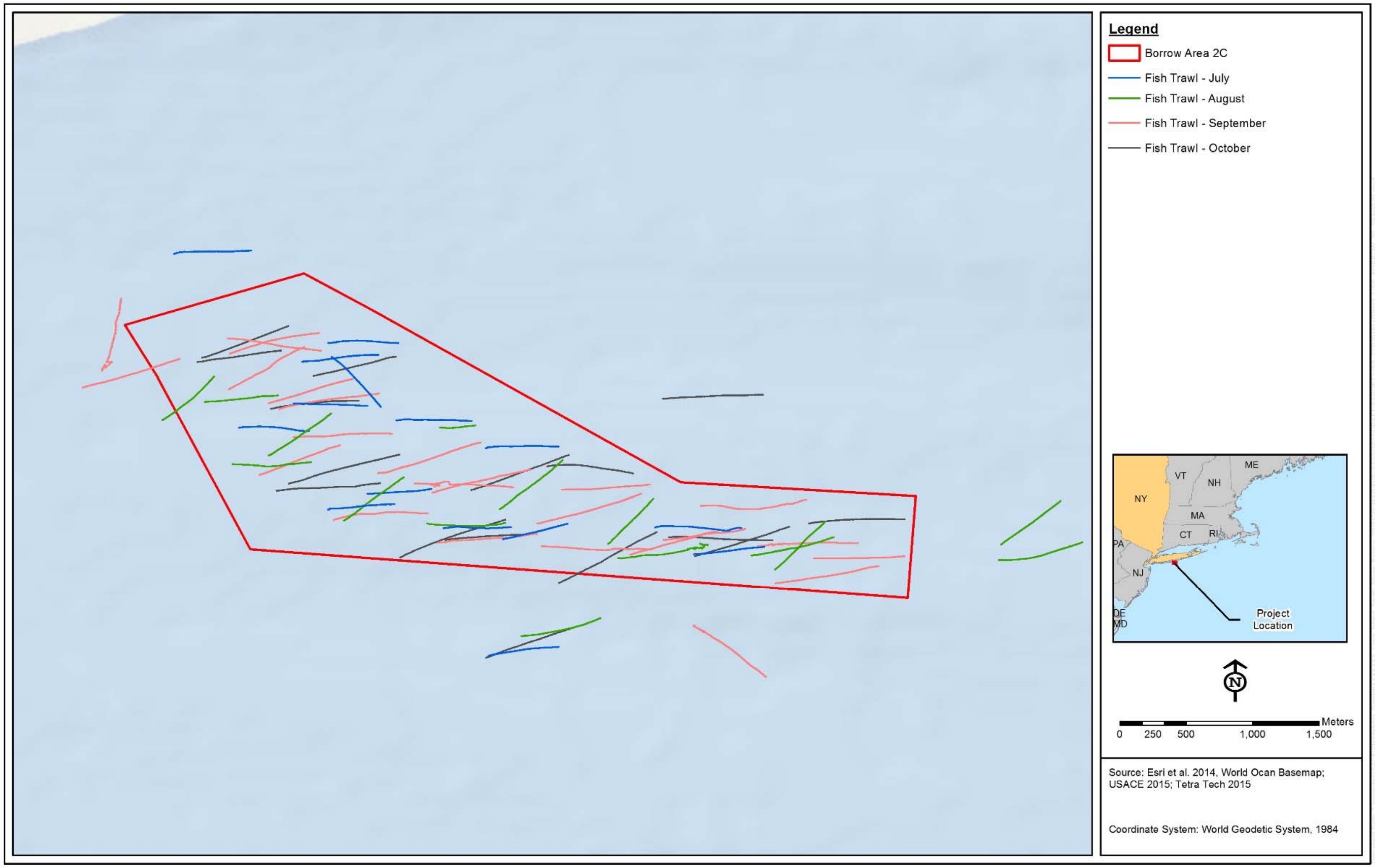
2.4 FISH TRAWLS

Fish trawls were conducted within the FIMI Borrow Area and at nearby reference sites between July and October of 2015 (Figure 9 and Figure 9: Trawls Conducted for Monthly Fish Sampling in FIMI Borrow Area 2C, Appendix C). The weather conditions and effort of each sampling event are summarized in Table 5. The first fishing trawls for Borrow Area 5B were conducted during the first week in August, since it was not possible to complete them in July. There were two trawl surveys conducted in Borrow Area 5B in August, 6-7 August and 19-20 August. The trawls conducted on 6-7 August were treated as July trawls for data analysis purposes. All fish sampling was conducted aboard the *F/V Sea Scout*. Each tow was processed for the identification, enumeration, length, and weight of each species collected. All common and scientific names of fishes are based on Page et al. 2013.

Table 5: Fish Sampling Effort within the FIMI Borrow Areas

Fish Sampling Effort within the FIMI Borrow Areas				
Borrow area	**Collection date (2015)**	**Weather conditions**	**Number of borrow area trawls**	**Number of reference trawls**
July 2015				
2C	28 July	Clear, 75-82°F, 5 knot winds	6	1
2C	29 July	Sunny, 80-88°F, 2 knot winds	6	1
August 2015				
5B*	6 August	Sunny, 85°F, 5-10 knot winds	6	1
5B*	7 August	Sunny, 75-85°F, 10-15 knot winds	9	1
2C	17 August	Clear, 90-95°F, 5-10 knot winds	6	2
2C	18 August	Partly cloudy, 75-88°F, 5-10 knot winds	6	2
5B	19 August	Fog in AM, sunny, 70-80°F, 5-10 knot winds	8	1
5B	20 August	Sunny, 75-80°F, 5-10 knot winds	8	1
September 2015				
5B	08 Sept	Sunny, 85°F, 5-10 knot winds	7	1
5B	09 Sept	Foggy, cloudy, 80-85°F, 10-15 knot winds	8	1
2C	10 Sept	Isolated thunderstorms, 72-79°F, 5 knot winds	7	1
2C	11 Sept	Cloudy, 70-75°F, 5-15 knot winds	7	1
5B	21 Sept	Sunny, 20-30 knot winds	1	1
2C	29 Sept	Foggy, light rain, 70-75°F, 5-15 knot winds	7	1
October 2015				
5B	11 Oct	Sunny, 43-66°F, 5-10 knot winds	7	1
5B	12 Oct	Sunny, 50-70°F, 5-10 knot winds	7	1
2C	13 Oct	Rain and fog clearing in PM, 60-70°F, 10-20 knot winds	7	1
2C	14 Oct	Partly cloudy, 54-66°F, west winds 5-10 knot winds	7	1

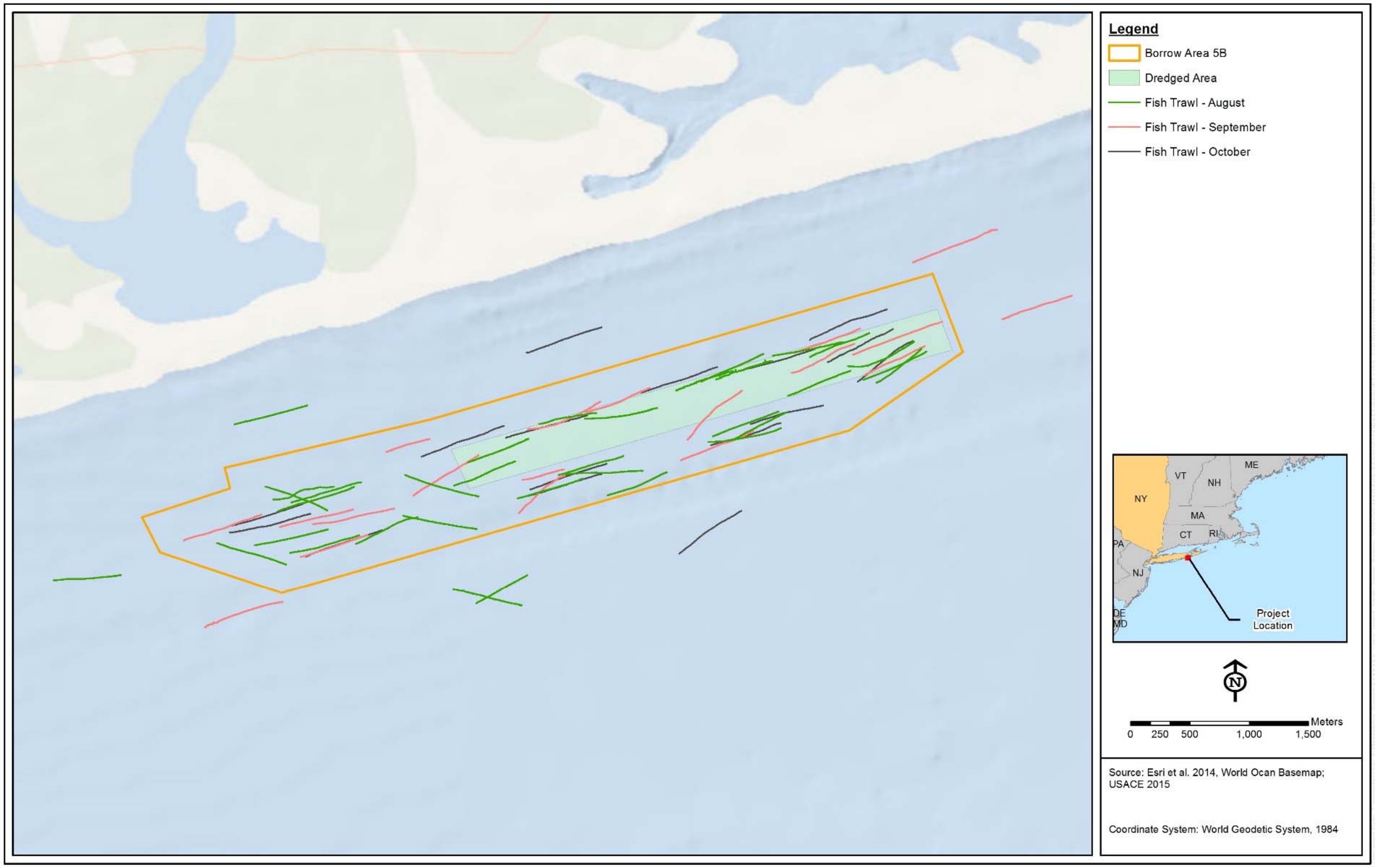
*Note: The 6-7 August, 5B trawls are treated as July trawls for purposes of data analysis.



Source: Esri et al. 2014, World Ocan Basemap; USACE 2015; Tetra Tech 2015

Coordinate System: World Geodetic System, 1984

Figure 9: Trawls Conducted for Monthly Fish Sampling in FIMI Borrow Area 2C



Source: Esri et al. 2014, World Ocan Basemap; USACE 2015

Coordinate System: World Geodetic System, 1984

Figure 10: Trawls Conducted for Monthly Fish Sampling in FIMI Borrow Area 5B

A 30-ft. headrope bottom otter trawl with a ¼-in. codend liner was towed for approximately 0.25 nautical miles at a speed of 2 to 3 knots, which equates to 8 to 10 minutes. Contents of the trawl net were processed on board the vessel (Figure 11). Each species of teleost, elasmobranch, and squid was identified to the lowest taxonomic level. The standard length (SL), the distance from the snout to the hypural bone, was measured to the nearest millimeter (mm) for each individual. For elasmobranchs, the total length (TL) from the nose to the tail was measured. Weight was collected to the nearest gram (g). For species with high abundance (i.e., >30 individuals), a bulk composite weight was measured for the additional individuals. With the exception of squid (due to their commercial importance), all mollusks were noted for presence but were otherwise not enumerated, weighed, or measured. Mantle length and weight were collected for squid.

Although abundance, length, and weight was collected for all fish species, in this report, attention is given to species of interest, which are identified as organisms that support a fishery valued at over $1 million.

Figure 11: Fish Sample Processing

2.5 DATA ANALYSIS

To analyze characteristics and patterns within the benthic data, several different parameters were investigated. Species richness (R) is the overall number of species. To measure diversity, the Shannon Diversity Index (H') was calculated as:

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

For taxon *i*, p_i is the proportion of individuals from the particular taxon relative to the total number of individuals. Greater values of H' correspond to higher diversity. This diversity index can then be used to look at relative abundances of different species, or evenness. Pielou's evenness index, calculated as:

$$J' = \frac{H'}{H'_{max}}$$

estimates the evenness of different species. H'_{max} is the maximum value of H', equivalent to the natural log (ln) of R (where R = total number of species). J' ranges from 0 to 1, with low values representing greater variation between species and high values indicative of more even abundances.

Species dominance was measured using Simpson's Dominance Index calculated as:

$$\lambda = \sum_{i=1}^{R} p_i^2$$

λ ranges from 0 to 1; a community not dominated by just a few species would have a value below 0.5 while a community dominated by one or a few species would have a value greater than 0.5. A comparison of these infauna community measures between spring and fall was conducted using a two-tailed student's t-test. To focus on spatial changes in the benthic community, these statistics were run separately for grabs conducted on-site and reference site grabs. However, the disproportionate number of grabs collected within the Borrow Area and at reference sites are not suitable for comparing the two types of areas using student's t-tests.

Finfish abundance is reported as percent composition, as well as catch per unit effort (CPUE). CPUE is a way to standardize abundance and is calculated as number of fishes captured per tow. During quality control (QC) of trawl data, the length-weight relationship of each individual organism, if available, was used to identify possible outliers. An assumption was made that if an inconsistency in the length-weight relationship was apparent, the error was in the weight measurement, rather than the length measurement. The movement of a vessel, an inescapable and common challenge working at sea, may impact a weight measurement, especially for smaller individuals. Therefore, based on the fish's length, an expected weight was calculated (Lange and Johnson 1978, NOAA 2003, Robinette 1983). All statistical tests were conducted in Microsoft Excel 2013 and used an error-rate of P = 0.05 to determine statistical significance.

3.0 RESULTS

3.1 WATER QUALITY

Water quality measurements were taken at the surface, middle, and bottom of the water column at each benthic grab and trawl site from July to October 2015 (Table 6). For the purposes of data analysis, the first survey in Borrow Area 5B on 5-7 August were treated as July data and the survey conducted a few weeks later in August were treated as the August data. Though more parameters were measured (Appendix B), temperature, salinity, and dissolved oxygen (DO) are highlighted here due to the biological relevance of these measurements, as well as the seasonal patterns evidenced. When the turbidity and DO meters did not function properly, the data was omitted from the analysis and the meters were repaired or replaced as soon as possible.

Seasonal changes in water quality were evident. Since the solubility of oxygen is greater in colder water, this could partially account for the high DO observed in Borrow Area 2C bottom waters in August. In addition to this, wave action and photosynthetic organisms may have contributed to increased oxygen in surface waters in July, September, and October (Millero 2006). As is common at temperate latitudes, a pycnocline was evident during the summer months. Although the densest water (which is also the coldest and saltiest) is in the bottom layer for all months, it is only during July, August, and September that the surface temperature is warm enough to become less dense, thus creating a pycnocline (i.e., density gradient). In July and September, oxygen levels in bottom water were depleted due to respiration of organisms and lack of mixing with oxygen-rich surface waters (Millero 2006). In October, however, surface waters began to cool, breaking down the pycnocline. Increased wind and storms facilitated the mixing of the water column, maintaining high levels of DO, which would be expected to remain as winter storms replenished atmospheric oxygen into the water.

Table 6: Average Water Quality Parameters by Month at FIMI Borrow Areas 2C and 5B

Average Water Quality Parameters by Month at FIMI Borrow Areas 2C and 5B							
Sampling month	**Borrow Area**	**Average depth (ft.)**	**Reading depth**	**Temperature (°C)**	**Salinity (ppt)**	**DO (mg/L)**	**DO (%)**
July	**2C**	58.39	Surface	22.13	31.18	8.29	115.45
			Middle	19.62	31.30	8.24	111.99
			Bottom	17.50	31.50	7.91	103.96
	5B	45.16	Surface	19.55	31.28	6.62	87.61
			Middle	18.25	31.34	6.44	84.87
			Bottom	17.19	31.48	6.29	79.96
August	**2C**	61.75	Surface	21.88	31.50	7.20	98.62
			Middle	20.15	31.59	7.30	97.53
			Bottom	17.63	31.80	7.66	96.40
	5B	45.44	Surface	22.22	31.25	5.51	76.19
			Middle	20.59	31.31	5.58	75.89
			Bottom	19.29	31.38	5.52	76.57
September	**2C**	58.58	Surface	22.45	32.13	6.02	81.84
			Middle	21.85	32.25	5.70	78.06
			Bottom	18.85	32.57	5.66	74.60

Average Water Quality Parameters by Month at FIMI Borrow Areas 2C and 5B

Sampling month	Borrow Area	Average depth (ft.)	Reading depth	Temperature (°C)	Salinity (ppt)	DO (mg/L)	DO (%)
	5B	45.88	Surface	20.98	32.15	6.11	82.85
			Middle	19.23	32.20	6.03	79.69
			Bottom	18.10	32.31	5.90	75.47
October	**2C**	59.1	Surface	17.74	32.83	7.80	99.95
			Middle	17.77	32.91	7.53	96.42
			Bottom	17.98	33.18	7.41	94.66
	5B	45.97	Surface	17.40	32.96	7.85	100.18
			Middle	17.25	33.06	7.56	96.41
			Bottom	17.10	33.37	7.51	95.01

3.2 BENTHIC GRABS

Benthic sample collection occurred in August and October 2015. Physical attributes, such as sediment type, are presented separately for the summer and fall seasons for each borrow area. Collectively, they provide a characterization of the FIMI Borrow Area benthic habitat. Benthic organisms and communities displayed temporal differences, which are explored in the following section based on the month of collection.

3.2.1 BENTHIC HABITAT AND SEDIMENT TYPES

Each benthic sample collected in the summer and fall of 2015 was described quantitatively through laboratory analysis of grain size. Field data sheets of benthic sample collection are included in Appendix A; detailed laboratory results are provided in Appendix D. In this section, reference sites are distinguished with an "R" after the site number.

Samples collected for grain size analysis were taken in replicate from each sampling site, one to represent the whole grab sample and one to represent the top layer of the sediment. Refer to Section 2.2 for an explanation of how the samples were procured. Whole and top samples were taken to see if finer sediment sizes were filling in depressed areas of the borrow areas that had already been dredged. At the time that this survey was conducted only Borrow Area 5B had been previously dredged.

3.2.1.1 Borrow Area 2C

Overall, samples collected in both the summer and fall were dominated by coarse-sized sand.

Summer

On average, whole grab samples (herein after identified as "W") contained 55.07% of coarse particles and top grab samples (herein after identified as "T") contained 56.28% of coarse particles (Table 7). A closer look at this data revealed that for both the whole and top samples, the on-site samples had higher percentages of coarse sand particles compared to the reference sites. Medium-sized sand (0.0098-0.0197 in.) made up 33.18% W and 31.75% T of the samples. Fine to very fine-sized sand (0.0025-0.0098 in.) made up 9.14% W and 8.63% T; silt and clay (<0.0025 in.) made up 2.25% W and 2.93% T, and granule gravel (0.1570-0.0787 in.) made up 0.33% W and 0.41% T of the samples. Cobble and pebble-sized particles were not identified in the summer 2C samples.

Table 7: Average Particle-size Distribution of Summer Benthic Grabs for Borrow Area 2C

Average Particle-size Distribution of Summer Benthic Grabs for Borrow Area 2C								
Benthic sample type	Location	Gravel-size (%)			Sand-size (%)			Silt-size & clay-size (%)
		Cobble	Pebble	Granule	Coarse	Medium	Fine	
Whole	On-site	0.00	0.00	0.37	58.07	33.53	6.22 ɫ	1.80
	Reference	0.00	0.00	0.00	31.09	30.38	32.48	6.05
	Combined	0.00	0.00	0.33	55.07	33.18	9.14	2.28
Top	On-site	0.00	0.00	0.46	60.15	31.51	5.01 ɫ	2.87
	Reference	0.00	0.00	0.00	25.34	33.67	37.61	3.38
	Combined	0.00	0.00	0.41	56.28	31.75	8.63	2.93

Note: Significantly different values are distinguished with a ɫ. “On-site” is the data for the entire borrow area; “Reference” is the data from areas outside of the borrow area; “Combined” is the On-site and Reference location data together.

Comparisons of whole to top grain size samples were conducted using two-tailed student’s t-tests for paired samples. These tests were run separately for grabs conducted on-site and reference site grabs. The disproportionate number of on-site and reference site grabs did not allow for comparisons using parametric statistics. For on-site samples in 2C the only significant difference between whole and top samples was for fine sand (P=0.003) (Table 7). None of the reference site samples were significantly different between the whole and top samples.

In the field, the most common descriptor of samples collected in the summer for Borrow Area 2C was “brown sand.” Traces of organic matter, invertebrates, and pieces of shell were apparent in several samples. Only one sample was not described as sand; 2C32 R was described as “black brown silt.” Other than this one site, reference site descriptions were similar overall. Table 8 shows the dominant sediment type for each benthic grab separated by whole and top samples as quantified through lab analysis. For sediment collected at 2C in the summer, 33 of 45 whole grab samples and 36 of 45 top grab samples were dominated by coarse-sized sand (0.0197-0.0787 in.). Medium sand was the dominant size in 11 W and 7 T; and fine sand was the dominant size in 1 W and 2 T samples. None of the gravel sizes or silt and clay size sediment types were dominant in any samples. The quantitative analysis of sediment size is depicted in Figure 12 and Figure 13. The figures show the percentage composition for each sediment type in the benthic samples; each sediment type is signified by a particular color.

Table 8: Dominant Sediment Type Based on Lab Analysis of Summer Benthic Grabs for Borrow Area 2C

Dominant Sediment Type Based on Lab Analysis of Summer Benthic Grabs for Borrow Area 2C			
Site	Depth (ft.)	Whole sample	Top sample
2C1	57	Medium sand	Coarse sand
2C2	56	Coarse sand	Coarse sand
2C3	56	Coarse sand	Coarse sand
2C4	58	Coarse sand	Coarse sand
2C5	55	Coarse sand	Coarse sand
2C6	57	Coarse sand	Coarse sand
2C7	59	Coarse sand	Coarse sand

Dominant Sediment Type Based on Lab Analysis of Summer Benthic Grabs for Borrow Area 2C			
Site	**Depth (ft.)**	**Whole sample**	**Top sample**
2C8	61	Coarse sand	Coarse sand
2C9	58	Coarse sand	Coarse sand
2C10	55	Medium sand	Medium sand
2C11	59	Coarse sand	Medium sand
2C12	58	Medium sand	Coarse sand
2C13	55	Medium sand	Medium sand
2C14	53	Coarse sand	Coarse sand
2C15	55	Coarse sand	Coarse sand
2C16	57	Coarse sand	Coarse sand
2C17	62	Medium sand	Coarse sand
2C18 R	60	Fine sand	Fine sand
2C19	60	Coarse sand	Coarse sand
2C20	55	Coarse sand	Coarse sand
2C21	54	Coarse sand	Coarse sand
2C22	52	Medium sand	Coarse sand
2C23	56	Medium sand	Coarse sand
2C24 R	73	Medium sand	Medium sand
2C25	57	Coarse sand	Coarse sand
2C26	55	Medium sand	Coarse sand
2C27	54	Medium sand	Coarse sand
2C28	54	Coarse sand	Coarse sand
2C29 R	58	Coarse sand	Coarse sand
2C30	59	Coarse sand	Coarse sand
2C31	56	Coarse sand	Coarse sand
2C32 R	56	Coarse sand	Fine sand
2C33	54	Coarse sand	Coarse sand
2C34	62	Coarse sand	Coarse sand
2C35	56	Coarse sand	Coarse sand
2C36	58	Coarse sand	Coarse sand
2C37	58	Coarse sand	Coarse sand
2C38	60	Coarse sand	Medium sand
2C39	67	Medium sand	Medium sand
2C40	62	Coarse sand	Coarse sand
2C41	62	Coarse sand	Coarse sand
2C42 R	66	Coarse sand	Medium sand
2C43	67	Coarse sand	Coarse sand
2C44	65	Coarse sand	Coarse sand
2C45	59	Coarse sand	Coarse sand

Another way to look at the possible differences between whole and top samples is to see if the dominant sediment type differs between them. The majority of dominant sediment types did not change from the whole to top parts of each sediment grab. Within Borrow Area 2C, 31 samples had the same dominant sediment type for whole and top samples, 7 whole samples had dominant grain sizes that were smaller than the top sample, and 2 whole samples were bigger than the top sample. In reference samples, 3 were the same, and 2 whole samples were bigger than the top sample.

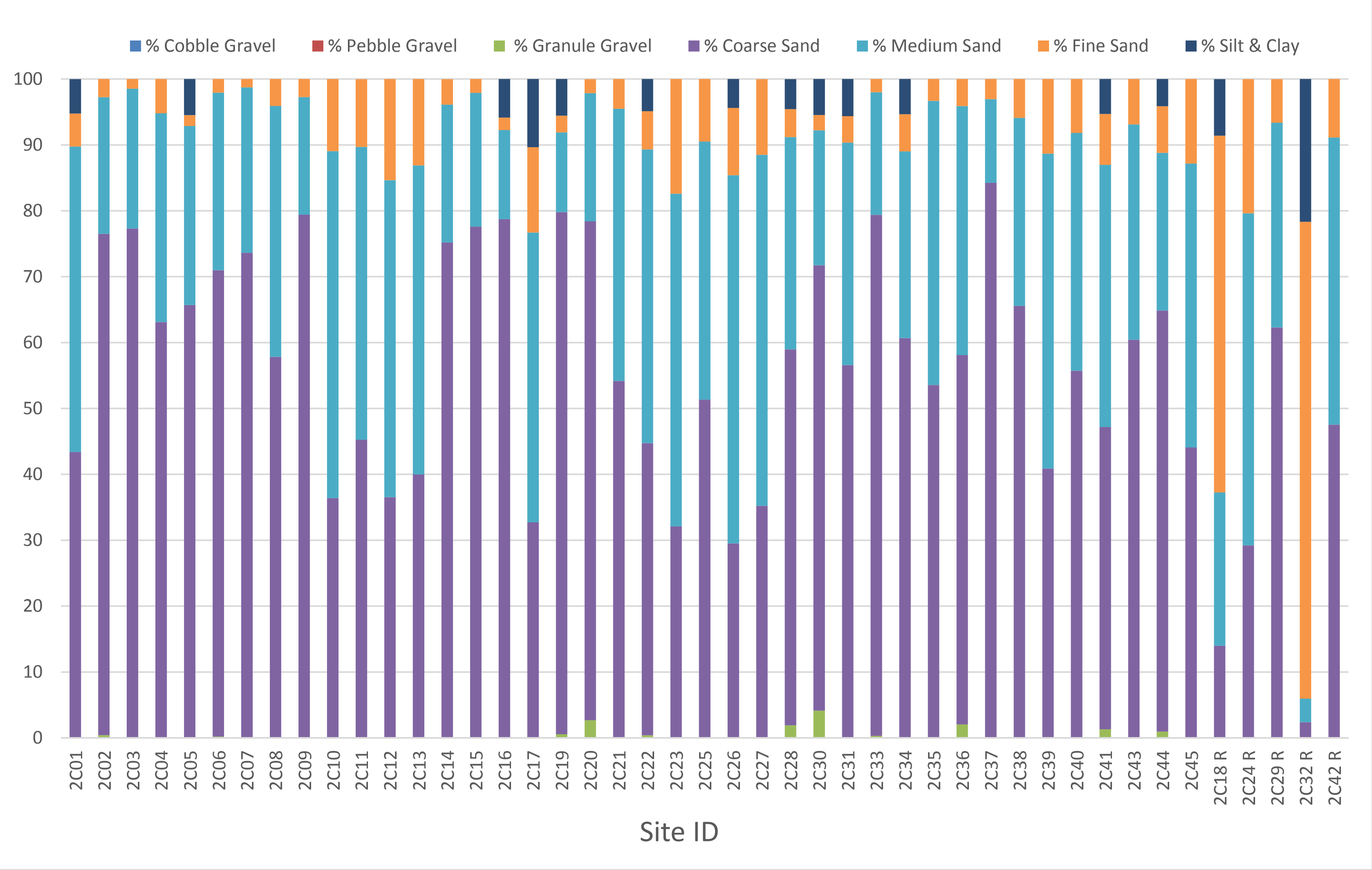


Figure 12: Sediment Composition of Whole Summer Benthic Grabs by Site for Borrow Area 2C (R=reference site)

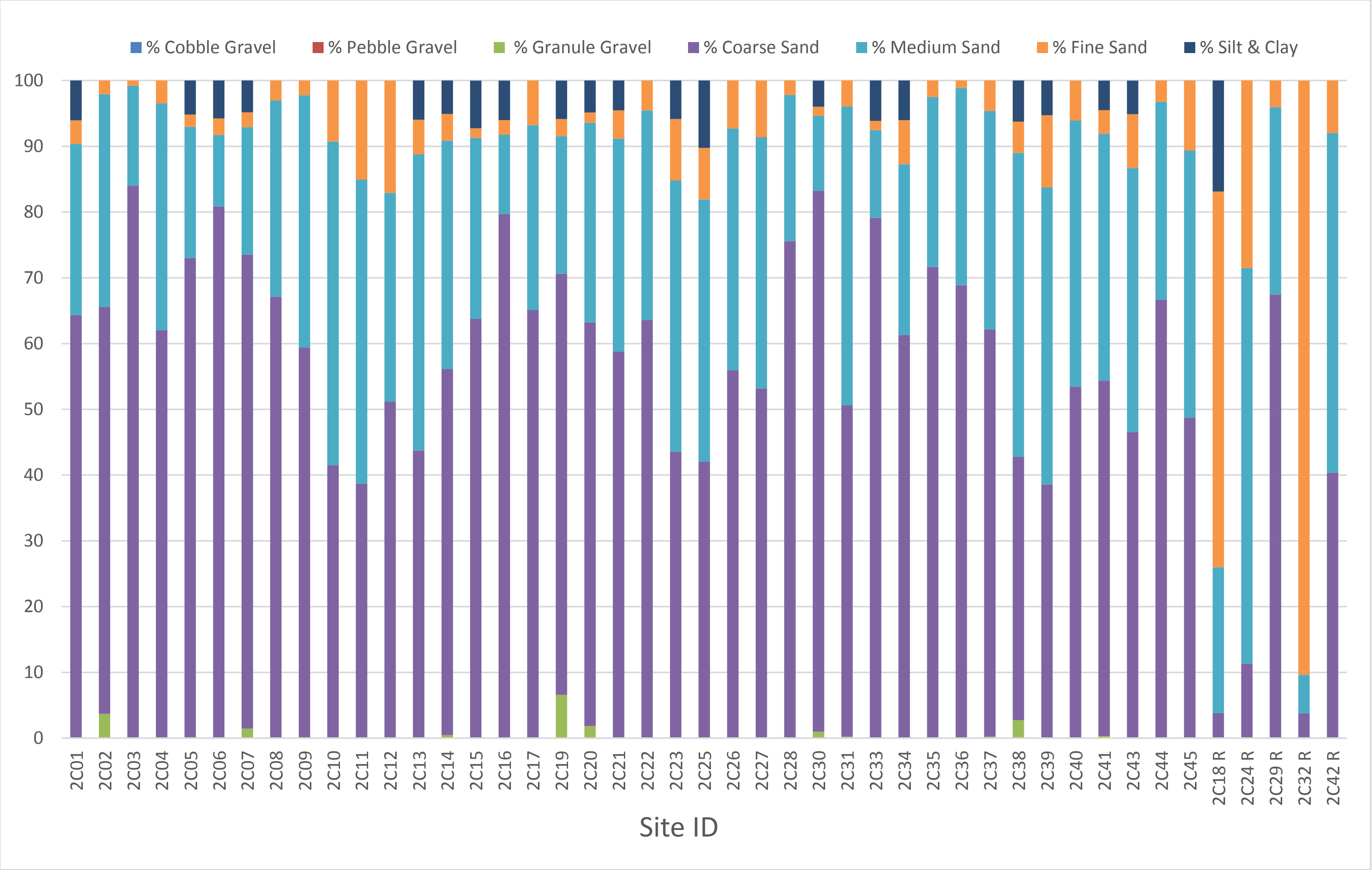


Figure 13: Sediment Composition of Top Summer Benthic Grabs by Site for Borrow Area 2C (R=reference site)

Fall

On average, samples contained 51.41% W and 50.46% T of coarse particles (Table 9). A closer look at this data reveals that for both the whole and top samples, the on-site samples had higher percentages of coarse sand particles compared to the reference sites. Medium-sized sand made up 37.31% W and 37.16% T of the samples. Fine to very fine-sized sand made up 7.62% W and 8.41% T, silt and clay made up 2.07% W and 2.97% T, granule gravel made up 1.42% W and 0.88% T of the samples, and pebble-sized granules made up 0.17% W and 0.12% T of the samples. Cobble-sized particles were not identified in the fall 2C samples.

Table 9: Average Particle-size Distribution of Fall Benthic Grabs for Borrow Area 2C

Average Particle-size Distribution of Fall Benthic Grabs for Borrow Area 2C								
Benthic sediment type	**Location**	**Gravel-size (%)**			**Sand-size (%)**			**Silt-size & clay-size (%)**
		Cobble	**Pebble**	**Granule**	**Coarse**	**Medium**	**Fine**	
Whole	On-site	0.00	0.12	1.52 ƚ	53.62	38.07	5.21	1.46
	Reference	0.00	0.57	0.63	33.72	31.23	26.85	6.99
	Combined	0.00	0.17	1.42	51.41	37.31	7.62	2.07
Top	On-site	0.00	0.14	0.97ƚ	52.79	38.49	5.59	2.02
	Reference	0.00	0.00	0.13	31.84	26.55	30.93	10.55
	Combined	0.00	0.12	0.88	50.46	37.16	8.41	2.97

Note: Significantly different values are distinguished with a ƚ. “Combined” is the On-site and Reference location data together.

Comparisons of whole to top grain size samples were conducted using two-tailed student’s t-tests for paired samples. The only significant differences between the whole and top samples was for on-site granule-sized gravel; the percentage of granule-sized gravel was significantly greater in whole samples versus top samples (P=0.013). Most of the fall samples were described as “brown or light brown sand.” Pieces of shell were again present, as well as sand dollars and bits of organic matter. For sediment collected at 2C in the fall and analyzed in the lab, 32 of 45 whole grab samples and 30 of 45 top grab samples were dominated by coarse-sized sand. Medium sand was the dominant size in 11 W and 13 T; and fine sand was the dominant size in 2 W and 2 T samples. None of the gravel sizes or silt and clay size sediment types were dominant in any samples.

Table 10: Dominant Sediment Type Based on Lab Analysis of Fall Benthic Grabs for Borrow Area 2C

Dominant Sediment Type Based on Lab Analysis of Fall Benthic Grabs for Borrow Area 2C			
Site	**Depth (ft.)**	**Whole sample**	**Top sample**
2C1 R	54	Coarse sand	Coarse sand
2C2	54	Coarse sand	Coarse sand
2C3 R	54	Fine sand	Fine sand
2C4	53	Coarse sand	Coarse sand
2C5	58	Coarse sand	Coarse sand
2C6	59	Coarse sand	Coarse sand
2C7	56	Coarse sand	Coarse sand
2C8	54	Coarse sand	Coarse sand

Dominant Sediment Type Based on Lab Analysis of Fall Benthic Grabs for Borrow Area 2C			
Site	**Depth (ft.)**	**Whole sample**	**Top sample**
2C9	54	Coarse sand	Coarse sand
2C10	57	Medium sand	Medium sand
2C11	56	Medium sand	Medium sand
2C12	55	Coarse sand	Coarse sand
2C13	56	Coarse sand	Coarse sand
2C14	60	Coarse sand	Coarse sand
2C15	60	Coarse sand	Coarse sand
2C16	56	Coarse sand	Coarse sand
2C17	60	Coarse sand	Coarse sand
2C18	61	Coarse sand	Coarse sand
2C19	58	Coarse sand	Coarse sand
2C20	54	Coarse sand	Coarse sand
2C21	55	Coarse sand	Medium sand
2C22	59	Medium sand	Medium sand
2C23 R	75	Coarse sand	Coarse sand
2C24	60	Medium sand	Medium sand
2C25	56	Medium sand	Medium sand
2C26	56	Coarse sand	Medium sand
2C27	56	Coarse sand	Coarse sand
2C28	58	Coarse sand	Coarse sand
2C29	60	Coarse sand	Coarse sand
2C30 R	67	Fine sand	Fine sand
2C31	56	Coarse sand	Coarse sand
2C32	55	Coarse sand	Coarse sand
2C33	57	Coarse sand	Medium sand
2C34	58	Medium sand	Coarse sand
2C35	57	Coarse sand	Coarse sand
2C36	57	Medium sand	Coarse sand
2C37	55	Coarse sand	Medium sand
2C38	59	Coarse sand	Coarse sand
2C39	60	Medium sand	Medium sand
2C40	60	Medium sand	Medium sand
2C41	60	Medium sand	Coarse sand
2C42	62	Coarse sand	Coarse sand
2C43	65	Coarse sand	Coarse sand
2C44	60	Medium sand	Medium sand
2C45 R	65	Coarse sand	Medium sand

Comparisons of dominant sediment sizes between whole and top samples for each site show that the majority of them, 33 samples, were the same for on-site samples. Three of the whole on-site samples had bigger dominant grain sizes that were bigger than the top samples, four whole samples that were bigger than the top samples. The reference sites had four sites that were the same and one whole sample that had a bigger dominant grain size than the top sample. The quantitative analysis of sediment size is depicted in Figure 14 and Figure 15.

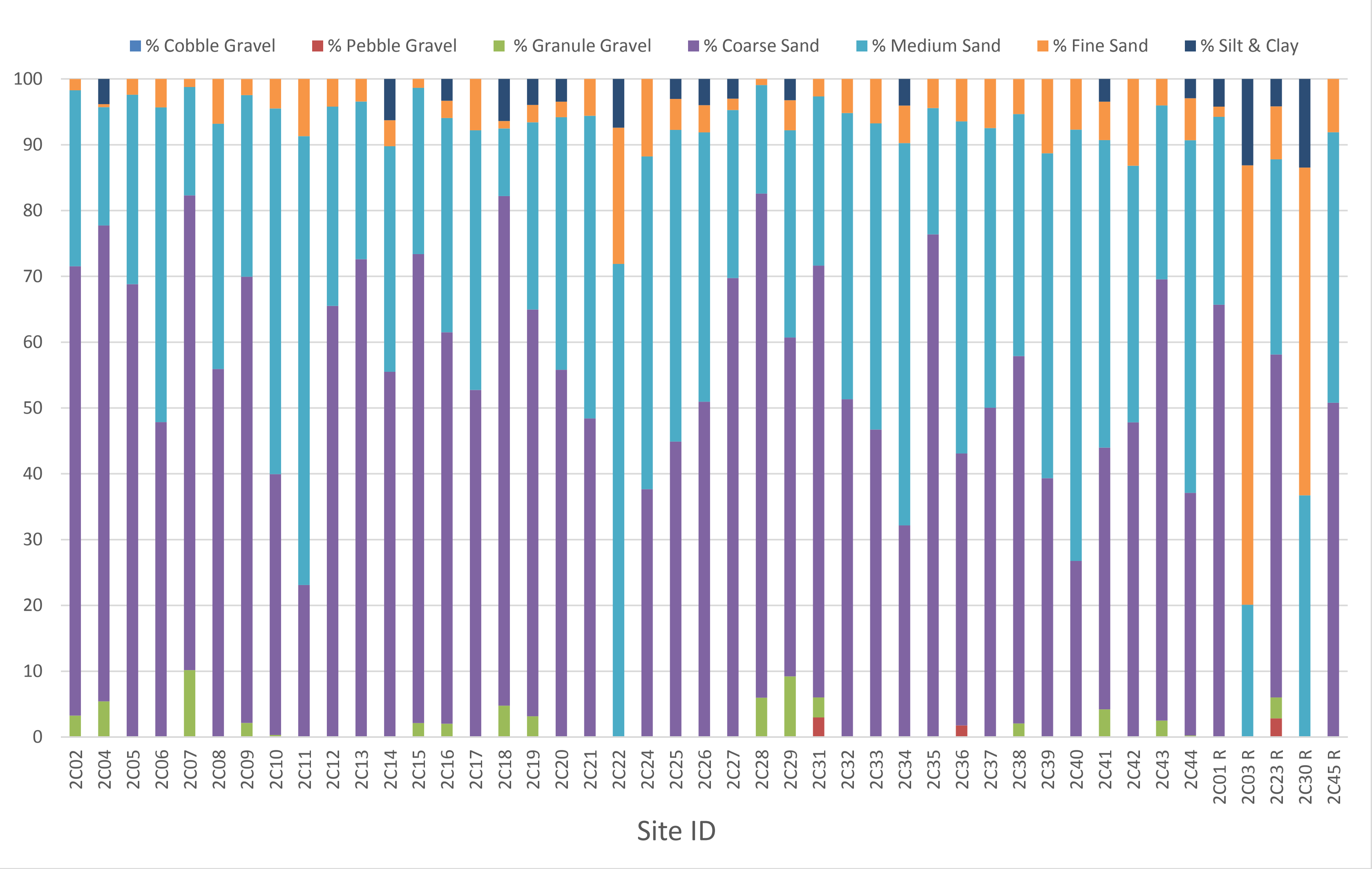


Figure 14: Sediment Composition of Whole Fall Benthic Grabs by Site for Borrow Area 2C (R=reference site)

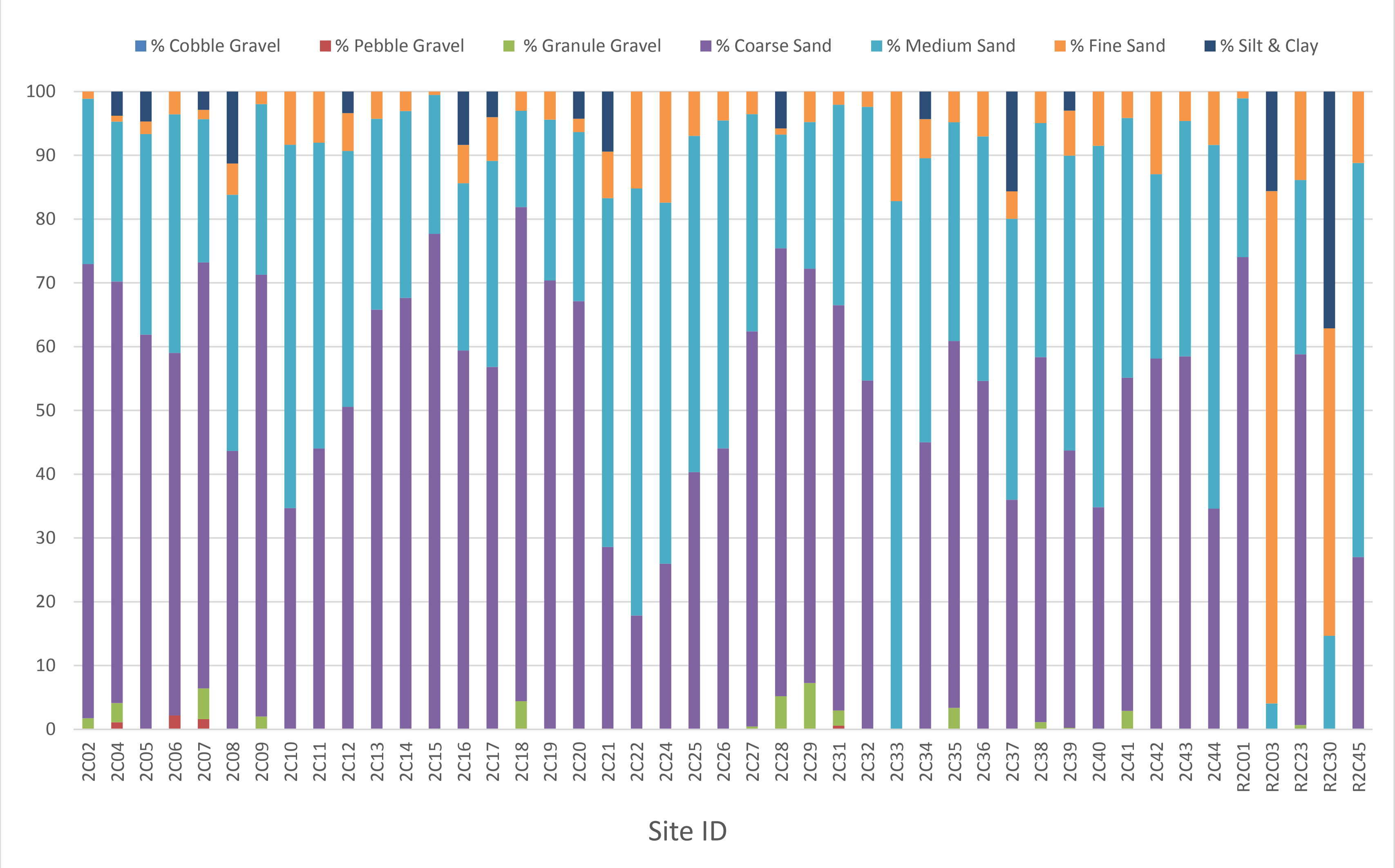


Figure 15: Sediment Composition of Top Fall Benthic Grabs by Site for Borrow Area 2C (R=reference site)

3.2.1.2 Borrow Area 5B

Overall, samples collected in both the summer and fall were predominantly medium-sized sand, with some coarse sand. Samples were analyzed as On-site or Reference, with the On-site samples further split into categories of On-site not including the dredged box, and the Dredged box. The On-site samples were divided into On-site not including the dredged box and the Dredged box to determine if the previously dredged area was filling in with fine sediment. Previous work that occurred in Borrow Area 5B include the West Hampton Bay and FIMI Smith Point projects.

Summer

On average, medium-sized particles made up 37.17% W samples and 41.41% T samples (Table 11). A closer look at this data reveals that for both the whole and top samples, the on-site samples had higher percentages of medium sand particles compared to the reference sites. Coarse-sized sand made up 31.94% W and 31.99% T of the samples. Fine to very fine-sized sand made up 26.46% W and 23.24% T, and silt and clay made up 2.11% W and 1.24% T. Cobble, pebble, and granule-sized gravel made up 2.32% W and 2.12% T combined. Cobble gravel was found in only one sample, 5B10, which is located on-site in the dredged box. The dredged box had less fine sand-sized sediment in whole and top summer samples compared to all other sample locations.

Table 11: Average Particle-size Distribution of Summer Benthic Grabs for Borrow Area 5B

Average Particle-size Distribution of Summer Benthic Grabs for Borrow Area 5B									
Benthic sample type	Location		Particle-size distribution						
			Gravel-size (%)			Sand-size (%)			Silt-size & clay-size (%)
			Cobble	Pebble	Granule	Coarse	Medium	Fine	
Whole	**On-site**	Entire borrow area	0.90	0.36	1.34	34.03	37.88ɫ	23.39	2.09
		Dredged box only	3.61	1.11	3.87	44.28	30.97	14.32	1.84
		Not including dredged box	0.00	0.12	0.49	30.62	40.19	26.42	2.17
	Reference		0.00	0.00	0.06	15.16	31.50	50.98	2.31
	Combined		0.80	0.32	1.20	31.94	37.17	26.46	2.11
Top	**On-site**	Entire borrow area	1.18	0.47	0.74	33.90	43.26ɫ	19.19	1.26
		Dredged box only	4.70	1.88	2.11	40.39	35.91	14.61	0.40
		Not including dredged box	0.00	0.00	0.29	31.74	45.71	20.72	1.54
	Reference		0.00	0.00	0.00	16.67	26.65	55.59	1.10
	Combined		1.04	0.42	0.66	31.99	41.41	23.24	1.24

Note: Significantly different values between benthic sample types are distinguished with a ɫ. "On-site Entire borrow area" is data for the entire borrow area including the dredged box; "On-site Dredged box only" is only the data for the previously dredged area; "On-site Not incld. dredged box" is the borrow area data without the dredged box data; "Reference" is the data from areas outside of the borrow area; "Combined" is the On-site and Reference location data together.

For Borrow Area 5B, student's t-tests for paired comparisons were run separately for grabs conducted on-site, in reference sites, and in the dredged box. The comparisons between whole and top samples were significantly different only for on-site entire borrow area: medium sized sand (P=0.03); the samples in the reference sites or dredged box were not significantly different. In the field, the most common descriptor of samples collected in the summer for Borrow Area 5B was “brown sand.” Traces of organic matter, invertebrates, and pieces of shell were apparent in several samples. For sediment collected at 5B in the summer, cobble was the dominant sediment type of one W and one T sample, coarse sand was the dominant type for 16 W and 16 T, medium sand was the dominant size in 19 W and 20 T; and fine sand was the dominant size in 9 W and 8 T samples. None of the pebble and granule gravel sizes or silt and clay size sediment types were dominant in any samples.

Table 12: Dominant Sediment Type Based on Lab Analysis of Summer Benthic Grabs for Borrow Area 5B

Dominant Sediment Type Based on Lab Analysis of Summer Benthic Grabs for Borrow Area 5B			
Site	**Depth (ft.)**	**Whole sample**	**Top sample**
5B1 R	41	Fine sand	Fine sand
5B2	36	Fine sand	Fine sand
5B3*	44	Medium sand	Medium sand
5B4	48	Fine sand	Medium sand
5B5	48	Medium sand	Coarse sand
5B6	46	Coarse sand	Coarse sand
5B7*	43	Coarse sand	Coarse sand
5B8	36	Fine sand	Fine sand
5B9	37	Medium sand	Coarse sand
5B10*	47	Cobble gravel	Cobble gravel
5B11	56	Medium sand	Coarse sand
5B12	52	Fine sand	Medium sand
5B13 R	57	Medium sand	Fine sand
5B14	53	Coarse sand	Coarse sand
5B15	57	Medium sand	Medium sand
5B16*	45	Coarse sand	Coarse sand
5B17*	42	Coarse sand	Coarse sand
5B18	39	Coarse sand	Coarse sand
5B19*	48	Medium sand	Medium sand
5B20	50	Medium sand	Coarse sand
5B21	53	Medium sand	Medium sand
5B22	48	Coarse sand	Coarse sand
5B23*	46	Coarse sand	Coarse sand
5B24	41	Coarse sand	Coarse sand
5B25 R	29	Medium sand	Medium sand
5B26	37	Fine sand	Fine sand
5B27*	44	Coarse sand	Coarse sand
5B28*	49	Coarse sand	Fine sand
5B29	54	Medium sand	Medium sand
5B30	54	Medium sand	Medium sand

Dominant Sediment Type Based on Lab Analysis of Summer Benthic Grabs for Borrow Area 5B

Site	Depth (ft.)	Whole sample	Top sample
5B31	48	Medium sand	Medium sand
5B32*	45	Coarse sand	Medium sand
5B33	42	Fine sand	Fine sand
5B34	38	Medium sand	Medium sand
5B35	45	Medium sand	Coarse sand
5B36	46	Coarse sand	Medium sand
5B37	51	Medium sand	Medium sand
5B38	54	Coarse sand	Medium sand
5B39	52	Fine sand	Medium sand
5B40	46	Medium sand	Medium sand
5B41	37	Coarse sand	Coarse sand
5B42	37	Medium sand	Medium sand
5B43	47	Medium sand	Medium sand
5B44 R	29	Fine sand	Fine sand
5B45 R	58	Coarse sand	Medium sand

Note: * = site inside the dredged box and R = reference

Comparisons of dominant sediment sizes between whole and top samples for each site show that 20 of them were the same for on-site samples. Eight of the whole on-site samples had a smaller dominant grain sizes than the top sample, and two whole samples that were bigger than the top sample. The reference sites had three sites that were the same and two whole samples that had bigger dominant grain size than the top sample. Whole and top samples were the same for eight of the sites in the dredged box while two whole samples had bigger grain size compared to the top sample. The quantitative analysis of sediment size is depicted in Figure 16 and Figure 17.

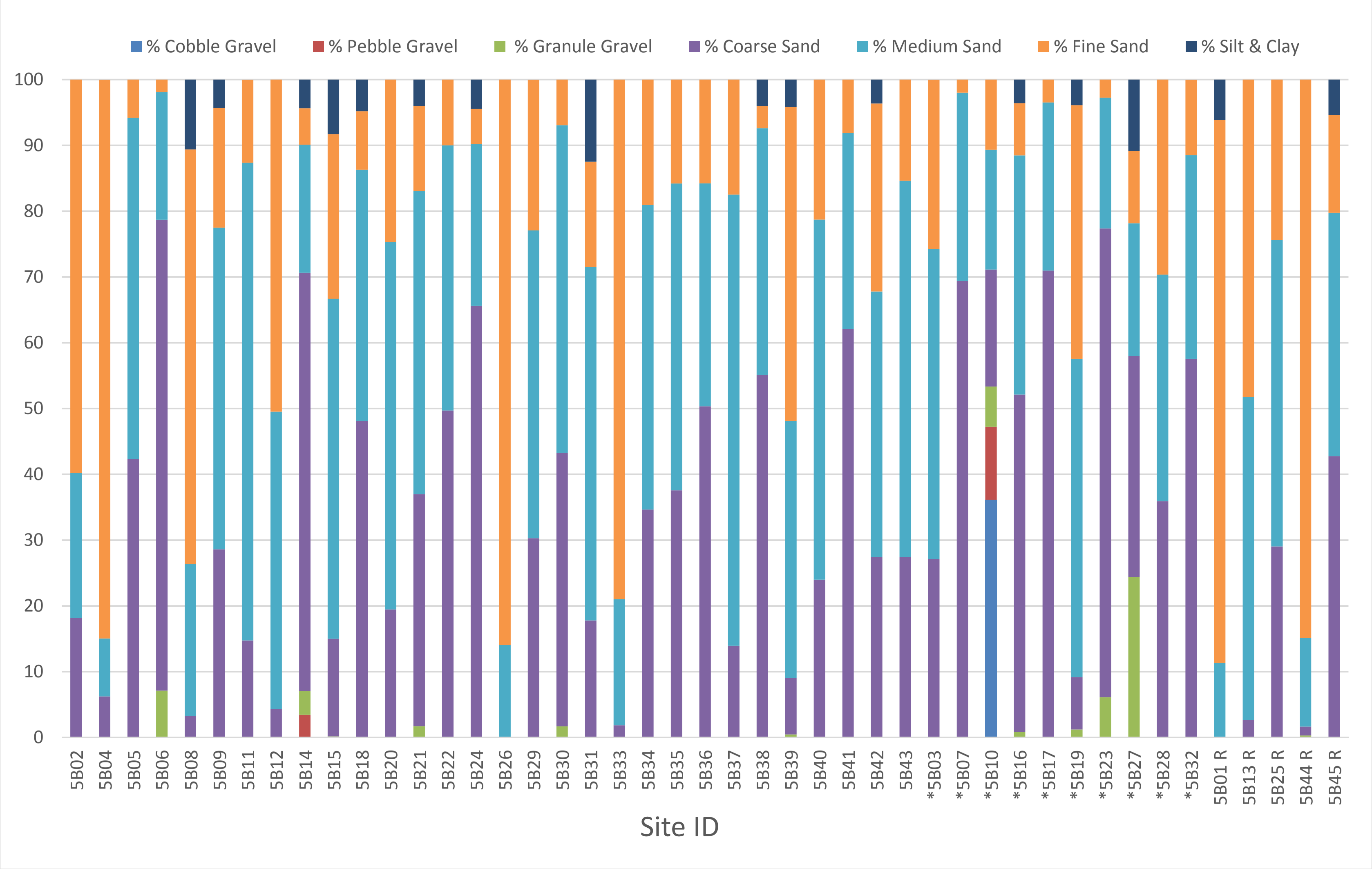


Figure 16: Sediment Composition of Whole Summer Benthic Grabs by Site for Borrow Area 5B (*in Dredged Box, R=reference site)

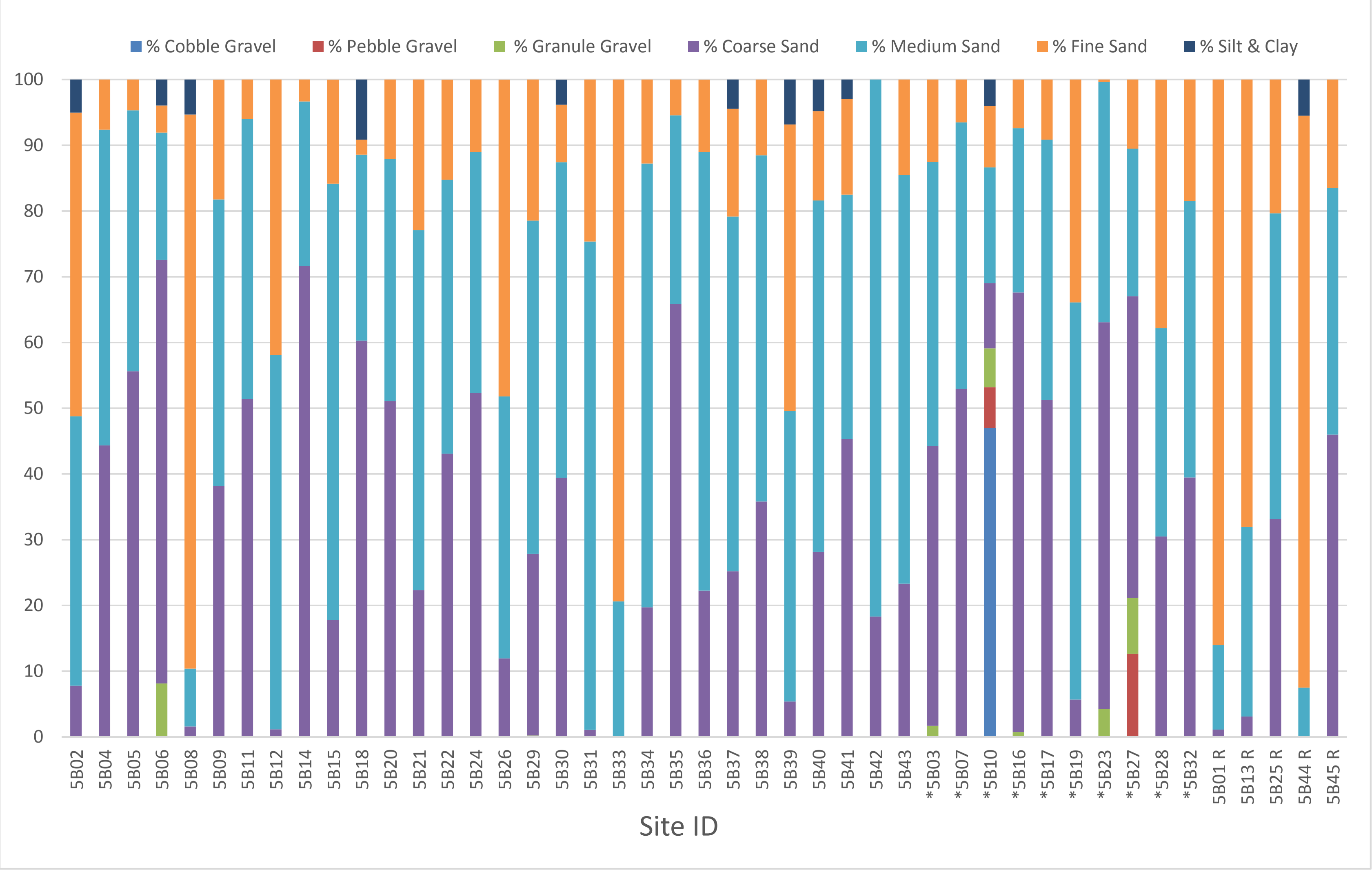


Figure 17: Sediment Composition of Top Summer Benthic Grabs by Site for Borrow Area 5B (*in Dredged Box, R=reference site)

Fall

Overall on average, samples contained 37.65% W and 38.70% T of coarse particles (Table 13). A closer look at this data reveals that for both the whole and top samples, the on-site and dredged box samples had higher percentages of coarse and medium sand particles compared to the reference sites. Medium-sized sand made up 31.68% W and 34.86% T of the samples. Fine to very fine-sized sand made up 25.34% W and 22.82% T, silt and clay made up 1.67% W and 1.33% T, pebble sized gravel made up 2.67% W and 1.51% T, and granule-sized gravel made up 0.99% W and 0.79% T. Cobble gravel was not found in any samples. The dredged box had less fine sand-sized sediment in whole and top fall samples compared to all other sample locations.

Table 13: Average Particle-size Distribution of Fall Benthic Grabs for Borrow Area 5B

Average Particle-size Distribution of Fall Benthic Grabs for Borrow Area 5B									
Benthic sample type	**Location**		**Particle-size distribution**						
			Gravel-size (%)			**Sand-size (%)**			**Silt-size & clay-size (%)**
			Cobble	**Pebble**	**Granule**	**Coarse**	**Medium**	**Fine**	
Whole	**On-site**	Entire borrow area	0.00	3.00	1.06	38.83	32.05ŧ	23.52ŧ	1.55
		Dredged box only	0.00	7.56	1.54	39.81	28.19	22.52	0.39
		Not including dredged box	0.00	0.00	0.74	36.67	33.26	26.62	2.25
	Reference		0.00	0.00	0.44	28.21	28.77	39.94	2.63
	Combined		0.00	2.67	0.99	37.65	31.68	25.34	1.67
Top	**On-site**	Entire borrow area	0.00	1.70	0.86	39.81	35.73ŧ	20.41ŧ	1.49
		Dredged box only	0.00	4.64	1.75	41.96	30.78	19.24	1.64
		Not including dredged box	0.00	0.00	0.36	37.22	36.70	24.44	1.19
	Reference		0.00	0.00	0.22	29.81	27.85	42.12	0.00
	Combined		0.00	1.51	0.79	38.70	34.86	22.82	1.33

Note: Significantly different values are distinguished with a ŧ. "On-site Entire borrow area" is data for the entire borrow area including the dredged box; "On-site Dredged box only" is only the data for the previously dredged area; "On-site Not incld. dredged box" is the borrow area data without the dredged box data; "Reference" is the data from areas outside of the borrow area; "Combined" is the On-site and Reference location data together.

Student t-tests between whole and top samples were significantly different only for on-site: medium sand (P=0.01) and fine sand (P=0.04); none of the samples in the reference sites or dredged box were significantly different (Table 13). In the field, the most common descriptor of samples collected in the fall for Borrow Area 5B was "brown sand." Traces of organic matter, invertebrates, and pieces of shell were apparent in several samples. For sediment collected at 5B, one W and one T samples were dominated by pebble, 23 W grab samples and 24 T grab samples were dominated by coarse-sized sand, 12 W and 12 T samples were dominated by medium sand and 9 W and 8 T samples were dominated by fine sand (Table 14). Cobble gravel, and silt and clay-size particles were not dominant sediment types in the fall samples.

Table 14: Dominant Sediment Type Based on Lab Analysis of Fall Benthic Grabs for Borrow Area 5B

Dominant Sediment Type Based on Lab Analysis of Fall Benthic Grabs for Borrow Area 5B			
Site	**Depth (ft.)**	**Whole sample**	**Top sample**
5B1 R	40	Fine sand	Fine sand
5B2*	41	Coarse sand	Coarse sand
5B3*	45	Medium sand	Coarse sand
5B4	52	Coarse sand	Coarse sand
5B5	47	Coarse sand	Coarse sand
5B6*	47	Coarse sand	Coarse sand
5B7*	42	Coarse sand	Coarse sand
5B8*	38	Coarse sand	Coarse sand
5B9*	45	Coarse sand	Coarse sand
5B10	49	Medium sand	Medium sand
5B11 R	61	Coarse sand	Coarse sand
5B12	55	Coarse sand	Coarse sand
5B13*	47	Medium sand	Medium sand
5B14*	46	Coarse sand	Medium sand
5B15	40	Coarse sand	Coarse sand
5B16*	41	Coarse sand	Coarse sand
5B17*	47	Fine sand	Fine sand
5B18	50	Coarse sand	Coarse sand
5B19	49	Coarse sand	Coarse sand
5B20*	45	Medium sand	Medium sand
5B21*	43	Coarse sand	Coarse sand
5B22	37	Fine sand	Fine sand
5B23 R	30	Coarse sand	Coarse sand
5B24*	41	Fine sand	Fine sand
5B25*	44	Pebble gravel	Pebble gravel
5B26	47	Fine sand	Medium sand
5B27	51	Fine sand	Fine sand
5B28	54	Medium sand	Medium sand
5B29	47	Medium sand	Medium sand
5B30	43	Fine sand	Fine sand
5B31	40	Coarse sand	Coarse sand
5B32	37	Coarse sand	Coarse sand
5B33	42	Coarse sand	Medium sand
5B34	46	Coarse sand	Coarse sand
5B35	50	Medium sand	Coarse sand
5B36	52	Medium sand	Medium sand

Dominant Sediment Type Based on Lab Analysis of Fall Benthic Grabs for Borrow Area 5B			
Site	**Depth (ft.)**	**Whole sample**	**Top sample**
5B37	46	Coarse sand	Coarse sand
5B38	40	Medium sand	Medium sand
5B39	35	Coarse sand	Coarse sand
5B40	39	Medium sand	Medium sand
5B41	42	Coarse sand	Coarse sand
5B42	50	Medium sand	Coarse sand
5B43 R	56	Medium sand	Medium sand
5B44	43	Fine sand	Fine sand
5B45 R	28	Fine sand	Fine sand

Note: * = site inside the dredged box and R = reference

Comparisons of dominant sediment sizes between whole and top samples for each site show that 22 of them were the same for on-site samples not including the dredged box. Three of the on-site samples had top samples that had bigger dominant grain sizes than the whole sample and one top sample that was smaller than the whole sample. All five reference sites were the same. The dredged box had 12 samples that were the same, one that had a bigger grain size on top and one with a smaller grain size on top. The quantitative analysis of sediment size is depicted in Figure 18 and Figure 19.

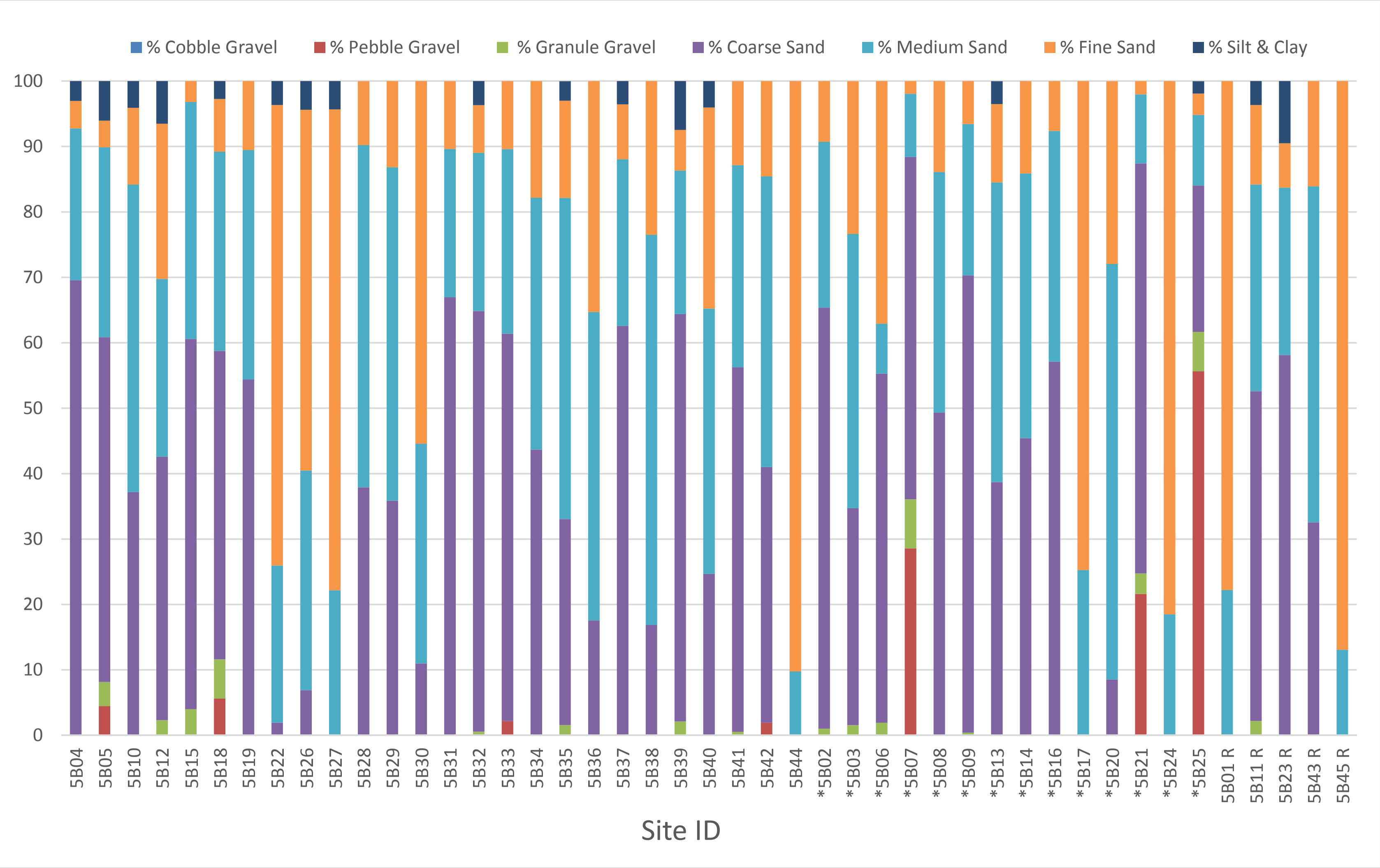


Figure 18: Sediment Composition of Whole Fall Benthic Grabs by Site for Borrow Area 5B (*in Dredged Box, R=reference site)

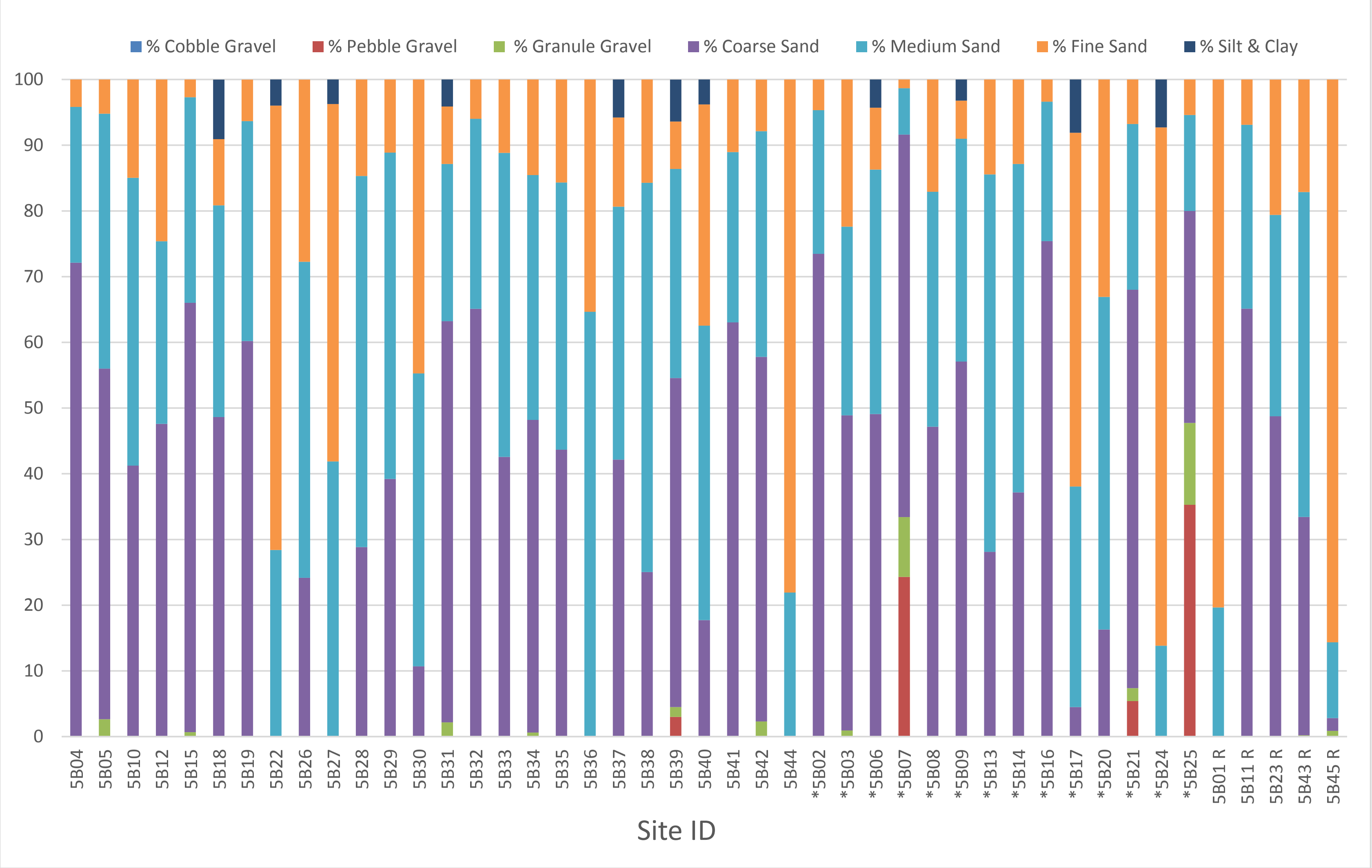


Figure 19: Sediment Composition of Top Fall Benthic Grabs by Site for Borrow Area 5B (*in Dredged Box, R=reference site)

3.2.2 BENTHIC INFAUNA

Although the benthic community in the FIMI Borrow Areas showed species overlap in the summer and fall, there were significant differences in many of the calculated community parameters. In order to focus on the benthic environment of the borrow areas, the following comparisons separate grabs conducted within the borrow areas (on-site), those conducted at nearby reference sites, and for grabs from the dredged box in Borrow Area 5B. Detailed laboratory results are provided in Appendix E. In Table 15 , a “ƚ” indicates a significant difference between seasons at the P = 0.05 level.

3.2.2.1 Borrow Area 2C

For Borrow Area 2C on-site samples, species richness, or the number of species, and the number of individuals per grab were significantly greater in samples collected in the summer relative to those collected in the fall (P < 0.0001 and P < 0.002) (Table 15). Species diversity, the dominance index, nor evenness were different between summer and fall. Reference areas for Borrow Area 2C did not differ between summer and fall sampling events for any of the calculated community parameters. One whole benthic grab that was not subsampled, identified as 2C34A in Appendix E, was sieved down for analysis to compare to samples that were subsampled. The presence of pollution sensitive species (*Acanthohaustorius intermedius*, *Acanthohaustorius millsi*, *Parahaustorius attenuates*, *Protohaustorius wigleyi*, *Chiridotea tuftsi*, *Tanaissus psammophilus*, *Lumbrinereis acuta*, and *Nephtys incisa*) indicate that the benthic environment in Borrow Area 2C is not impacted by pollution (Pelletier et al. 2010).

Table 15: Comparison of Average Benthic Parameters for Borrow Area 2C

Comparison of Average Benthic Parameters for Borrow Area 2C					
Season/ P-value	**Average species richness (R)**	**Individuals per grab**	**Shannon diversity index (H’)**	**Simpson’s dominance index (λ)**	**Pielou’s evenness index (J’)**
On-site (n = 40 summer, n = 40 fall)					
Summer	18.50ƚ	176.08ƚ	1.81	0.31	0.63
Fall	14.00ƚ	94.20ƚ	1.79	0.28	0.68
P-value	< 0.0001	0.003	0.83	0.35	0.12
Reference (n = 5 summer, n = 5 fall)					
Summer	17.80	224.00	1.56	0.40	0.55
Fall	15.00	92.20	1.88	0.24	0.71
P-value	0.31	0.14	0.37	0.24	0.26

Note: ƚ indicates significantly different values.

In Borrow Area 2C, a total of 12,534 individual organisms representing 117 different species from eight phyla were collected for the summer and fall benthic grabs (Table 17).

Table 16: Benthic Community Composition in Borrow Area 2C

Benthic Community Composition in Borrow Area 2C				
Summer 2015				
Phylum	**On-site**		**Reference**	
	Individ	**%**	**Individ**	**%**
Arthropoda	4,277	61.17	725	64.85
Nematoda	1,417	20.27	122	10.91
Annelida - Polychaeta	959	13.72	184	16.46
Molluska	194	2.77	56	5.01
Echinodermata	80	1.14	9	0.81
Annelida - Oligochaeta	44	0.63	19	1.70
Nemetinea	19	0.27	3	0.27
Actiniaria	2	0.03	0	0.00
Platyhelminthes	0	0.00		
Total	6,992	100	1,118	100
Fall 2015				
Phylum	**On-site**		**Reference**	
	Individ	**%**	**Individ**	**%**
Annelida - Polychaeta	1,421	35.86	231	50.11
Arthropoda	1,161	29.30	47	10.20
Nematoda	1,144	28.87	122	26.46
Molluska	117	2.95	51	11.06
Echinodermata	79	1.99	4	0.87
Annelida - Oligochaeta	30	0.76	6	1.30
Platyhelminthes	5	0.12	0	0.00
Nemetinea	4	0.10	0	0.00
Actiniaria	2	0.05	0	0.00
Total	3,963	100	461	100

Note: Individ = number of individuals

Fall and summer samples shared 55.56% of the same species. Of the overall total, 8,110 (64.70%) were collected in the summer, and 4,424 (35.30%) were collected in the fall. As was indicated by the community parameters, the summer had greater species richness, with 94 distinct taxa identified, while the fall had 90 taxa. The most abundant phylum in the summer for on-site samples was Arthropoda (61.17%) followed by Nematoda (20.27%) and Annelida-Polychaeta (13.72%). These phyla also dominated the reference site benthic community but in different proportions (Arthropoda [64.85%], Annelida-Polychaeta [16.46%], Nematoda [10.91%]. In the fall the top three phyla didn't change but for on-site samples there was not a strongly dominant phyla among them (Annelida-Polychaeta [35.86%], Arthropoda [29.30%], Nematoda [28.87%]. In fall reference sites Annelida-Polychaeta dominated (50.11%) along with Nematoda (26.46%), Molluska (11.06%), and Arthropoda (10.20%). Molluska makes up a higher proportion of the fall reference benthic community compared to summer samples. The species richness for the benthic grab that was not subsampled, 2C34A, was 27. Sample 2C34A did not have any species that were not also collected in the subsampled samples.

At the species level, the dominant species were similar between on-site and reference samples within a particular season, but summer and fall samples were dominated by different organisms. *Pseudunciola obliquua*, an amphipod, was the most dominant species in both on-site and reference summer samples (Table 17). This species made up 52.55% of on-site samples with Nematoda species making up another 20.27%. All other on-site species made up less than 4% each. *Pseudunciola obliquua* made up 60.38% of the reference site species with Nematoda species making up another 10.91%. All other summer reference species made up less than 5% each. In the fall, Nematoda species dominated abundance in on-site samples at 28.87% (Table 18). The polychaete *Polygordius jouinae* and amphipod *Pseudunciola obliquua* were also abundant at 25.41% and 16.70%, respectively. All other on-site species made up less than 4% each. The fall reference samples were dominated by *Polygordius jouinae* at 30.63% and Nematoda species at 26.70%. *Nucula proxima* made up 8.97% and *Capitellidae* juveniles made up 7.44%; all other species made up less than 3% each.

Table 17: Twenty Most Abundant Benthic Infauna Present in Borrow Area 2C in Summer

Twenty Most Abundant Benthic Infauna Present in Borrow Area 2C in Summer							
On-site				Reference			
Taxon	Species	Total	%	Taxon	Species	Total	%
Arthropoda - Amphipoda	*Pseudunciola obliquua*	3674	52.55	Arthropoda - Amphipoda	*Pseudunciola obliquua*	675	60.38
Nematoda	Nematoda spp.	1417	20.27	Nematoda	Nematoda spp.	122	10.91
Annelida - Polychaeta	*Tharyx* spp.	232	3.32	Annelida - Polychaeta	*Polygordius jouinae*	52	4.65
Annelida - Polychaeta	*Aricidea catherinae*	186	2.66	Annelida - Polychaeta	*Capitellidae juveniles*	50	4.47
Annelida - Polychaeta	*Polygordius jouinae*	182	2.60	Molluska - Bivalvia	*Tellina agilis*	39	3.49
Arthropoda - Amphipoda	*Rhepoxynuis epistomus*	181	2.59	Annelida - Oligochaeta	Oligochaeta spp.	19	1.70
Arthropoda - Amphipoda	*Protohaustorius wigleyi*	143	2.05	Arthropoda - Amphipoda	*Rhepoxynuis epistomus*	16	1.43
Molluska - Bivalvia	*Tellina agilis*	116	1.66	Arthropoda - Amphipoda	*Ampelisca verrilli*	10	0.89
Annelida - Polychaeta	*Goniadella gracilis*	68	0.97	Molluska - Bivalvia	*Yoldia limatula*	10	0.89
Arthropoda - Maxillopoda	Harpacticoid copepod spp.	59	0.84	Annelida - Polychaeta	*Leitoscoloplos robustus*	9	0.81
Annelida - Polychaeta	*Brania wellfleetensis*	53	0.76	Annelida - Polychaeta	*Nepthys picta*	8	0.72
Arthropoda - Tanaidacea	*Tanaissus psammophilus*	51	0.73	Annelida - Polychaeta	*Nephtys bucera*	8	0.72
Annelida - Oligochaeta	Oligochaeta spp.	44	0.63	Annelida - Polychaeta	*Tharyx* spp.	7	0.63
Arthropoda - Amphipoda	*Acanthohaustorius millsi*	41	0.59	Arthropoda - Amphipoda	*Protohaustorius wigleyi*	7	0.63
Molluska - Bivalvia	*Spisula solidissima*	34	0.49	Annelida - Polychaeta	*Drilonereis longa*	6	0.54
Arthropoda - Cumacea	*Pseudoleptocuma minor*	33	0.47	Arthropoda - Tanaidacea	*Tanaissus psammophilus*	5	0.45
Annelida - Polychaeta	*Parougia caeca*	20	0.29	Annelida - Polychaeta	*Parougia caeca*	4	0.36
Annelida - Polychaeta	*Sigalion arenicola*	20	0.29	Annelida - Polychaeta	*Clymenella zonalis*	4	0.36
Nemertinea	Nemertinea spp.	19	0.27	Annelida - Polychaeta	*Sigalion arenicola*	3	0.27
Arthropoda - Isopoda	*Politolana polita*	18	0.26	Nemertinea	Nemertinea spp.	3	0.27

Note: “On-site” is the data for samples within the borrow area; “Reference” is the data for the area sampled outside of the borrow area.

Table 18: Twenty Most Abundant Benthic Infauna Present in Borrow Area 2C in Fall

Twenty Most Abundant Benthic Infauna Present in Borrow Area 2C in Fall							
On-site				**Reference**			
Taxon	**Species**	**Total**	**%**	**Taxon**	**Species**	**Total**	**%**
Nematoda	Nematoda spp.	1144	28.87	Annelida - Polychaeta	*Polygordius jouinae*	140	30.63
Annelida - Polychaeta	*Polygordius jouinae*	1007	25.41	Nematoda	Nematoda spp.	122	26.70
Arthropoda - Amphipoda	*Pseudunciola obliquua*	662	16.70	Molluska - Bivalvia	*Nucula proxima*	41	8.97
Arthropoda - Tanaidacea	*Tanaissus psammophilus*	143	3.61	Annelida - Polychaeta	*Capitellidae juveniles*	34	7.44
Arthropoda - Amphipoda	*Rhepoxynuis epistomus*	137	3.46	Arthropoda - Amphipoda	*Pseudunciola obliquua*	17	3.72
Annelida - Polychaeta	*Tharyx* spp.	118	2.98	Annelida - Polychaeta	*Goniadella gracilis*	10	2.19
Arthropoda - Amphipoda	*Protohaustorius wigleyi*	109	2.75	Arthropoda - Tanaidacea	*Tanaissus psammophilus*	6	1.31
Molluska - Bivalvia	*Tellina agilis*	89	2.25	Annelida - Oligochaeta	Oligochaeta spp.	6	1.31
Annelida - Polychaeta	*Syllides setosa*	65	1.64	Annelida - Polychaeta	*Spiochaetopterus oculatus*	6	1.31
Annelida - Polychaeta	*Goniadella gracilis*	36	0.91	Arthropoda - Amphipoda	*Corophium* spp.	5	1.09
Annelida - Polychaeta	*Aricidea catherinae*	34	0.86	Annelida - Polychaeta	*Leitoscoloplos* spp. juveniles	5	1.09
Arthropoda - Amphipoda	*Acanthohaustorius millsi*	32	0.81	Annelida - Polychaeta	*Asabellides oculata*	5	1.09
Arthropoda - Maxillopoda	Harpacticoid copepod spp.	31	0.78	Molluska - Bivalvia	*Tellina agilis*	4	0.88
Annelida - Oligochaeta	Oligochaeta spp.	30	0.76	Annelida - Polychaeta	*Aricidea catherinae*	4	0.88
Annelida - Polychaeta	*Paraonis fulgens*	24	0.61	Annelida - Polychaeta	*Paraonis fulgens*	4	0.88
Annelida - Polychaeta	*Parapionosyllis longicirrata*	24	0.61	Annelida - Polychaeta	*Tharyx* spp.	3	0.66
Annelida - Polychaeta	*Aricidea wassi*	10	0.25	Annelida - Polychaeta	*Exogone* sp.	3	0.66
Annelida - Polychaeta	*Sigalion arenicola*	10	0.25	Arthropoda - Amphipoda	*Unciola irrorata*	3	0.66
Annelida - Polychaeta	*Spiophanes bombyx*	10	0.25	Arthropoda - Cumacea	*Diastylis sculpta*	3	0.66
Annelida - Polychaeta	*Exogone* sp.	9	0.23	Annelida - Polychaeta	*Nepthys picta*	3	0.66

Note: “On-site” is the data for samples within the borrow area; “Reference” is the data for the area sampled outside of the borrow area.

3.2.2.2 Borrow Area 5B

To focus on the benthic environment of the borrow areas, the following comparisons separate grabs conducted within the borrow areas (on-site), those conducted at nearby reference sites, and for grabs from the dredged box. In Table 19, a "ƚ" indicates a significant difference between seasons at the P = 0.05 level. For Borrow Area 5B on-site samples, all of the calculated parameters were significantly different between seasons; species richness, individuals per grab, and dominance index were greater in the summer. The greater dominance index indicateds that fewer taxa make up most of the individuals in the fall. The diversity index and evenness index were greater in the fall. For reference samples the number of individuals per grab was significantly greater in the summer (P = 0.025) and for the dredged area, species richness and the number of individuals were significantly greater in the summer. The other calculated parameters were not significantly different. The presence of pollution sensitive species (*Acanthohaustorius intermedius*, *Acanthohaustorius millsi*, *Parahaustorius attenuates*, *Protohaustorius wigleyi*, *Chiridotea tuftsi*, and *Tanaissus psammophilus*) indicate that the benthic environment in Borrow Area 5B is not impacted by pollution (Pelletier et al. 2010).

Table 19: Comparison of Average Benthic Parameters for Borrow Area 5B

Comparison of Average Benthic Parameters for Borrow Area 5B					
Season/ P=value	**Average species richness (R)**	**Individuals per grab**	**Shannon diversity index (H')**	**Simpson's dominance index (λ)**	**Pielou's evenness index (J')**
On-site (not including dredged box) (n = 30 summer, n = 26 fall)					
Summer	17.03ƚ	602.83ƚ	1.17	0.52ƚ	0.41
Fall	12.31	97.96	1.52ƚ	0.36	0.61ƚ
P-value	< 0.0001	< 0.0002	0.02	0.005	0.0001
Reference (n = 5 summer, n = 5 fall)					
Summer	17.60	244.8ƚ	1.54	0.40	0.54
Fall	12.20	72.80	1.43	0.40	0.62
P-value	0.15	0.025	0.74	0.99	0.53
Dredged box (n = 10 summer, n = 14 fall)					
Summer	16.30ƚ	220.20ƚ	1.46	0.39	0.53
Fall	10.57	85.00	1.37	0.42	0.59
P-value	0.0009	0.012	0.59	0.60	0.24

Note: ƚ indicates a significantly greater value between seasons.

In Borrow Area 5B, a total of 25,612 individual organisms representing 99 different species from seven phyla were collected for the summer and fall benthic grabs (Table 20; Appendix E). Of these, 21,511 (83.99%) were collected in the summer, and 4,101 (16.01%) were collected in the fall. As was indicated by the community parameters, the summer had greater species richness, with 90 distinct taxa identified, while the fall had 67 taxa. The most abundant phylum in the summer for on-site samples was Arthropoda (63.36%) followed by Nematoda (23.84%) and Annelida-Polychaeta (10.71%). These phyla also dominated the reference site benthic community but in different proportions (Nematoda [37.25%], Annelida-Polychaeta [31.62%], Arthropoda [24.67%]). The sites in the dredged box exhibited a similar pattern (Nematoda [37.60%], Arthropoda [35.88%], Annelida-Polychaeta [22.30%]). In the fall the top three phyla didn't change but for on-site samples there wasn't a strongly dominant phyla among them (Nematoda [39.62%], Arthropoda [29.41%], Annelida-Polychaeta [26.82%]). Fall reference sites were dominated by Nematoda (57.69%) and Annelida-Polychaeta (28.85%). The fall dredged area samples were dominated by Nematoda (38.40%), Arthropoda (31.26%), and Annelida-Polychaeta (26.55%) in proportions similar to the summer samples.

Table 20: Benthic Community Composition in Borrow Area 5B

Benthic Community Composition in Borrow Area 5B						
Summer 2015						
Phylum	**On-site**		**Reference**		**Box**	
	Individ	**%**	**Individ**	**%**	**Individ**	**%**
Arthropoda	11,477	63.46	302	24.67	790	35.88
Nematoda	4,312	23.84	456	37.25	828	37.60
Annelida - Polychaeta	1,936	10.71	387	31.62	491	22.30
Molluska	252	1.39	66	5.39	79	3.59
Echinodermata	66	0.36	8	0.65	7	0.32
Annelida - Oligochaeta	20	0.11	1	0.08	4	0.18
Nemetinea	18	0.10	4	0.33	3	0.14
Platyhelminthes	4	0.02	0	0.00	0	0.00
Total	18,085	100.00	1,224	100.00	2,202	100.00
Fall 2015						
Phylum	**On-site**		**Reference**		**Box**	
	Individ	**%**	**Individ**	**%**	**Individ**	**%**
Nematoda	1,009	39.62	210	57.69	457	38.40
Arthropoda	749	29.41	29	7.97	372	31.26
Annelida - Polychaeta	683	26.82	105	28.85	316	26.55
Echinodermata	77	3.02	4	1.10	25	2.10
Molluska	23	0.90	13	3.57	16	1.34
Annelida - Oligochaeta	4	0.16	2	0.55	1	0.08
Nemetinea	2	0.08	0	0.00	3	0.25
Platyhelminthes	0	0.00	1	0.27	0	0.00
Total	2,547	100.00	364	100.00	1,190	100.00

At the species level, Borrow Area 5B summer and fall samples were dominated by a handful of taxa and had 59.60% of species in common. In summer samples, *Pseudunciola obliquua,* an amphipod, was the most dominant species in on-site samples making up 60.56% of the sample (Table 21). Nematoda species made up 23.84% and Capitellidae juveniles made up another 6.10%; the remaining species made up less than 2% each. For reference samples, Nematoda species were the most abundant taxa at 37.25%. The other dominant reference sample species were Capitillidae juveniles at 23.04% and *Protohaustorius wigleyi* at 14.79%; all other species made up less than 6% each. In the dredged area samples, Nematoda species were the most abundant taxa at 37.60%. Similar to the other sample types, *Pseudunciola obliquua* and Capitellidae juveniles were also dominant at 33.51% and 11.26%, respectively. All other species made up less than 3% each.

The most abundant species for fall in on-site samples did not change from the summer; Nematoda species were the most abundant at 39.62%, *Pseudunciola obliquua* made up 23.95%, and Capitellidae juveniles made up 9.78%; all other species made up less than 5% each (Table 22). Fall reference samples were very similar to the on-site samples. Reference samples were dominated by Nematoda at 38.40% just like the summer samples. *Pseudunciola obliquua* made up 28.24%, and Capitellidae juveniles made up 5.57%; all other species made up less than 5% each. The dredged box samples were more strongly dominated by Nematoda species in the fall compared to spring at 57.69%. Capitillidae juveniles and *Apoprionospio pygmaea* were also present in larger numbers than other species at 6.87% and 6.04%, respectively. All other species were present at less than 6% each.

Table 21: Twenty Most Abundant Benthic Infauna Present in Borrow Area 5B in Summer

Twenty Most Abundant Benthic Infauna Present in Borrow Area 5B in Summer											
On-site				**Reference**				**Dredged box**			
Taxon	**Species**	**Total**	**%**	**Taxon**	**Species**	**Total**	**%**	**Taxon**	**Species**	**Total**	**%**
Arthropoda - Amphipoda	*Pseudunciola obliquua*	10,952	60.56	Nematoda	*Nematoda* spp.	456	37.25	Nematoda	*Nematoda* spp.	828	37.60
Nematoda	Nematoda spp.	4,312	23.84	Annelida - Polychaeta	Capitellidae juveniles	282	23.04	Arthropoda - Amphipoda	*Pseudunciola obliquua*	738	33.51
Annelida - Polychaeta	Capitellidae juveniles	1,104	6.10	Arthropoda - Amphipoda	*Protohaustorius wigleyi*	181	14.79	Annelida - Polychaeta	*Capitellidae juveniles*	248	11.26
Arthropoda - Amphipoda	*Protohaustorius wigleyi*	337	1.86	Arthropoda - Amphipoda	*Pseudunciola obliquua*	62	5.07	Annelida - Polychaeta	*Polygordius jouinae*	60	2.72
Annelida - Polychaeta	*Tharyx* spp.	262	1.45	Molluska - Bivalvia	*Spisula solidissima*	37	3.02	Annelida - Polychaeta	*Tharyx* spp.	59	2.68
Annelida - Polychaeta	*Polygordius jouinae*	216	1.19	Molluska - Bivalvia	*Tellina agilis*	28	2.29	Molluska - Bivalvia	*Tellina agilis*	43	1.95
Molluska - Bivalvia	*Tellina agilis*	174	0.96	Arthropoda - Amphipoda	*Acanthohaustorius millsi*	20	1.63	Molluska - Bivalvia	*Spisula solidissima*	28	1.27
Molluska - Bivalvia	*Spisula solidissima*	72	0.40	Annelida - Polychaeta	*Megalona* sp.	18	1.47	Annelida - Polychaeta	*Goniadella gracilis*	27	1.23
Echinodermata - Echinodea	*Echinarachnius parma*	66	0.36	Annelida - Polychaeta	*Spiophanes bombyx*	17	1.39	Annelida - Polychaeta	*Spiophanes bombyx*	19	0.86
Annelida - Polychaeta	*Megalona* sp.	51	0.28	Arthropoda - Amphipoda	*Rhepoxynuis epistomus*	14	1.14	Arthropoda - Amphipoda	*Protohaustorius wigleyi*	13	0.59
Arthropoda - Tanaidacea	*Tanaissus psammophilus*	48	0.27	Annelida - Polychaeta	*Tharyx* spp.	14	1.14	Annelida - Polychaeta	*Paraonis fulgens*	11	0.50
Arthropoda - Amphipoda	*Acanthohaustorius millsi*	37	0.20	Arthropoda - Amphipoda	*Psammonyx nobilis*	11	0.90	Annelida - Polychaeta	*Spio setosa*	9	0.41
Arthropoda - Amphipoda	*Rhepoxynuis epistomus*	32	0.18	Annelida - Polychaeta	*Aricidea wassi*	11	0.90	Arthropoda - Tanaidacea	*Tanaissus psammophilus*	8	0.36
Annelida - Polychaeta	*Spiophanes bombyx*	32	0.18	Annelida - Polychaeta	*Polygordius jouinae*	8	0.65	Annelida - Polychaeta	*Orbinia swani*	8	0.36
Annelida - Polychaeta	*Aricidea wassi*	30	0.17	Echinodermata - Echinodea	*Echinarachnius parma*	8	0.65	Annelida - Polychaeta	*Nepthys picta*	7	0.32
Annelida - Polychaeta	*Orbinia swani*	28	0.15	Annelida - Polychaeta	*Apoprionospio pygmaea*	6	0.49	Echinodermata - Echinodea	*Echinarachnius parma*	7	0.32
Annelida - Polychaeta	*Asabellides oculata*	25	0.14	Annelida - Polychaeta	*Asabellides oculata*	5	0.41	Arthropoda - Isopoda	*Politolana polita*	6	0.27

Twenty Most Abundant Benthic Infauna Present in Borrow Area 5B in Summer											
On-site				Reference				Dredged box			
Taxon	**Species**	**Total**	**%**	**Taxon**	**Species**	**Total**	**%**	**Taxon**	**Species**	**Total**	**%**
Annelida - Polychaeta	*Goniadella gracilis*	25	0.14	Annelida - Polychaeta	*Paraonis fulgens*	5	0.41	Annelida - Polychaeta	*Megalona* sp.	5	0.23
Annelida - Polychaeta	*Paraonis fulgens*	25	0.14	Arthropoda - Tanaidacea	*Tanaissus psammophilus*	4	0.33	Annelida - Polychaeta	*Polydora socialis*	5	0.23
Annelida - Oligochaeta	*Oligochaeta* spp.	20	0.11	Annelida - Polychaeta	*Nephtys bucera*	4	0.33	Arthropoda - Maxillopoda	Harpacticoid copepod spp.	5	0.23

Note: "On-site" is the data for samples within the borrow area but not the dredged box; "Reference" is the data for the area sampled outside of the borrow area; "Dredged box" is the data for the dredged area.

Table 22: Twenty Most Abundant Benthic Infauna Present in Borrow Area 5B in Fall

Twenty Most Abundant Benthic Infauna Present in Borrow Area 5B in Fall											
On-site				Reference				Box			
Taxon	**Species**	**Total**	**%**	**Taxon**	**Species**	**Total**	**%**	**Taxon**	**Species**	**Total**	**%**
Nematoda	Nematoda spp	1,009	39.62	Nematoda	Nematoda spp	457	38.40	Nematoda	*Nematoda spp*	210	57.69
Arthropoda - Amphipoda	*Pseudunciola obliquua*	610	23.95	Arthropoda - Amphipoda	*Pseudunciola obliquua*	336	28.24	Annelida - Polychaeta	Capitellidae juveniles	25	6.87
Annelida - Polychaeta	Capitellidae *juveniles*	249	9.78	Annelida - Polychaeta	Capitellidae juveniles	102	8.57	Annelida - Polychaeta	*Apoprionospio pygmaea*	22	6.04
Annelida - Polychaeta	*Tharyx spp*	109	4.28	Annelida - Polychaeta	*Tharyx* spp	70	5.88	Annelida - Polychaeta	*Polygordius jouinae*	21	5.77
Annelida - Polychaeta	*Polygordius jouinae*	93	3.65	Annelida - Polychaeta	*Polygordius jouinae*	61	5.13	Arthropoda - Amphipoda	*Protohaustorius wigleyi*	9	2.47
Echinodermata - Echinodea	*Echinarachnius parma*	70	2.75	Echinodermata - Echinodea	*Echinarachnius parma*	20	1.68	Annelida - Polychaeta	*Tharyx* spp	8	2.20
Annelida - Polychaeta	*Apoprionospio pygmaea*	68	2.67	Arthropoda - Tanaidacea	*Tanaissus psammophilus*	13	1.09	Molluska - Bivalvia	*Tellina agilis*	7	1.92
Arthropoda - Amphipoda	*Protohaustorius wigleyi*	45	1.77	Annelida - Polychaeta	*Megalona* sp.	12	1.01	Arthropoda - Amphipoda	*Pseudunciola obliquua*	5	1.37
Arthropoda - Tanaidacea	*Tanaissus psammophilus*	30	1.18	Arthropoda - Amphipoda	*Protohaustorius wigleyi*	11	0.92	Annelida - Polychaeta	*Megalona* sp.	5	1.37
Annelida - Polychaeta	*Megalona* sp.	26	1.02	Molluska - Bivalvia	*Tellina agilis*	11	0.92	Annelida - Polychaeta	*Goniadella gracilis*	5	1.37

Twenty Most Abundant Benthic Infauna Present in Borrow Area 5B in Fall											
On-site				**Reference**				**Box**			
Taxon	**Species**	**Total**	**%**	**Taxon**	**Species**	**Total**	**%**	**Taxon**	**Species**	**Total**	**%**
Annelida - Polychaeta	*Polydora* spp.(juvenile)	23	0.90	Annelida - Polychaeta	*Goniadella gracilis*	11	0.92	Molluska - Bivalvia	*Spisula solidissima*	5	1.37
Annelida - Polychaeta	*Spiophanes bombyx*	20	0.79	Annelida - Polychaeta	*Paraonis fulgens*	10	0.84	Echinodermata - Echinodea	*Echinarachnius parma*	4	1.10
Annelida - Polychaeta	*Paraonis fulgens*	18	0.71	Annelida - Polychaeta	*Parougia caeca*	8	0.67	Annelida - Polychaeta	*Paraonis fulgens*	4	1.10
Annelida - Polychaeta	*Parougia caeca*	15	0.59	Annelida - Polychaeta	*Spiophanes bombyx*	7	0.59	Annelida - Polychaeta	*Spiophanes bombyx*	4	1.10
Arthropoda - Amphipoda	*Rhepoxynuis epistomus*	14	0.55	Annelida - Polychaeta	*Sigalion arenicola*	6	0.50	Annelida - Polychaeta	*Aricidea catherinae*	3	0.82
Molluska - Bivalvia	*Tellina agilis*	11	0.43	Echinodermata - Holothuroidea	*Leptosynapta* spp.	5	0.42	Arthropoda - Amphipoda	*Ampelisca verrilli*	3	0.82
Annelida - Polychaeta	*Aricidea wassi*	10	0.39	Annelida - Polychaeta	*Aricidea wassi*	4	0.34	Arthropoda - Amphipoda	*Psammonyx nobilis*	3	0.82
Arthropoda - Amphipoda	*Unciola irrorata*	9	0.35	Annelida - Polychaeta	*Apoprionospio pygmaea*	3	0.25	Annelida - Polychaeta	*Aricidea wassi*	2	0.55
Molluska - Bivalvia	*Lyonsia hyalina*	7	0.27	Molluska - Bivalvia	*Lyonsia hyalina*	3	0.25	Arthropoda - Amphipoda	*Rhepoxynuis epistomus*	2	0.55
Annelida - Polychaeta	*Sigalion arenicola*	7	0.27	Annelida - Polychaeta	*Aricidea catherinae*	3	0.25	Annelida - Oligochaeta	Oligochaeta spp.	2	0.55

Note: “On-site” is the data for samples within the borrow area but not the dredged box; “Reference” is the data for the area sampled outside of the borrow area; “Dredged box” is the data for the dredged area.

3.3 FISH TRAWLS

Between July and October 2015, 140 trawls were conducted within and adjacent to the FIMI Borrow Areas, with 70 trawls in Borrow Area 2C and 70 trawls in Borrow Area 5B. In total, 52 fish species and 19 macroinvertebrate species were identified. A total of 13,966 individual fish were captured.

3.3.1 BORROW AREA 2C TRAWLS

Overall, 36 species were collected in the project trawls. The total biomass of the trawls in Borrow Area 2C was 832,927 g (Table 23). Throughout all months the most numerically abundant species was the longfin squid, followed by northern searobin (*Prionotus carolinus*) and scup (*Stenotomus chrysops*). Winter skate had the greatest biomass, followed by clearnose skate (*Raja eglanteria*) and northern searobin. The fish trawl results are presented in more detail in the following sections, first by temporal trends, then by spatial patterns.

3.3.1.1 MONTHLY COMPARISONS

In July and August, northern searobin had the greatest biomass (Table 23). In July, clearnose skate had the second greatest biomass followed by summer flounder. Clearnose and winter skate had the second and third highest biomass in August. Clearnose skate had the highest biomass in September followed by winter skate and northern searobin. By month, winter skate had the greatest biomass only in October even though it had the greatest overall biomass. Longfin squid and spiny dogfish had the second and third highest biomasses in October, respectively. October was the only month that spiny dogfish were recorded in this borrow area.

Although many species showed overlap from month to month, the overall catch composition showed variation depending on the time of year (Table 24). Northern searobin and longfin squid were the most abundant species by number in Borrow Area 2C during the monthly trawls. In July and September northern searobin was the most abundant and in August and October, longfin squid was the most abundant. Of the 36 species collected, 12 species (33.33% of total species) were collected during all four months: winter skate, clearnose skate, northern searobin, longfin squid, summer flounder (*Paralichthys dentatus*), windowpane (*Scophthalmus aquosus*), spotted hake (*Urophycis regia*), little skate (*Leucoraja erinacea*), scup, northern puffer (*Sphoeroides maculatus*), smallmouth flounder (*Etropus microstomus*), and lined seahorse (*Hippocampus erectus*). Five species (13.89%) occurred in three of the four months of trawls and eight species (22.22%) were captured in two of the four months of trawls. There were 11 species (30.56%) that were captured in only one month.

Catch per unit effort (CPUE) is a standardization of abundance based on the number of trawls (i.e., effort). In this case the number of individuals of each species is divided by the number of trawls. Although the level of effort was not similar among months, with between 14 and 24 total trawls, CPUE did display the same patterns as abundance. For example, the same species that dominated each month numerically also had the highest CPUE (Figure 20). Of the 36 species collected, five are among the commercially landed species that generated over $1 million in New York (Table 1): longfin squid, summer flounder, scup, silver hake (*Merluccius bilinearis*), and goosefish (*Lophius americanus*). Three of these species (longfin squid, summer flounder and scup) had relatively low abundance and CPUE in July; goosefish and silver hake were not caught in July trawls. In August, abundance and CPUE increased for longfin squid, scup and silver hake. In September, abundance and CPUE increased for summer flounder and silver hake but decreased for longfin squid and scup. Longfin squid was the dominant species in October, but northern searobin and scup were also present in high numbers, with summer flounder decreasing in abundance. Summer flounder abundance and CPUE was relatively stable compared to the other commercial species throughout all survey months. The single goosefish that was collected in the study was caught in October.

Table 23: Monthly Biomass (g) of Each Species for Borrow Area 2C

Monthly Biomass (g) of Each Species for Borrow Area 2C							
Species	Scientific name	July	August	September	October	Total	
		Total weight	Total weight	Total weight	Total weight	Total weight	Average length (mm)
Winter skate	*Leucoraja ocellata*	14,465	8,105	35,630	331,800	390,000	472
Clearnose skate	*Raja eglanteria*	25,964	8,520	129,770	11,875	176,129	596
Northern searobin	*Prionotus carolinus*	27,630	9,895	34,485	2,550	74,560	155
Longfin squid	*Doryteuthis pealeii*	1,429	3,820	9,420	35,830	50,499	74
Summer flounder	*Paralichthys dentatus*	17,660	6,991	16,750	7,110	48,511	321
Weakfish	*Cynoscion regalis*	--	--	17,700	60	17,760	203
Spiny dogfish	*Squalus acanthias*	--	--	--	15,850	15,850	721
Windowpane	*Scophthalmus aquosus*	2,340	730	2,675	8,265	14,010	229
Spotted hake	*Urophycis regia*	326	2,880	4,565	2,685	10,456	218
Little skate	*Leucoraja erinacea*	2,120	890	630	4,870	8,510	391
Striped anchovy	*Anchoa hepsetus*	--	--	5,200	2,100	7,300	60
Scup	*Stenotomus chrysops*	153	701	587	4,440	5,881	57
Striped searobin	*Prionotus evolans*	--	--	1,630	2,265	3,895	190
Northern puffer	*Sphoeroides maculatus*	56	46	550	2,619	3,271	71
Smallmouth flounder	*Etropus microstomus*	853	366	596	125	1,940	68
Northern stargazer	*Astroscopus guttatus*	--	--	1,330	--	1,330	310
Northern kingfish	*Menticirrhus saxatilis*	--	--	370	705	1,075	215
Atlantic croaker	*Micropogonias undulatus*	--	--	450		450	204
Butterfish	*Peprilus triacanthus*	--	--	130	125	255	124
Striped cusk-eel	*Ophidion marginatum*	--	--	237		237	162
Black sea bass	*Centropristis striata*	--	--	192	11	203	53
Smooth dogfish	*Mustelus canis*	170	--	--	--	170	352
Bluefish	*Pomatomus saltatrix*	--	--	145	--	145	156
Silver hake	*Merluccius bilinearis*	--	4	31	83	118	72
Bluespotted cornetfish	*Fistularia tabacaria*	6	13	94	--	113	315

Monthly Biomass (g) of Each Species for Borrow Area 2C							
Species	**Scientific name**	**July**	**August**	**September**	**October**	**Total**	
		Total weight	**Total weight**	**Total weight**	**Total weight**	**Total weight**	**Average length (mm)**
Goosefish	*Lophius americanus*	--	--	--	110	110	175
Planehead filefish	*Stephanolepis hispidus*	18	--	50	--	68	101
Lined seahorse	*Hippocampus erectus*	4	4	19	4	31	68
Naked goby	*Gobiosoma bosc*	2	5	17	--	24	44
Northern pipefish	*Syngnathus fuscus*	3	1	8	--	12	136
Fourspot flounder	*Paralichthys oblongus*	1	4	--	2	7	50
Atlantic moonfish	*Selene setapinnis*	--	--	3		3	48
Round scad	*Decapterus punctatus*	--	--	--	2	2	43
American sand lance	*Ammodytes americanus*	1	--	--	--	1	70
Snowy grouper	*Hyporthodus niveatus*	1	--	--	--	1	19
Atlantic stingray	*Dasyatis sabina*	--	--	--	--	--	1000▫
Grand Total		**93,202**	**42,975**	**263,264**	**433,486**	**832,927**	**7,541**

Note: weight is total weight of each species in grams; length is average standard length of measured individuals in mm; ▫ = estimated weight.

Table 24: Abundance and Composition of Monthly Trawls for Borrow Area 2C

Abundance and Composition of Monthly Trawls for Borrow Area 2C										
Species	July		August		September		October		Total	
	Individ	%	Individ	%	Individ	%	Individ	%	Individ	%
Longfin squid	73	10.04	239	30.92	330	18.71	662	36.47	1,304	25.67
Northern searobin	359	49.38	161	20.83	391	22.17	28	1.54	939	18.49
Scup	4	0.55	213	27.55	160	9.07	275	15.15	652	12.84
Winter skate	28	3.85	16	2.07	65	3.68	504	27.77	613	12.07
Striped anchovy	--	--	--	--	317	17.97	92	5.07	409	8.05
Smallmouth flounder	152	20.91	76	9.83	65	3.68	20	1.10	313	6.16
Clearnose skate	16	2.20	10	1.29	121	6.86	10	0.55	157	3.09
Weakfish	--	--	--	--	143	8.11	1	0.06	144	2.84
Northern puffer	21	2.89	7	0.91	18	1.02	68	3.75	114	2.24
Summer flounder	37	5.09	14	1.81	33	1.87	22	1.21	106	2.09
Spotted hake	4	0.55	18	2.33	31	1.76	23	1.27	76	1.50
Windowpane	13	1.79	3	0.39	11	0.62	42	2.31	69	1.36
Striped searobin	--	--	--	--	14	0.79	15	0.83	29	0.57
Silver hake	--	--	1	0.13	8	0.45	16	0.88	25	0.49
Little skate	5	0.69	3	0.39	2	0.11	13	0.72	23	0.45
Lined seahorse	2	0.28	2	0.26	8	0.45	1	0.06	13	0.26
Naked goby	3	0.41	5	0.65	5	0.28	--	--	13	0.26
Black sea bass	--	--	--	--	10	0.57	2	0.11	12	0.24
Striped cusk-eel	--	--	--	--	10	0.57	--	--	10	0.20
Northern kingfish	--	--	--	--	4	0.23	5	0.28	9	0.18
Spiny dogfish	--	--	--	--	--	--	9	0.50	9	0.18
Bluespotted cornetfish	1	0.14	2	0.26	4	0.23	--	--	7	0.14
Butterfish	--	--	--	--	3	0.17	4	0.22	7	0.14

Abundance and Composition of Monthly Trawls for Borrow Area 2C

Species	July		August		September		October		Total	
	Individ	%	Individ	%	Individ	%	Individ	%	Individ	%
Northern pipefish	3	0.41	1	0.13	2	0.11	--	--	6	0.12
Fourspot flounder	1	0.14	2	0.26	--	--	1	0.06	4	0.08
Bluefish	--	--	--	--	3	0.17	--	--	3	0.06
Atlantic croaker	--	--	--	--	2	0.11	--	--	2	0.04
Atlantic moonfish	--	--	--	--	2	0.11	--	--	2	0.04
Planehead filefish	1	0.14	--	--	1	0.06	--	--	2	0.04
American sand lance	1	0.14	--	--	--	--	--	--	1	0.02
Atlantic stingray	1	0.14	--	--	--	--	--	--	1	0.02
Goosefish	--	--	--	--	--	--	1	0.06	1	0.02
Northern stargazer	--	--	--	--	1	0.06	--	--	1	0.02
Round scad	--	--	--	--	--	--	1	0.06	1	0.02
Smooth dogfish	1	0.14	--	--	--	--	--	--	1	0.02
Snowy grouper	1	0.14	--	--	--	--	--	--	1	0.02
Grand Total	**727**	**100.00**	**773**	**100.00**	**1764**	**100.00**	**1815**	**100.00**	**5079**	**100.00**

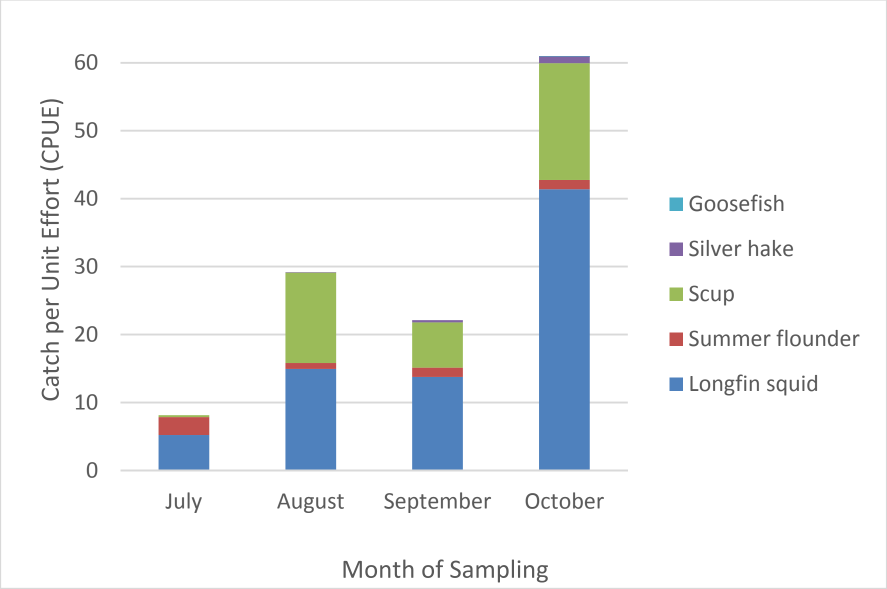


Figure 20: Monthly Catch Per Unit Effort (CPUE) of the Most Commercially Important Species for Borrow Area 2C

With the exception of squid species, invertebrates were not enumerated, measured, or weighed. However, the presence of other organisms in the catch was noted (Table 25). A total of 19 species were observed: nine arthropods, four mollusks, three echinoderms, one cephalopod egg mass, one fish egg case, and one cnidarian. Six of these species were encountered during all four months of the survey: hermit crab, quahog, sand dollar, skate egg cases, spider crab, and sea star. Jellyfish, Jonah crab, and moon snail were present in three of the months; and mahogany clam, rock crab, and whelk were present in only two of the months. The remaining seven species were present in only one of the four months.

Table 25: Presence of Macroinvertebrates Collected in Monthly Fish Trawls in Borrow Area 2C

Presence of Macroinvertebrates Collected in Monthly Fish Trawls in Borrow Area 2C				
Species	**July**	**August**	**September**	**October**
Blue crab			x	
Blue mussel			x	
Calico crab		x		
Hermit crab	x	x	x	x
Horseshoe crab			x	
Jellyfish		x	x	x
Jonah crab		x	x	x
Lady crab			x	
Mahogany clam			x	x
Moon snail	x	x	x	
Quahog	x	x	x	x
Rock crab	x		x	

Presence of Macroinvertebrates Collected in Monthly Fish Trawls in Borrow Area 2C

Species	July	August	September	October
Sand dollar	x	x	x	x
Sea urchin			x	
Skate egg case	x	x	x	x
Spider crab	x	x	x	x
Squid egg mass			x	
Sea star	x	x	x	x
Whelk		x	x	

3.3.1.2 REFERENCE SITE COMPARISONS

To provide a local comparison, as well as a baseline for future projects, reference tows were conducted adjacent to Borrow Area 2C during each monthly sampling event from July to October (Table 26). Since more tows were conducted within Borrow Area 2C, it was expected that greater species would be observed on-site when compared to reference sites. This section presents the overlap of species and presence/absence of species in the reference tows relative to the on-site tows for all months combined and then by month.

As expected, for all months combined there were a greater number of species (33 species) collected in on-site trawls compared to the number of species collected in the reference trawls (26 species) which was likely due to the larger number of on-site trawls. There were 10 species that were collected in on-site trawls that were not also collected in reference trawls; and there were three species that were collected in reference trawls that were not also collected in on-site trawls. It is important to note that none of these species individually accounted for more than 1% of the catch composition of monthly trawls. The great overlap of species between on-site and reference trawls indicates that the same fish assemblages populate on-site and reference areas.

In July, northern searobin were the most abundant species by a large margin in on-site and reference trawls; smallmouth flounder were the second most abundant. Only two of the 14 species collected in reference tows were unique to the catch and not also collected in the Borrow Area; seven species of 19 species were unique to on-site trawls. The August trawls in on-site and reference sites were dominated by three species: longfin squid, scup, and northern searobin with percent composition greater for on-site trawls. One of the 13 species collected in reference tows was unique to the catch. Four of 16 species were caught in on-site trawls and not in reference trawls. September on-site trawls were dominated by northern searobin, longfin squid, and striped anchovy (*Anchoa hepsetus*); reference trawls were dominated by northern searobin, weakfish (*Cynoscion regalis*), striped anchovy, and scup. Striped anchovy were not collected in trawls in previous months. One of the 19 species collected in reference tows was unique to the September catch, while nine of 27 species were only caught in on-site trawls. In October, the longfin squid returned as the dominant species in on-site and reference tows with winter skate and scup following in abundance. There were no unique species caught in October reference trawls but seven of 23 species were only captured in on-site trawls.

Except for July, the CPUE of the total catch from month to month followed the same pattern both within the borrow area and at the reference sites with a gradual increase in CPUE over time (Figure 21).

Reference site trawls had a much greater CPUE than on-site trawls in July. The high number of northern searobin in July reference trawls drove this pattern. The lowest CPUE within the borrow area occurred in July and in August in the reference sites. In September CPUE increased in both areas. October had the highest CPUE of all months in both areas. Catches of large numbers of longfin squid and winter skate within borrow areas and longfin squid, winter skate and scup in reference areas contributed to the higher CPUE.

Table 26: Monthly Comparisons of Catch Composition of On-site and Reference Trawls at Borrow Area 2C

Monthly Comparisons of Catch Composition of On-site and Reference Trawls at Borrow Area 2C								
Species	**July**		**August**		**September**		**October**	
	On-site	**Ref.**	**On-site**	**Ref.**	**On-site**	**Ref.**	**On-site**	**Ref.**
Longfin squid	11.05%	7.43%	31.69%	28.05%	21.30%	4.71%	36.23%	38.25%
Northern searobin	45.33%	59.90%	20.85%	20.73%	22.38%	21.01%	1.44%	2.30%
Scup	0.38%	0.99%	29.39%	20.73%	8.27%	13.41%	14.14%	22.58%
Winter skate	3.24%	5.45%	1.15%	5.49%	3.63%	3.99%	28.54%	22.12%
Striped anchovy	--	--	--	--	18.08%	17.39%	5.76%	--
Smallmouth flounder	24.00%	12.87%	9.03%	12.80%	3.90%	2.54%	1.00%	1.84%
Clearnose skate	1.71%	3.47%	1.48%	0.61%	6.85%	6.88%	0.56%	0.46%
Weakfish	--	--	--	--	6.18%	18.48%	0.06%	--
Northern puffer	3.81%	0.50%	0.99%	0.61%	1.14%	0.36%	3.69%	4.15%
Summer flounder	5.33%	4.46%	1.48%	3.05%	1.41%	4.35%	0.94%	3.23%
Spotted hake	0.38%	0.99%	1.97%	3.66%	1.68%	2.17%	1.25%	1.38%
Windowpane	1.90%	1.49%	0.16%	1.22%	0.54%	1.09%	2.44%	1.38%
Striped searobin	--	--	--	--	0.94%	--	0.94%	--
Silver hake	--	--	0.16%	--	0.54%	--	0.94%	0.46%
Little skate	0.57%	0.99%	0.16%	1.22%	0.07%	0.36%	0.75%	0.46%
Lined seahorse	0.19%	0.50%	0.33%	--	0.47%	0.36%	0.06%	--
Naked goby	0.57%	0.00%	0.66%	0.61%	0.34%	--	--	--
Black sea bass	--	--	--	--	0.47%	1.09%	0.13%	--
Striped cusk-eel	--	--	--	--	0.60%	0.36%	--	--
Northern kingfish	--	--	--	--	0.27%	--	0.31%	--
Spiny dogfish	--	--	--	--	--	--	0.44%	0.92%
Bluespotted cornetfish	0.19%	--	--	1.22%	0.27%	--	--	--
Butterfish	--	--	--	--	0.20%	--	0.19%	0.46%
Northern pipefish	0.57%	--	0.16%	--	0.07%	0.36%	--	--
Fourspot flounder	0.19%	--	0.33%	--	--	--	0.06%	--
Bluefish	--	--	--	--	0.13%	0.36%	--	--
Atlantic croaker	--	--	--	--	--	0.72%	--	--
Atlantic moonfish	--	--	--	--	0.13%	--	--	--
Planehead filefish	0.19%	--	--	--	0.07%	--	--	--
American sand lance	0.19%	--	--	--	--	--	--	--
Atlantic stingray	--	0.50%	--	--	--	--	--	--

Monthly Comparisons of Catch Composition of On-site and Reference Trawls at Borrow Area 2C								
Species	**July**		**August**		**September**		**October**	
	On-site	**Ref.**	**On-site**	**Ref.**	**On-site**	**Ref.**	**On-site**	**Ref.**
Goosefish	--	--	--	--	--	--	--	--
Northern stargazer	--	--	--	--	0.07%	--	--	--
Round scad	--	--	--	--	--	--	0.06%	--
Smooth dogfish	--	0.50%	--	--	--	--	--	--
Snowy grouper	0.19%	--	--	--	--	--	--	--

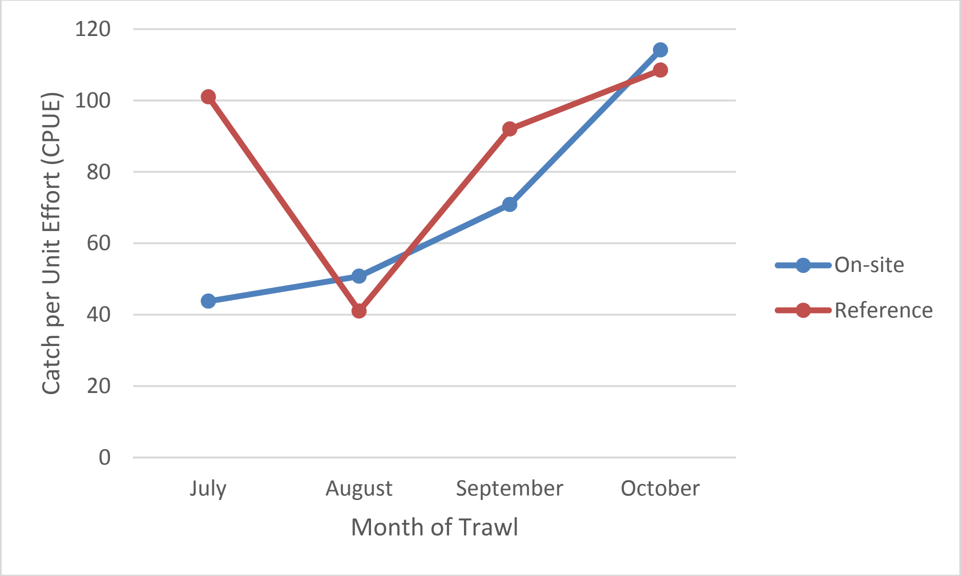


Figure 21: Average Catch per Unit Effort (CPUE) of Monthly Fish Trawls for FIMI Borrow Area 2C

3.3.1.3 LENGTH-FREQUENCY DISTRIBUTIONS

Lengths of all fish species were collected (Appendix A), but the length-frequency distribution data focus on the most important New York commercial species (longfin squid, summer flounder, scup, silver hake and goosefish) which generated over $1 million of revenue individually in 2014. Figure 22 represents the length-frequency distributions for longfin squid, summer flounder, scup, and silver hake; there was only one goosefish collected so it was not included in the figure. Longfin squid ranged in mantle length from a minimum of 13 mm to a maximum of 250 mm. The average length was 97 mm. The majority of longfin squid fell between 26-100 mm. Summer flounder ranged from 198 to 648 mm in standard length, with an average of 327 mm. Most fish fell between 201-400 mm standard length. The standard length of scup ranged from 19 to 194 mm and averaged 81 mm. The most common lengths were between 26 and 50 mm. Silver hake standard lengths were between 54 and 104 mm, averaging 90 mm. The most common lengths were around 61 mm, with only one measurements above 89 mm. Only one goosefish was collected and it was 175 mm.

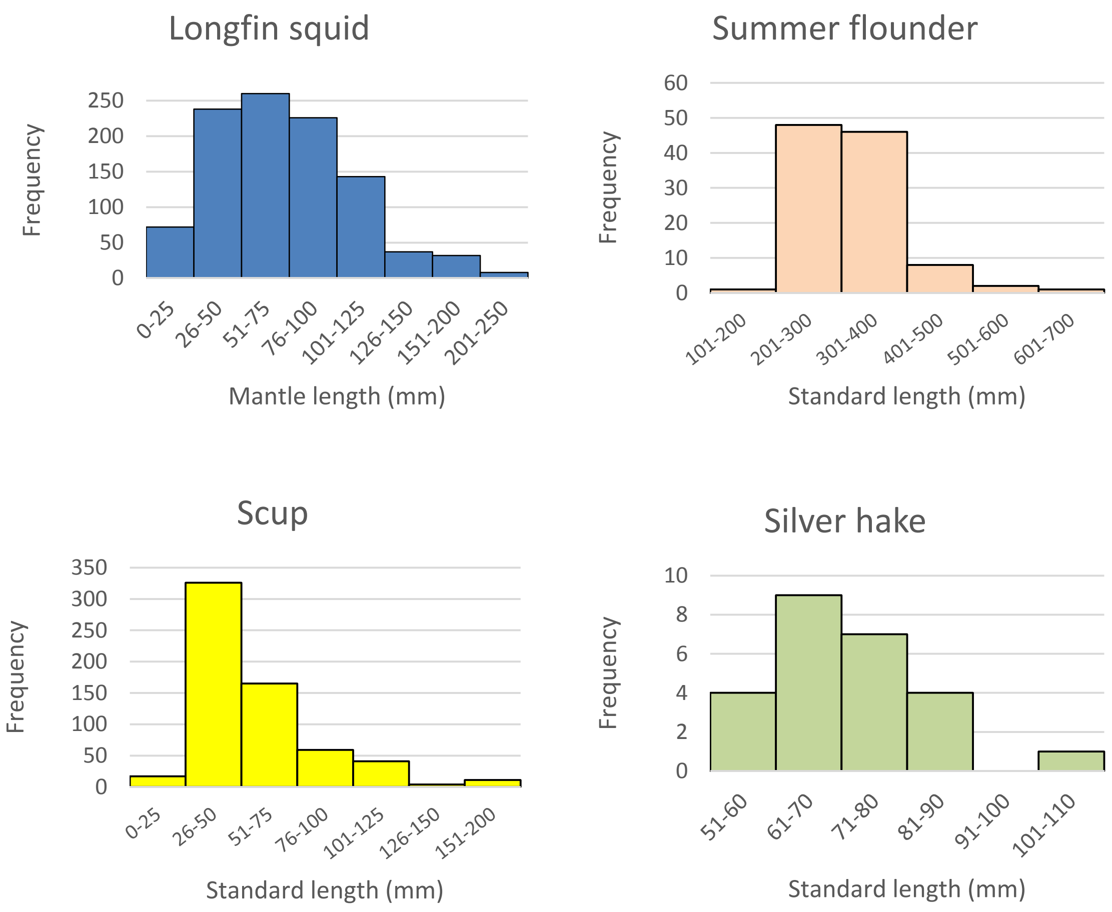


Figure 22: Length Frequency Distribution of Commercially Important New York Fish Species Collected in Borrow Area 2C Which Generated Over $1 Million in Revenue in 2014

3.3.2 BORROW AREA 5B TRAWLS

Overall, 47 species were collected in the trawls. The total biomass of the trawls in Borrow Area 5B was 1,155,369 g (Table 27). Winter skate had the greatest biomass, followed by clearnose skate and scup. Overall, the most numerically abundant species was scup, followed by striped anchovy, and longfin squid. The fish trawl results are presented in more detail in the following sections, first by temporal trends, then by spatial patterns.

3.3.2.1 MONTHLY COMPARISONS

In July, August, and September, clearnose skate had the greatest biomass (Table 27). In July, winter skate had the second greatest biomass followed by northern searobin. Scup and winter skate had the second and third highest biomass in August. In September, the species with the second highest biomass was winter skate followed by summer flounder. By month, winter skate had the greatest biomass only in October even though it had the greatest overall biomass. Striped anchovy and spotted hake had the second and third highest biomasses in October. October was the only month that striped anchovy were recorded in this borrow area.

Although many species showed overlap from month to month, the overall catch composition showed variation depending on the time of year (Table 28). Scup, striped anchovy, and longfin squid were the most abundant species in Borrow Area 5B during the monthly trawls. In July, northern searobin was the most abundant and in August and September, scup was the most abundant species. Of the 47 species collected, 12 species (26.09% of total species) were collected during all four months (Table 27). Thirteen species (28.26%) occurred in three of the four months of trawls, and three species (6.52%) were captured in two of the four months of trawls. There were 18 species (39.13%) that were capture in only one month.

Although the level of effort was not similar among months, with between 16 and 24 total trawls, CPUE did display the same patterns as abundance (i.e., the same species that dominated each month numerically also had the highest CPUE). Of the 47 species collected, four are among the commercially important species (Table 1): longfin squid, summer flounder, scup and silver hake. Two species, scup and longfin squid, had relatively high abundance and CPUE in July (Figure 23). In August, there was a sharp peak in scup abundance. September abundance decreased greatly for longfin squid but their numbers peaked in October. Summer flounder were present in all months and abundances remained relatively consistent throughout the study period. Silver hake was not present until October.

Table 27: Monthly Biomass of Each Fish Species for Borrow Area 5B

Monthly Biomass of Each Fish Species for Borrow Area 5B							
Species	Scientific name	July	August	September	October	Total	
		Total weight (g)	Total weight (g)	Total weight (g)	Total weight (g)	Total weight (g)	Average length (mm)
Winter skate	*Leucoraja ocellata*	48,230	17,960	16,580	472,750	555,520	466
Clearnose skate	*Raja eglanteria*	82,320	71,600	30,550	9,100	193,570	611
Scup	*Stenotomus chrysops*	18,564	40,110	8,019	9,000	75,693	71
Striped anchovy	*Anchoa hepsetus*	--	--	--	67,345	67,345	56
Spotted hake	*Urophycis regia*	1,490	--	1,285	57,430	60,205	229
Northern searobin	*Prionotus carolinus*	22,607	14,110	10,630	1,704	49,051	149
Summer flounder	*Paralichthys dentatus*	1,725	5,715	18,835	18,135	44,410	296
Longfin squid	*Doryteuthis pealeii*	2,661	3,748	2,758	31,526	40,693	68
Windowpane	*Scophthalmus aquosus*	2,572	550	1,880	15,065	20,067	225
Northern kingfish	*Menticirrhus saxatilis*	--	180	100	8,720	9,000	185
Atlantic stingray	*Dasyatis sabina*	--	6,804	--	--	6,804	1,219
Striped searobin	*Prionotus evolans*	1,153	--	1,450	3,746	6,349	175
Little skate	*Leucoraja erinacea*	1,090	--	250	4,331	5,671	279
Black sea bass	*Centropristis striata*	1,701	525	2,617	754	5,597	134
Northern puffer	*Sphoeroides maculatus*	--	8	358	4,237	4,603	73
Tautog	*Tautoga onitis*	80	220	1,103	1,325	2,728	203
Butterfish	*Peprilus triacanthus*	596	1	--	817	1,414	72
Silver hake	*Merluccius bilinearis*	4	--	--	1,319	1,323	75
Weakfish	*Cynoscion regalis*	--	--	--	900	900	163
Striped cusk-eel	*Ophidion marginatum*	--	--	--	650	650	126
Smallmouth flounder	*Etropus microstomus*	184	148	58	241	631	70
Bluefish	*Pomatomus saltatrix*	--	--	--	461	461	133
Oyster toadfish	*Opsanus tau*	--	--	--	450	450	262

Monthly Biomass of Each Fish Species for Borrow Area 5B

Species	Scientific name	July	August	September	October	Total	
		Total weight (g)	Total weight (g)	Total weight (g)	Total weight (g)	Total weight (g)	Average length (mm)
Grey triggerfish	*Balistes capriscus*	--	--	--	410	410	223
Planehead filefish	*Stephanolepis hispidus*	102	183	90	--	375	88
Northern pipefish	*Syngnathus fuscus*	38	32	228	74	371	162
Round scad	*Decapterus punctatus*	12	218	1	--	231	70
Dwarf goatfish	*Upeneus parvus*	38	110	--	--	148	64
Glasseye snapper	*Heteropriacanthus cruentatus*	42	17	--	70	129	66
Bluespotted cornetfish	*Fistularia tabacaria*	40	5	60	3	108	279
Cunner	*Tautogolabrus adspersus*	--	9	69	15	93	37
Winter flounder	*Pseudopleuronectes americanus*	--	--	--	90	90	172
Naked goby	*Gobiosoma bosc*	20	7	39	--	66	48
Striped burrfish	*Chilomycterus schoepfi*	--	--	60	--	60	82
Fourspot flounder	*Paralichthys oblongus*	20	--	22	15	57	61
Atlantic moonfish	*Selene setapinnis*	18	2	--	14	34	41
Spotfin butterflyfish	*Chaetodon ocellatus*	--	--	--	15	15	50
Atlantic herring	*Clupea harengus*	--	--	14	--	14	111
Scrawled filefish	*Aluterus scriptus*	12	--	--	--	12	99
Lined seahorse	*Hippocampus erectus*	--	3	--	3	6	64
Rock gunnel	*Pholis gunnellus*	--	--	6	--	6	116
Atlantic menhaden	*Brevoortia tyrannus*	--	--	--	3	3	59
Atlantic silverside	*Menidia menidia*	2	--	--	--	2	35
Snowy grouper	*Hyporthodus niveatus*	--	--	2	--	2	30
Twospot cardinalfish	*Apogon pseudomaculatus*	--	--	2	--	2	37
Red hake	*Urophycis chuss*	--	--	1	--	1	57

Monthly Biomass of Each Fish Species for Borrow Area 5B							
Species	Scientific name	July	August	September	October	Total	
		Total weight (g)	Total weight (g)	Total weight (g)	Total weight (g)	Total weight (g)	Average length (mm)
Short bigeye	*Pristigenys alta*		1			1	20
	Grand Total	**185,319**	**162,266**	**97,067**	**710,718**	**1,155,369**	**--**

Table 28: Abundance and Composition of Monthly Trawls for Borrow Area 5B

Abundance and Composition of Monthly Trawls for Borrow Area 5B										
Species	July		August		September		October		Total	
	Individ	%	Individ	%	Individ	%	Individ	%	Individ	%
Scup	447	28.24	1,130	61.65	477	42.97	230	5.27	2,284	25.70
Striped anchovy	--	--	--	--	--	--	1,537	35.24	1,537	17.29
Longfin squid	304	19.20	228	12.44	83	7.48	588	13.48	1,203	13.54
Winter skate	88	5.56	30	1.64	30	2.70	803	18.41	951	10.70
Northern searobin	451	28.49	237	12.93	164	14.77	56	1.28	908	10.22
Spotted hake	9	0.57	--	--	6	0.54	352	8.07	367	4.13
Silver hake	1	0.06	--	--	--	--	217	4.98	218	2.45
Northern pipefish	16	1.01	45	2.45	88	7.93	21	0.48	170	1.91
Clearnose skate	75	4.74	59	3.22	23	2.07	6	0.14	163	1.83
Northern puffer	0	0.00	4	0.22	15	1.35	124	2.84	143	1.61
Summer flounder	6	0.38	16	0.87	47	4.23	55	1.26	124	1.40
Northern kingfish	--	--	1	0.05	2	0.18	102	2.34	105	1.18
Windowpane	15	0.95	3	0.16	12	1.08	71	1.63	101	1.14
Butterfish	40	2.53	1	0.05	--	--	54	1.24	95	1.07
Smallmouth flounder	22	1.39	19	1.04	35	3.15	15	0.34	91	1.02
Black sea bass	21	1.33	5	0.27	21	1.89	18	0.41	65	0.73

Abundance and Composition of Monthly Trawls for Borrow Area 5B										
Species	July		August		September		October		Total	
	Individ	%	Individ	%	Individ	%	Individ	%	Individ	%
Cunner	--	--	5	0.27	51	4.59	1	0.02	57	0.64
Striped searobin	7	0.44	--	--	19	1.71	22	0.50	48	0.54
Naked goby	27	1.71	7	0.38	12	1.08	--	--	46	0.52
Little skate	3	0.19	--	--	1	0.09	25	0.57	29	0.33
Dwarf goatfish	11	0.69	13	0.71	--	--	--	--	24	0.27
Striped cusk-eel	--	--	--	--	--	--	18	0.41	18	0.20
Round scad	1	0.06	15	0.82	1	0.09	--	--	17	0.19
Atlantic moonfish	9	0.57	2	0.11	--	--	5	0.11	16	0.18
Planehead filefish	6	0.38	6	0.33	4	0.36	--	--	16	0.18
Fourspot flounder	7	0.44	--	--	3	0.27	3	0.07	13	0.15
Tautog	1	0.06	1	0.05	6	0.54	5	0.11	13	0.15
Weakfish	--	--	--	--	--	--	13	0.30	13	0.15
Bluefish	--	--	--	--	--	--	12	0.28	12	0.14
Bluespotted cornetfish	7	0.44	1	0.05	3	0.27	1	0.02	12	0.14
Glasseye snapper	5	0.32	1	0.05	--	--	1	0.02	7	0.08
Atlantic silverside	3	0.19	--	--	--	--	--	--	3	0.03
Lined seahorse	--	--	2	0.11	--	--	1	0.02	3	0.03
Snowy grouper	--	--	--	--	2	0.18	--	--	2	0.02
Atlantic herring	--	--	--	--	1	0.09	--	--	1	0.01
Atlantic menhaden	--	--	--	--	--	--	1	0.02	1	0.01
Atlantic stingray	--	--	1	0.05	--	--	--	--	1	0.01
Gray triggerfish	--	--	--	--	--	--	1	0.02	1	0.01
Oyster toadfish	--	--	--	--	--	--	1	0.02	1	0.01
Red hake	--	--	--	--	1	0.09	--	--	1	0.01
Rock gunnel	--	--	--	--	1	0.09	--	--	1	0.01

Abundance and Composition of Monthly Trawls for Borrow Area 5B

Species	July		August		September		October		Total	
	Individ	**%**	**Individ**	**%**	**Individ**	**%**	**Individ**	**%**	**Individ**	**%**
Scrawled filefish	1	0.06	--	--	--	--	--	--	1	0.01
Short bigeye	--	--	1	0.05	--	--	--	--	1	0.01
Spotfin butterflyfish	--	--	--	--	--	--	1	0.02	1	0.01
Striped burrfish	--	--	--	--	1	0.09	--	--	1	0.01
Twospot cardinalfish	--	--	--	--	1	0.09	--	--	1	0.01
Winter flounder	--	--	--	--	--	--	1	0.02	1	0.01
Grand Total	**1,583**		**1,833**		**1,110**		**4,361**		**8,887**	

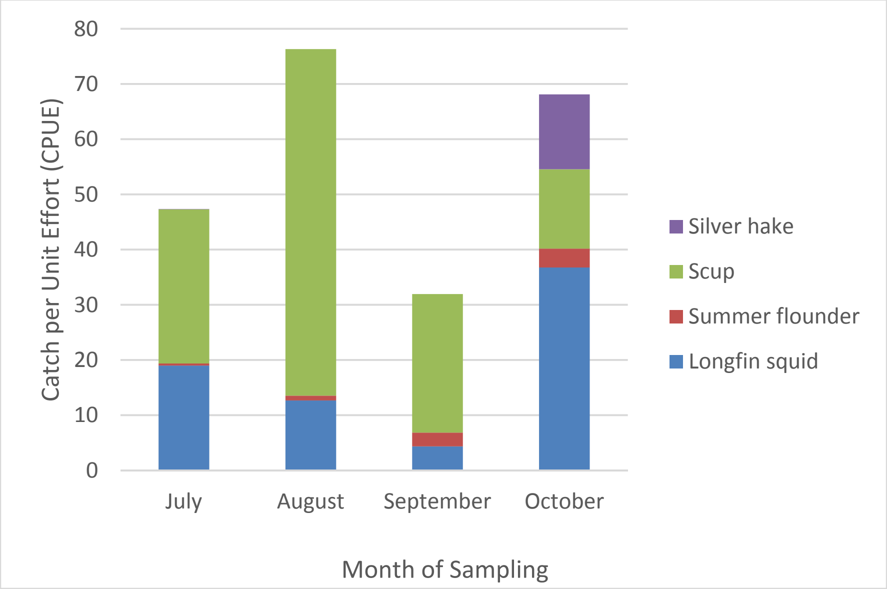


Figure 23: Monthly Catch Per Unit Effort (CPUE) of the Most Commercially Important Species for Borrow Area 5B

With the exception of squid species, invertebrates were not enumerated, measured, or weighed. However, the presence of other organisms in the catch was noted (Table 29). A total of 22 species were observed: 12 arthropods, 4 mollusks, 2 echinoderms, 2 egg cases/masses, and 2 cnidarian. Six of these species were encountered during all 4 months of the survey: hermit crab, Jonah crab, moon snail, rock crab, sand dollar, and spider crab. Brown shrimp, horseshoe crab, lady crab, and squid egg were present in three of the months; and American lobster, calico crab, isopod, jellyfish, and octopus were present in only 2 of the months. The remaining 7 species were present in only 1 of the 4 months.

Table 29: Presence of Macroinvertebrates Collected in Monthly Fish Trawls in Borrow Area 5B

Presence of Macroinvertebrates Collected in Monthly Fish Trawls in Borrow Area 5B				
Species	**July**	**August**	**September**	**October**
American lobster			x	x
Blue crab			x	
Blue mussel			x	
Brown shrimp	x	x		x
Calico crab		x		
Hermit crab	x	x	x	x
Horseshoe crab		x	x	x
Isopod		x	x	
Jellyfish			x	x
Jonah crab	x	x	x	x
Lady crab		x	x	x
Moon snail	x	x	x	x
Mud crab			x	
Octopus	x		x	

Presence of Macroinvertebrates Collected in Monthly Fish Trawls in Borrow Area 5B				
Species	**July**	**August**	**September**	**October**
Quahog	x			
Rock crab	x	x	x	x
Sand dollar	x	x	x	x
Skate egg case		x		
Spider crab	x	x	x	x
Squid egg	x	x	x	
Sea star	x			
Whelk	x			

3.3.2.2 REFERENCE SITE COMPARISONS

To provide a local comparison, as well as a baseline for future projects, reference tows were conducted adjacent to the Borrow Area 5B during each monthly sampling event from July to October (Table 30). Since more tows were conducted within Borrow Area 5B, it was expected that greater diversity (i.e., more species) would be observed on-site when compared to reference sites. This section presents the overlap of species and presence/absence of species in the reference tows relative to the on-site tows for all months combined and then by month.

As expected, for all months combined there were a greater number of species (40 species) collected in on-site trawls compared to the number of species collected in reference trawls (29 species) which was likely due to the larger number of on-site trawls. There were 34 species collected in on-site trawls that were conducted in the previously dredged area (dredged box). For comparison, the number of species that were collected in each area but absent in others is presented here. For on-site trawls there were 14 species that were not also collected in reference trawls and 10 species that were not also collected in dredged box trawls. Nine species were collected in dredged box trawls that were not also collected in reference trawls and four species that were not also collected in on-site trawls. In reference trawls there were three species that were not also collected in dredged box trawls and four species that were not also collected in on-site trawls. It is important to note that none of these species individually accounted for more than 4% of the catch composition of monthly trawls. The great overlap of species between on-site outside the dredged box, the dredged box (which is also onsite) and reference trawls indicates that the same fish assemblages populate on-site and reference areas. It is also significant that the dredged box area had more species than the reference area.

In July reference site trawls, northern searobin were the most abundant species with longfin squid as the second most abundant (Table 30). Within the borrow area, on-site, scup was the most abundant species northern searobin as the second most abundant. Only 1 of the 19 species collected in reference tows were not collected within the borrow area (Table 30). For on-site trawls, 6 of the 25 species that were caught were not also caught in reference tows. The August trawls in on-site and reference sites were dominated by three species: longfin squid, scup, and northern searobin with percent composition greater for only scup during on-site trawls. In reference tows, 1 of the 11 species collected was unique to the catch, while 15 of 25 species were unique for on-site trawls. September on-site and reference trawls were dominated by scup, and northern searobin. In October, striped anchovy and winter skate were the most abundant species in the reference sites. On-site the most abundant species was also striped anchovy with longfin squid and winter skate following in abundance. Striped anchovy were not collected in trawls in previous months. In reference tows, 3 of the 23 species collected were unique to the October catch, while 11 of 32 species were unique for on-site trawls.

Table 30: Monthly Comparisons of Catch Composition of On-site and Reference Trawls at Borrow Area 5B

Monthly Comparisons of Catch Composition of On-site and Reference Trawls at Borrow Area 5B								
Species	**July**		**August**		**September**		**October**	
	On-site	**Ref.**	**On-site**	**Ref.**	**On-site**	**Ref.**	**On-site**	**Ref.**
Scup	30.19%	11.11%	63.58%	40.00%	44.73%	30.99%	4.64%	12.91%
Striped anchovy	--	--	--	--	--	--	36.97%	14.41%
Longfin squid	18.86%	22.22%	11.29%	25.33%	6.40%	14.79%	13.85%	9.01%
Winter skate	5.21%	8.64%	1.43%	4.00%	3.00%	0.70%	18.74%	14.41%
Northern searobin	27.52%	37.04%	12.24%	20.67%	14.05%	19.72%	1.29%	1.20%
Spotted hake	0.56%	0.62%	--	--	0.31%	2.11%	7.94%	9.61%
Silver hake	0.07%	--	--	--	--	--	4.59%	9.61%
Northern pipefish	1.06%	0.62%	2.61%	0.67%	8.78%	2.11%	0.35%	2.10%
Clearnose skate	4.93%	3.09%	3.27%	2.67%	1.24%	7.75%	0.15%	--
Northern puffer	--	--	0.12%	1.33%	1.24%	2.11%	2.46%	7.51%
Summer flounder	0.35%	0.62%	0.89%	0.67%	3.72%	7.75%	1.27%	1.20%
Northern kingfish	--	--	0.06%	--	--	1.41%	2.23%	3.60%
Windowpane	0.77%	2.47%	0.18%	--	0.83%	2.82%	1.46%	3.60%
Butterfish	2.67%	1.23%	0.06%	--	--	--	1.22%	1.50%
Smallmouth flounder	1.34%	1.85%	0.77%	4.00%	3.10%	3.52%	0.30%	0.90%
Black sea bass	1.48%	--	0.30%	--	2.17%	--	0.40%	0.60%
Cunner	--	--	0.30%	--	5.27%	--	0.02%	--
Striped searobin	0.35%	1.23%	--	--	1.76%	1.41%	0.52%	0.30%
Naked goby	1.90%	--	0.42%	--	1.03%	1.41%	--	--
Little skate	0.14%	0.62%	--	--	0.10%	--	0.45%	2.10%
Dwarf goatfish	0.70%	0.62%	0.77%	--	--	--	0.00%	0.00%
Striped cusk-eel	--	--	--	--	--	--	0.42%	0.30%
Round scad	0.07%	--	0.89%	--	0.10%	--	--	--
Atlantic moonfish	0.21%	3.70%	0.12%	--	--	--	0.07%	0.60%
Planehead filefish	0.42%	--	0.36%	--	0.41%	--	--	--
Fourspot flounder	0.28%	1.85%	--	--	0.31%	--	0.07%	--
Tautog	0.07%	--	0.06%	--	0.62%	--	0.12%	--
Weakfish	--	--	--	--	--	--	--	3.90%
Bluefish	--	--	--	--	--	--	0.27%	0.30%
Bluespotted cornetfish	0.49%	--	--	0.67%	0.10%	1.41%	0.02%	--
Glasseye snapper	0.28%	0.62%	0.06%	--	--	--	0.02%	--
Atlantic silverside	--	1.85%	--	--	--	--	--	--

Monthly Comparisons of Catch Composition of On-site and Reference Trawls at Borrow Area 5B								
Species	**July**		**August**		**September**		**October**	
	On-site	**Ref.**	**On-site**	**Ref.**	**On-site**	**Ref.**	**On-site**	**Ref.**
Lined seahorse	--	--	0.12%	--	--	--	0.02%	--
Snowy grouper	--	--	--	--	0.21%	--	--	--
Atlantic herring	--	--	--	--	0.10%	--	--	--
Atlantic menhaden	--	--	--	--	--	--	0.02%	--
Atlantic stingray	--	--	0.06%	--	--	--	--	--
Gray triggerfish	--	--	--	--	--	--	0.02%	--
Oyster toadfish	--	--	--	--	--	--	0.02%	--
Red hake	--	--	--	--	0.10%	--	--	--
Rock gunnel	--	--	--	--	0.10%	--	--	--
Scrawled filefish	0.07%	--	--	--	--	--	--	--
Short bigeye	--	--	0.06%	--	--	--	--	--
Spotfin butterflyfish	--	--	--	--	--	--	0.02%	--
Striped burrfish	--	--	--	--	0.10%	--	--	--
Twospot cardinalfish	--	--	--	--	0.10%	--	--	--
Winter flounder	--	--	--	--	--	--	--	0.30%

The CPUE of the total catch from month to month followed the same pattern both on-site and at the reference sites with a decrease in September and an increase in CPUE over time (Figure 24). On-site trawls had a much greater CPUE than reference trawls for all months. The lowest CPUE for on-site and reference trawls occurred in September. October had the highest CPUE of all months in both areas. Catches of large numbers of striped anchovy, longfin squid, and winter skate on-site; and longfin squid, winter skate, and scup in reference areas contributed to the higher CPUE.

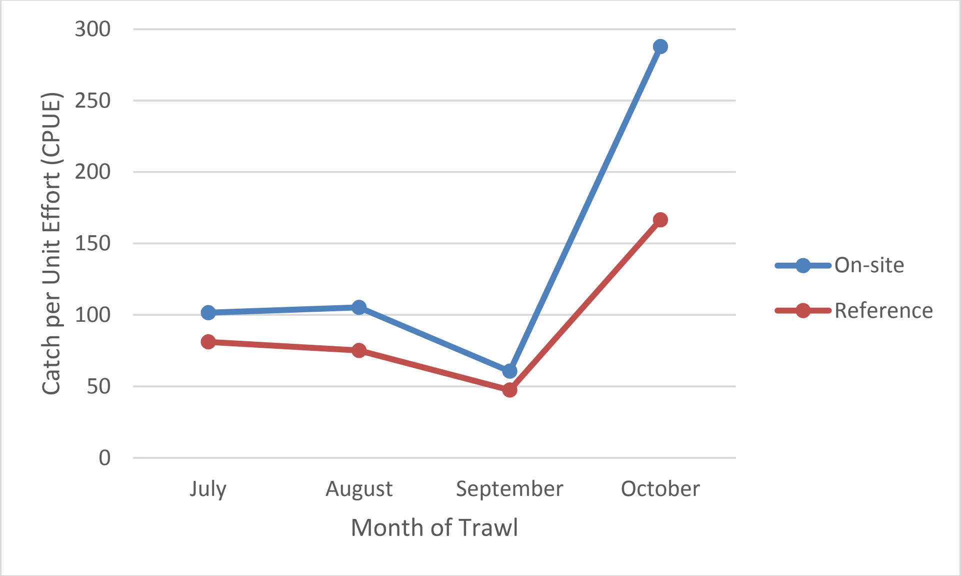


Figure 24: Average Catch per Unit Effort (CPUE) of Monthly Fish Trawls for FIMI Borrow Area 5B

3.3.2.3 LENGTH-FREQUENCY DISTRIBUTIONS

Lengths of all fish species were collected (Appendix A), but the length-frequency distribution data focus on the most important New York commercial species (longfin squid, summer flounder, scup and silver hake) which generated over $1 million of revenue individually in 2014 (Figure 25). Longfin squid ranged in mantle length from a minimum of 18 mm to a maximum of 260 mm. The average length was 68 mm. The most common length was around 50 mm. Summer flounder ranged from 98 to 547 mm in standard length, with an average of 296 mm. A peak in length frequency was apparent at lengths less than 300 mm. The standard length of scup ranged from 18 to 212 mm and averaged 71 mm. The most common length was around 50 mm. Silver hake standard lengths were between 43 and 163 mm, averaging 75 mm. The most common lengths were around 89 mm, with only one measurements above 135 mm.

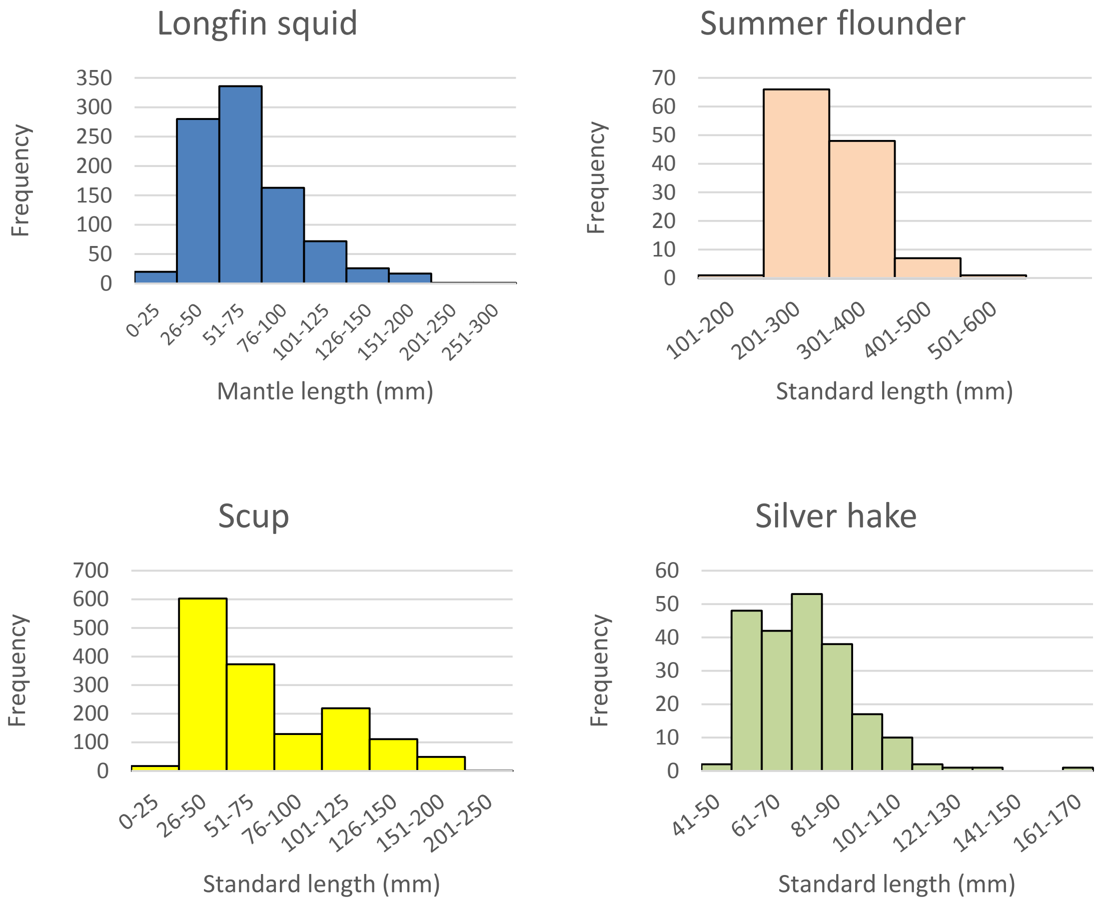


Figure 25: Length Frequency Distributions of Commercially Important Fish New York Fish Species Collected in Borrow Area 5B Which Generated Over $1 Million in Revenue in 2014

4.0 DISCUSSION

The structure and mixing of the water column impacts both benthic invertebrates and fish species. For biological organisms, summer is usually a time of increased growth, due to abundant food and prey resources (e.g., Malloy and Targett 1994). Abiotic factors affect habitat utilization, though. A behavioral response to temperature changes varies greatly by species; however, most fishes strive to remain in their thermal niche (i.e., ±2 or 5°C of the preferred temperature; Magnuson and Destasio 1997). Bottom-dwelling species, such as flatfish, often experience less temperature variation and therefore, move less, while more mobile fishes, like bluefish (*Pomatomus saltatrix*), must seek out their thermal niche, which results in a broader distribution and greater movement (Cranshaw and O'Connor 1997). The greatest temperature-induced movement, however, occurs in species like Atlantic herring (*Clupea harengus*), which may migrate over 100 km in response to a 1°C temperature change (Cranshaw and O'Connor 1997). Locally, thermal refuge may be found in bottom waters; however, if oxygen levels drop below 5 mg/L, non-demersal animals may not remain in the bottom layer for long periods of time. Eventually, these animals would need to move farther offshore until temperatures dropped and oxygen increased in the fall. Warm-water fish species would likely benefit from the competitive advantage of being capable of utilizing the entire water column in the summer months, but may need to migrate southward during the winter. Benthic organisms are more vulnerable to stress due to temperature extremes or oxygen levels since they are less mobile. The existing conditions, as well as the potential impacts of dredge activities, are discussed for both benthos and fishes in the following sections.

4.1 BENTHIC COMMUNITY COMPARISONS

The findings of this study are consistent with previous studies and reports conducted in the FIMI Borrow Areas. Borrow Area 2C and parts of Borrow Area 5 were surveyed in two previous USACE projects. The Draft Benthic Invertebrate Survey: East of Shinnecock Inlet to east of Fire Island Inlet surveyed Borrow Area 2C and Borrow Area 5 (USACE 2004a). USACE's Benthic Invertebrate Survey: Napeague to East of Fire Island Inlet surveyed Borrow Area 2C and Borrow Area 5A and 5B were surveyed and reported together (USACE 2001). The East of Shinnecock Inlet to east of Fire Island Inlet survey characterized the dominant sediment type as sand but did not indicate the breakdown of coarse, medium, or fine sand and the Napeague to East of Fire Island Inlet survey did not provide the dominant sediment type. Although comparisons of the sediment type to these previous studies will not offer much detail, comparisons of benthic infauna data provided insight into trends in species richness, dominant species, species richness, and abundance.

4.1.1 BORROW AREA 2C

This study compared on-site samples to reference samples and benthic samples taken from the top inch of the benthic sample to a vertical "core" of the benthic grab. Bottom sediment in the Borrow Area 2C showed some variation between on-site and reference samples. Notably, for both seasons, only reference sites had fine-sized sand particles as the dominant grain size, while none of the on-site samples had fine-sized grains as the dominant sediment type. At this level of characterization, most of the whole grab samples and the top samples had the same characterization during the summer in Borrow Area 2C. Looking further, on-site whole samples had a significantly greater percentage of fine sand particles compared to on-site top samples during the summer, a pattern that was not evident in the fall. This indicates a possible shift from fine sand particles from summer to fall, and the potential that the fine sand particles were not confined to the top inch of the seafloor in this borrow area. Overall, for Borrow Area 2C, the sediment characterization was very similar between the summer and fall samples. For both seasons, the dominant sediment size was coarse sand for whole and top samples. The increase in the number of top samples with medium-sized sand as the dominant sediment type and decrease in the number of top samples with coarse sand as the dominant type from summer to fall may be an indication that between the seasons, medium sand replaced or covered some of the coarse sand in the top layer of sediment in the borrow area. This change was only evident in the top sediment samples and not in the whole samples.

Offshore, continental shelf benthic communities are often diverse, especially along the eastern United States. A review by Allen Brooks et al. (2006) revealed that diversity was greater on the East Coast relative to the Gulf of Mexico. This paper also found a lack of strong correlation between species and sediment or depth. In this survey of Borrow Area 2C, Arthropoda were the most abundant in the summer, but the most abundant phylum in the fall was Annelida. This difference appeared to be driven by a shift in the dominant species found in the Borrow Area during the summer. Species richness (R) and abundance were significantly greater in summer samples compared to fall samples, but only on-site. At reference sites, however, there was no significant difference between seasons, although species richness and abundance did decrease slightly. This pattern of greater species richness and abundance is evident in the data provided in the Draft Benthic Invertebrate Survey: East of Shinnecock Inlet to east of Fire Island Inlet for Borrow Area 5 (2004a) and the data in the Benthic Invertebrate Survey: Napeague to East of Fire Island Inlet for Borrow Area 5A and 5B (USACE 2001) (Table 31) and is likely due to lower productivity which is typical in cooler months. Productivity starts to decrease in the fall in temperate climates when sunlight is limited and thermoclines develop which prevents the mixing of nutrients.

Table 31: Summary of Parameters and Comparison with Past Studies in New York Borrow Areas for 2C

Summary of Parameters and Comparison with Past Studies in New York Borrow Areas for 2C						
Parameters	**Current study**		**USACE (2004a)**		**USACE (2001)**	
	Jul 2015	**Oct 2015**	**Jun 2001**	**Nov 2000**	**Aug 1999**	**Dec 1999**
Borrow Area	2C		2C		2C	
Number of grabs	45	45	20	20	33	33
Dominant sediment	Coarse sand	Coarse sand	Sand◊	Sand◊	Not calculated	Not calculated
Avg H' diversity index	1.8	1.8	2.08	2.06	2.53	1.49
Dominant infauna	*Pseudunciola obliquua* (Arthropoda)	Nematode spp. (Nematoda)	Nematode spp. (Nematoda)	Polygoriidae spp. (Annelida)	*Polygordius triestinus* (Annelida)	*Polygordius triestinus* (Annelida)
Avg species richness	18	14	Not calculated	Not calculated	Not calculated	Not calculated
Avg individuals per grab	176.1	94	106.6	66.15	169.09	154.7

Note: Sand◊ = not described further. Current study used a 0.1-m^2 grab sampler; USACE 2001 and 2004a used 0.025-m^2 grab sampler.

4.1.2 BORROW AREA 5B

Bottom sediment in the Borrow Area 5B showed some variation between on-site, dredged box, and reference samples from summer to fall. An interesting point when comparing the different sites is that for both seasons, only one site had cobble or pebble as the dominant grain size and they were located in the dredged box. The presence of cobble and pebble only in the dredged box could indicate that these layers only occur in deeper layers of the sediment and previous dredging removed enough of the top layer of the seafloor to expose it. None of the whole dredged box samples had fine-sized grains as the dominant sediment type although one top dredged box sample did. Lower percentage composition of fine sand-sized sediment in the dredged box compared to on-site samples taken outside of the dredged box, and reference samples indicate that the previously dredged box is not currently filled in with fine sediment. Changes in the dominant sediment type indicate that there was a shift from medium sand to coarse sand from the summer to fall.

Looking further at percentage composition of sediment of whole and top samples reveals that whole, on-site samples (including the dredged box) had a significantly greater percentage of fine sand particles compared to top samples during the fall but not the summer. The difference is reflected in the decrease in fine sand in the top samples from the dredged box. This indicates the possibility that the top layer of the sediment in the dredged box containing fine sand was removed by the dredging process. The lower amount of fine sand in the dredged box compared to on-site samples is also evident in the summer. An alternative is that there was a shift from fine sand particles from summer to fall and the fine sand particles were not confined to the top inch of the seafloor in this borrow area. In addition, for both seasons on-site (including dredged box samples), top samples had a significantly greater percentage of medium sand particles compared to whole samples. Overall, for Borrow Area 5B the sediment characterization shifted between the summer and fall. For whole and top on-site samples the dominant sediment size was medium sand for on-site for summer and coarse for fall; coarse sand was dominant in the dredged box samples. For whole and top reference samples fine and medium sand were dominant in the summer and coarse sand was dominant in the fall.

Arthropoda was the most abundant phylum in the summer while Nematoda was most abundant in the fall. Species richness (R) and organism abundance were all greater in summer samples for all sample types. Species richness and abundance was significantly greater for on-site and dredged box summer values compared to fall. Abundance was significantly greater in the summer for reference sites. Diversity (H') was greater in the fall for on-site samples compared to summer samples. Using these batches of data as a proxy for overall comparisons to Borrow Area 5B shows that they are in general agreement (**Error! Reference source not found.**). This pattern of greater species richness and abundance is evident in the data provided in the Draft Benthic Invertebrate Survey: East of Shinnecock Inlet to east of Fire Island Inlet for Borrow Area 5 (2004a) and the data in the Benthic Invertebrate Survey: Napeague to East of Fire Island Inlet for Borrow Area 5A and 5B (USACE 2001). A decrease in species richness and abundance was observed in these surveys as well and is likely due to lower productivity which is typical in cooler months.

Table 32: Summary of Parameters and Comparison with Past Studies in New York Borrow Areas for 5B

Summary of Parameters and Comparison with Past Studies in New York Borrow Areas for 5B						
Parameters	**Current study**		**USACE (2004a)**		**USACE (2001)**	
	Aug 15	Oct 15	Nov 2000	Jun 2001	Jul 1999	Nov 1999
Borrow Area	5B		5		5A & 5B	
Number of grabs	45	45	20	20	31	31
Dominant sediment	Medium sand	Coarse sand	Sand◊	Sand◊	Not calculated	Not calculated
Avg H' diversity index	1.17	1.52	2.39	2.04	2.60	2.70
Dominant infauna	*Pseudunciola obliquua* (Arthropoda)	Nematode spp. (Nematoda)	*Gammarus oceanicus* (Arthropoda)	*Protohaustorius wigleyi* (Arthropoda)	*Protohaustorius wigleyi* (Arthropoda)	*Protohaustorius wigleyi* (Arthropoda)
Avg species richness	17	12	Not calculated	Not calculated	Not calculated	Not calculated
Avg individuals per grab	602.83	97.96	61.30	58.55	129.13	35.54

Note: Sand◊ = not described further. Current study used a 0.1-m^2 grab sampler; USACE 2001 and 2004a used 0.025-m^2 grab sampler.

4.2 FISHERIES CONSIDERATIONS

The fishes collected in this study have both commercial and biological importance. This study revealed a high diversity of fishes, with 52 distinct species identified over four months of trawl sampling. Of these, 28 species have some commercial significance, based on the most recent information on landings in New York from 2014 (NOAA 2015a; Table 33). Additionally, four of the species collected in this study generated over $1 million in revenue last year: longfin squid, summer flounder, scup, and goosefish (Table 1). Since only one goosefish was captured, however, it will not be discussed further. Maintaining these populations ensures an economic resource for the local fishing fleet. Within the study area, various types of gear are used to target species. Landings data indicate that commercial dredge, gillnet, and pot have low landings from the study areas; commercial otter trawls land relatively higher catches (NYS DOS 2013). No landings are evident from longline or seine. Recreational charter and party boats have high use around the borrow areas (NYS DOS 2013).

Previous studies report that near both Borrow Areas, juvenile squid show medium abundance in both the spring and fall; adult squid, however, have moderate abundance near the study areas in the spring and medium abundance in the fall (NYS DOS 2013). Longfin squid spawn year round, with peaks in summer and winter. They have a short life span (around 6 to 8 months), and can grow up to 488 mm, but usually reach a maximum of 305 mm (NOAA 2015c). Most of the individuals captured were juveniles, with peak abundances in October in Borrow Area 2C and in July and October in Borrow Area 5B. This seasonal pattern of squid abundance was also observed in New York waters near the study area (USACE 2004b). In the New York Bight, summer flounder are typically found offshore in the spring and closer to shore in the fall (NYS DOS 2013), which was reflected in Borrow Area 5B, since the highest catch of the species occurred in October. In Borrow Area 2C, summer flounder was most abundant in July. They spawn over open areas on the continental shelf during fall and winter. With sexes combined, half of the summer flounder population is sexually mature at 276 mm (MAFMC 2013a). Based on the lengths of the summer flounder in this study, it can be inferred that both juveniles and adults were collected. Scup move seasonally, from offshore in the winter to inshore in the summer. The greatest abundances of scup in Borrow Area 5B occurred in August; in Borrow Area 2C, the species was most abundant in the fall. Scup spawn once a year in the summer over weedy or sandy areas; 50% are sexually mature at 2 years, or about 170 mm total length (MAFMC 2013b). Both juveniles and adults are likely present in the study areas, since, accounting for the use of standard length as measurement, some of the larger fishes would probably be sexually mature.

Essential Fish Habitat (EFH) is designated by lifestage and is broadly defined in the 1996 Magnuson-Stevens Act as "water and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The Mid-Atlantic Fishery Management Council aims to designate EFH for each managed species in the study area. Ten of the captured fish species have EFH designated in the same area as the FIMI Borrow Areas (NOAA 2015b; Table 33). The Fire Island Stabilization Project EFH Assessment concluded that dredging and placement of dredged materials on beaches would not cause adverse effects to EFH-designated species of EFH in Borrow Areas 2C and 5B (USACE 2014a).

Table 33: Commercial Use and Essential Fish Habitat Overlap of Each Captured Fish Species

Commercial Use and Essential Fish Habitat Overlap of Each Captured Fish Species		
Species	**Commercial fishery**	**Essential Fish Habitat (EFH) in 2C and 5B**
American sand lance		
Atlantic croaker	x	
Atlantic menhaden	x	
Atlantic moonfish		
Atlantic silverside	x	
Atlantic stingray		
Black sea bass	x	x
Bluefish	x	x
Bluespotted cornetfish		
Butterfish	x	
Clearnose skate	x (skates)	
Cunner	x	
Dwarf goatfish		
Fourspot flounder	x	
Glasseye snapper		
Goosefish	x	
Gray triggerfish		
Lined seahorse		
Little skate	x (skates)	
Longfin squid	x	x
Naked goby		

Commercial Use and Essential Fish Habitat Overlap of Each Captured Fish Species		
Species	**Commercial fishery**	**Essential Fish Habitat (EFH) in 2C and 5B**
Northern kingfish	x	
Northern pipefish		
Northern puffer	x	
Northern searobin	x (searobins)	
Northern stargazer		
Oyster toadfish	x	
Planehead filefish		
Red hake	x	x
Rock gunnel		
Round scad		
Scrawled filefish		
Scup	x	x
Short bigeye		
Silver hake	x	x
Smallmouth flounder		
Smooth dogfish	x	
Snowy grouper		
Spiny dogfish	x	x
Spotfin butterfly fish		
Spotted hake		
Striped anchovy		
Striped burrfish		
Striped cusk-eel		
Striped searobin	x (searobins)	
Summer flounder	x	x
Tautog	x	
Twospot cardinal fish		
Weakfish	x	
Windowpane	x	x
Winter flounder	x	x
Winter skate	x (skates)	

Note: species in bold support a >$1 million fishery

The USACE Fire Island to Montauk Point Reformulation Study summarized finfish data from surveys conducted from 1999 to 2002 (2004b). The CPUE in the current study (CPUE based on the number of monthly trawls) and the USACE report CPUE (based on trawl hours) are not equivalent metrics but illustrate some interesting trends for some key species. This study reflected the same trends in catches as those reported in past trawl surveys discussed in the USACE report (USACE 2004b). This study and the USACE Fire Island to Montauk Point Reformulation Study caught summer flounder in greatest abundance in the summer, and squid in greatest abundance in the fall. Anchovy catches were not reported USACE Fire Island to Montauk Point Reformulation Study, but they are important to coastal food webs. They feed on plankton and are then consumed by larger predators that often have commercial or recreational significance (e.g., striped bass, bluefish, and spotted seatrout) (Murdy et al. 1997). In the current study, striped anchovy was most abundant in Borrow Area 2C in September and in Borrow Area 5B in October.

There was considerable temporal variation in the species that were present every month. The number of species ranged from 17-28 species in Borrow Area 2C and 25-33 species in Borrow Area 5B, and quite a few were seen only once. This is also reflected in the fluctuation of the dominant species each month in both Borrow Areas. Similarly, abundance, indexed by CPUE, indicated that temporal changes were stronger than spatial variation since CPUE varied more from month to month rather than among areas (i.e., on-site and reference sites) within any given month.

4.3 POTENTIAL IMPACTS AND RECOVERY IN FIMI BORROW AREAS

The marine offshore environment, particularly the sea floor, would be impacted by dredging activities due to an acute disturbance, followed by a period of recovery. Dredging removes the surface sediments, creating a shallow depression. Typically, following this type of disturbance, a diverse benthic infaunal community would recolonize from adjacent undisturbed areas within a matter of 3 months to 3 years (Allen Brooks et al. 2006; Byrnes et al. 2004; Lundquist et al. 2010).

Physically, bottom sediment is suspended during dredge activities, resulting in increased turbidity and decreased water quality. Suspended particles usually remain within 49 to 131 ft (15 to 40 m) of activity, so adjacent areas would be minimally impacted (Spencer 1997); however, local oceanographic features would determine the extent of dispersal. Most sediment resettles within 30 minutes to 24 hours (Lambert and Goudreau 1996), with coarse pebbles and shell settling before finer sand and clay (Ruffin 1995). The greatest turbidity and slowest dissipation rates generally result from dredging in shallow environments with high silt and clay (Tarnowski 2006). The Borrow Areas 2C and 5B, which may be used for beach nourishment, are dominated by coarse- and medium-sized sand, so turbidity would be expected to be moderate. Therefore, dredge activities in this expansion site should not result in long-lasting sediment plumes. Excavation depths of borrow sites are similar to natural bathymetry and topography of New York’s offshore environment, so the recovery of the physical system is expected to follow natural patterns (Byrnes et al. 2004).

Mobile macroinvertebrates, such as crab, jellyfish, and squid species, are likely to avoid and evade dredge equipment. Any organism that cannot escape the dredge, however, would experience immediate mortality. A few months of recovery time between dredging any one particular area should provide sufficient time for recolonization by benthic invertebrates, due to their short life cycles, high reproductive potential, and recruitment of planktonic larvae from nearby areas (Naqvi and Pullen 1982). Recolonization usually occurs by an opportunistic species (either adult or larvae) from the surrounding area, if the sediment is similar (Boyd et al. 2005). The type of benthic organisms that are first to recruit may be affected by the timing of dredge activities; for example, ending dredge activities by spring would encourage the settlement of crustaceans, while ending in fall would benefit annelids (Diaz et al. 2004). A change in sediment size following sediment extraction may result in a restructuring of the marine benthic community (Desprez 2000). Although in Borrow Areas 2C and 5B it is expected that sediment of similar grain size will replenish the extracted sediment. The current environment of the Borrow Areas is primarily coarse- and medium-sized sand, and a change in the dominant sediment type may alter the benthic community composition. Alternatively, if post-dredging sediment does not achieve physical stability, recovery of organisms may be stalled in an early successional stage (Boyd et al. 2005).

Although dredging usually impacts benthos more than fish populations due to differences in mobility, fish species may also be affected. A recent USACE borrow area assessment off the New Jersey coast found that the habitats of ocean pout, black sea bass, and the early life history stages of winter flounder may be directly impacted by dredging (USACE 2014b). Black sea bass and winter flounder were collected in this study, though in relatively small numbers. In addition to direct impacts, indirect trophic effects may also impact fishes, since benthic organisms are an important prey resource (Diaz et al. 2004). Following benthic invertebrate recolonization after dredging activity, though, most fishes would be expected to return to the area in similar numbers as nearby reference areas, with natural seasonal variation in community composition (USACE 2008). Since fish community composition in the Borrow Areas displayed variation among months, the timing of dredge activities will likely affect demersal species differently.

5.0 CONCLUSIONS

The recovery of this bottom habitat is contingent upon the homogeneity of the underlying sediment. Similar-sized sand particles are needed to provide habitat for invertebrates that make up the offshore benthic environment. Recolonization and the accumulation of biomass usually occurs quickly, but the complete recovery of species diversity usually takes longer, and depends on many factors, such as available sediment, hydrodynamics, nearby resources, and the intensity of dredging activity. This study found that the FIMI Borrow Areas have coarse- and medium-sized sand, so similar suitable habitat should be available and stable for the re-settlement of benthic infauna. This study revealed that overall, nearby sites have similar habitat and populations of benthic organisms, which could provide a source of recruits. The samples in the dredged box that contained pebble and cobble sediment in Borrow Area 5B were the outliers; 80% and of the dredged box samples did not contain pebble or cobble. If dredge activity occurs at a high intensity, the Borrow Areas would likely require a longer recovery period. Since the sediment type in part of the Borrow Areas changed from summer to fall, it is possible that the ability of organisms to recolonize may be affected. Greater impacts such as trophic effects are unlikely given the expected rapid recovery of benthos which provides an important prey resource for organisms such as crustaceans and fishes.

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Appendix A – Field Data Sheets

Placeholder for Appendix A

Appendix B – Water Quality Data

Placeholder for Appendix B

Appendix C – Benthic and Trawl Site Coordinates

Placeholder for Appendix C

Appendix D – Raw Laboratory Data; Grain Size

Placeholder for Appendix D

Appendix E – Raw Laboratory Data; Benthic Infauna

Placeholder for Appendix E

Appendix F – Subcontractor Information

SUBCONTRACTOR INFORMATION

Tootser Seafood – Vessel, Captain & Mate
1674 Harvard Ave.
Brick, NJ 08724

APPENDIX L

BORROW SOURCE INVESTIGATIONS

1. **Project Location** The US Army Engineer District, New York (CENAN) is currently conducting a reformulation study of the shore protection and storm damage reduction project for the south shore of Long Island, New York. The project area is located entirely in Suffolk County, Long Island, along the Atlantic and the bay shores of the towns of Babylon, Islip, Brookhaven, Southampton, and East Hampton. The overall study area, is approximately 83 miles long and includes three large estuarial bays: Great South Bay (connected to the ocean by Fire Island Inlet), Moriches Bay (connected to the ocean by Moriches Inlet), and Shinnecock Bay (connected to the ocean by Shinnecock Inlet). The westernmost portion of the overall study area, the Nassau/Suffolk County border at Great South Bay, is located about 47 miles east of The Battery, NY. The area is primarily low-lying and as such, subject to flooding by storm surge from the Atlantic Ocean, surge propagation through tidal inlets, wave setup and run-up, and barrier island over wash and breaching.

2. **Objective.** The objective of the borrow area investigation was to identify and delineate sources of sand borrow material for use as design fill and nourishment material for FIMP beach erosion control project. The geology of the study area sets the framework of the sedimentary development of the shoreline and the offshore. Beach fill sediments were sought which had adequate data available, sufficient quantity, compatible sediment characteristics, would cause minimal adverse wave attenuation, would cause minimal geomorphological effects, contained minimal overburden of fines, contained minimal quantity of fines and minimal adverse environmental effects. Methodology from EM 1110-2-1100 (Coastal Engineering Manual) was used to determine sediment characteristic suitability. Beach sand models were created using samples along the shoreline between Fire Island and Montauk Point. Borrow sources investigated included upland (quarry), maintenance dredging of navigation channels, flood and ebb shoal mining at inlets, and offshore (dredging) sites. Sand Bypassing was evaluated in the Engineering Appendix, but is not expected to provide more than a small percentage of the fill needs. So the other sources were assumed to be required for all the fill, and if it turns out that sand bypassing is a cost effective way of diminishing the fill needs, then it will be become part of the usage plans. Usage plans were developed for the suitable sources.

3. **Study Area Geology** (*derived from Schwab, W.C., Thieler, E.R., Denny, J.F., Danforth, W.W. 2000. Seafloor Sediment Distribution Off Southern Long Island, New York: U.S. Geological Survey Open-File Report 00-243, performed as a part of this study)***.** Long Island marks the southern boundary of the late Pleistocene glacial advance in the eastern part of North America (Stone and Borns, 1986). Two end moraines are superimposed along the western part of northern Long Island. The moraines bifurcate in eastern Long Island, where each moraine forms the core of the two peninsulas north and south of Great Peconic Bay (Fig. 1). The topography of Long Island is a reflection of this glacial history and exhibits greater relief on the northern side, where the two moraines are superimposed, and a gentler southward dipping gradient on the outwash plains that make up much of the southern side of the island. The coast from Southampton to Montauk Point is a headland region where the Ronkonkoma moraine and associated outwash sediment are eroded directly by wave action (Williams, 1976). The south shore

of Long Island west of Southampton consists of reworked glaciofluvial outwash and includes shallow back-barrier bays, marshes, and low-relief, sandy (fine- to medium-grained sand) barrier islands.

4. Leatherman (1989) identified 26 historical inlet sites along the Fire Island barrier-island system east of Watch Hill (Fig. 1). Inlet breaches account for most of the littoral sand transport into the back-barrier bays, and relict flood-tidal deltas are common throughout Moriches and Shinnecock Bays (Leatherman, 1985). The great number of relict flood-tidal deltas east of Watch Hill and outcrops of tidal-marsh sediments on the upper shoreface provide evidence of landward migration of this portion of the barrier-island system (Leatherman and Allen, 1985). In contrast, most of Fire Island west of Watch Hill has experienced in-place submergence over the past ~1000 yr (Sanders and Kumar, 1975; Leatherman, 1985; Leatherman and Allen, 1985). From the early 1800's until 1931, the Fire Island barrier-island system from Shinnecock Bay west to Fire Island Inlet, formed a single spit. A strong storm in 1931 opened Moriches Inlet and the "great hurricane" of 1938 opened Shinnecock Inlet and 11 other smaller inlets between Shinnecock and Moriches Inlets (Howard, 1939). All of these inlets subsequently closed naturally except Shinnecock and Moriches Inlets, which were stabilized by jetties in 1954. The east side of Fire Island Inlet was stabilized with a jetty in 1940.

5. Recent USGS Geologic Investigations. Data coverage for the Fire Island to Montauk Point study area extends from 10 miles west of Fire Island Inlet to approximately 10 miles west of Montauk Point, and from 8-m isobath to about 10 km offshore. Sea floor mapping was accomplished by using side scan sonar, high-resolution seismic-reflection profiles, surficial sediment samples, and visual observations. Data products include:

    a. The bathymetric coverage was generated from track line bathymetric data collected and was tidally corrected using NOAA's Sandy Hook control tide station: 8531680. Side scan sonar cross-shore line spacing was 300 m (1000 ft.), and alongshore spacing was approximately 2 km (200 statute miles).

    b. Side scan sonar imagery with contrast augmentation was used to portray backscatter. Backscatter is related to sediment texture where high backscatter indicates coarse-grained sediment or rock outcropping and low backscatter indicates fine sands, silt, or clays.

    c. Fifty-two surficial samples were collected and analyzed in the 1996 tour, 131 in spring of 1997, and 134 in fall of 1997. Reported parameters include sample tour identification; sample number; location in geographic coordinates; percentages of sand, silt and clay; sediment description; and mean sediment diameter, median sediment diameter, standard deviation, skewness, and kurtosis (all in phi units).

    d. Seismic-reflection data, taken in conjunction with the side scan sonar images and surficial sediment samples allowed interpretive mapping estimating Cretaceous rock outcropping, subsurface Pleistocene and Early Holocene sediment filled channels and thicknesses, and mapping of modern reworked deposits and thicknesses.

6. Recent USGS Geologic Results (*derived from Schwab, W.C., Thieler, E.R., Denny, J.F., Danforth, W.W. 2000. Seafloor Sediment Distribution Off Southern Long Island, New York: U.S. Geological Survey Open-File Report 00-243, performed as a part of this study. The most recent results of this study can be found in the originating document*).

The USGS analysis identified a large outcrop of Cretaceous rock approximately 6km offshore of Watch Hill. To the west of this outcrop a field of shoreface-connected sand ridges that thin in the westward direction was identified. It was hypothesized that these features may reflect onshore sediment transport west of Watch Hill from erosion of the Cretaceous strata traveling via sand waves. Quantification and confirmation have yet to be studied. It was further hypothesized that removal of material from these ridges may interrupt the onshore migration of material from the ridges to the shore face. USACE acknowledges that the potential for this onshore movement is a plausible process. The U.S.G.S. investigators concluded that the coastlines in the study area are influenced by the geological framework. Figure 2 shows estimated thicknesses of Holocene deposits.

7. **Screening Criteria.** Screening criteria included: adequate data available, sufficient quantity, compatible sediment characteristics, would cause minimal adverse wave attenuation, would cause minimal geomorphological effects, contained minimal overburden of fines, contained minimal quantity of fines, minimal adverse environmental effects, and minimal effect on cultural resources. Data meant sediment characteristics at a minimum. Sufficient quantity meant a minimum of 150,000 cy from an upland source within 2 to 4 months, and 250,000 cy from an offshore source. The EM 1110-2-1100 optimal level of sediment compatibility is an overfill factor (defined below) between 1.00 and 1.05. This is not always possible due to limitations in available borrow sites. New York District has had success in long-term placement of sediments with overfill factors between 1.00 and 1.30. This range was adopted for this study. Minimal adverse wave attenuation meant negligible wave changes at the shoreline demonstrated in modeling study. An ERDC rule of thumb of avoiding offshore borrow areas with existing grades shallower than -37 ft. NGVD was utilized. Minimal geomorphological effects meant minimal long term effect on current sediment transport in sensitive offshore areas such as the areas west of Watch Hill on Fire Island. Minimal overburden of fines was defined as less than one foot. Minimal quantity of fines was defined as less than 10%. Minimal adverse environmental effects meant negligible long term impact to flora or fauna as demonstrated by surveying. Minimal effect on cultural resources meant negligible effect upon known cultural resources.

8. **Grain Size Characteristics**. Grain size characteristics are a critical design parameter. Most often, sand with grain size characteristics similar to those of the native beach is sought as beach fill. This is done to maximize compatibility with the existing beach system. Indirectly, selecting compatible material also maximizes the accuracy of predictions of future project performance, which is based on past observations of the native beach response. Occasionally, fills are designed using material with different properties because of limitations on sand availability and the cost to transport it to the project site. Sometimes the choice of a nourishment material with different characteristics is made to satisfy a particular design objective, such as use of a coarser-grained fill material to improve resistance to erosion (EM 1110-2-1100, Chapter 4).

9. Grain size characteristics are quantified based on sieve analyses of samples which are collected throughout the project domain. Those samples acquired on the profile between the berm crest (or mean high water line) and a water depth corresponding to the [position of the typical storm bar should be used to characterize native beach sand for the purpose of assessing the compatibility of sand from potential borrow sources. Compatibility of borrow and native beach material is primarily based on grain size characteristics, and to a lesser extent on color (EM 1110-2-1100, Part V, Chapter 4).

10. Sediment Suitability. The grain size distribution of the borrow material will affect the cross-shore shape of the nourished beach profile, the rater at which material is eroded from the project, and how the beach will respond to storms. Typically borrow material will not exactly match the native beach (except perhaps in some bypassing projects). An analysis is required to assess the compatibility of the borrow material with the native beach, from a functional perspective. A comparative analysis of sand suitability is also required to economically evaluate alternative borrow areas for a given project (EM 1110-2-1100, Part V, Chapter 4). Core composites were developed using averages weighted based on thickness of sediment layers.

11. Early research into compatibility of borrow area material by Krumbein (1957), Krumbein and James 91965), James (1974, 1975), and Dean (1974) addressed this issue by various comparative analysis techniques that utilize the sand size distributions of the natural beach in the fill area and the borrow material in the candidate borrow sites. These approaches develop a factor, or parameter, indicating how much fill is required in light of the different sediment characteristics between borrow and native beach materials. They assume that borrow material placed on the beach will undergo sorting as a result of the coastal processes; and given enough time, will approach the native grain size distribution. The portion of borrow material that does not match the native sediment gain size distribution is assumed to be lost to the offshore. James (1975) developed this concept into a method to calculate an overfill factor, Ra, and a renourishment factor, Rj. Conceptually, the overfill factor is the volume of borrow material required to produce a stable unit of usable fill material with the same grain size characteristics as the native beach sand. The renourishment factor addresses the higher alongshore transportability of the finer grain sizes in the borrow sands and provides an estimate of renourishment needs. Use of the renourishment factor is no longer recommended in beach fill design calculations (EM 1110-2-1100, Part V, Chapter 4).

12. Equations. Mechanical sieve analysis results indicate that the existing beach material consists of coarse to fine sand, however, the coarse material predominates. Simplified methodology of mean grain diameter and standard deviation was utilized due to the large amount of samples analyzed. It is acknowledged that there are more robust methods (e.g., Method of Moments), however the differences in results would not be great enough to change the inclusion or exclusion of a potential source. The simplified mean grain diameter, $M_{\phi i}$, is defined by the following formula:

$$M_{\phi} = \frac{\phi_{84} + \phi_{16}}{2}$$

$\phi =$ grain diameter defined in “phi” units

where phi_{84} is the phi transformation of the percentile at which 84 percent of the particles on the grain size distribution curve have larger diameters, and 16 percent have diameters finer than the diameter of the 84th percentile. Whereas, phi_{16} and phi_{50} are the phi value of the 16^{th} and 50^{th} percentile, similarly determined. The mean diameter is used to categorize the beach material into its appropriate component. The standard deviation, $Sigma_{phi}$, is a measure of the natural sorting of the sample. It is simplistically defined by:

$$\sigma_{\phi} = \frac{\phi_{84} - \phi_{16}}{2}$$

= Standard Deviation in phi units

13. **Beach Model Development.** Beach sediment samples were collected in 1995 along 59 selected profile lines in the entire project shoreline, as shown in Figure 3, with nine samples collected per profile line at the following elevations: Back-Berm; Fore-Berm; Mean High Water (MHW); 0 ft. NGVD; Mean Low Water (MLW); -6.0 ft. NGVD, -12.0 ft NGVD; -18 ft. NGVD; and -30.0 ft. NGVD. Eleven beach models were selected to represent the 83 miles of shoreline. Models were selected based on geographic/geomorphic profile location, and are delineated in Figure 3, and described in Table 1. Divisions within one geomorphic region were selected based on constructability factors (e.g., pumping distance), correlation with economic models, grouping based on sediment characteristic similarities, and fill need. Details on how the sediment characteristics were determined follows.

14. All beach sediment samples were used in the development of the beach models with the exception of: samples from elevations -18 and -30 ft. NGVD, anomalous samples, and gravel range samples. These omissions are described below:

    a. Offshore Samples. Offshore samples collected at –18 and –30 ft. NGVD were omitted from the composites. As recommended in EM 1110-2-1100, the most active portion of the profile, located between the natural crest of the berm and the depth corresponding to the typical storm bar. The storm bar is typically located landward of the -18 ft. NGVD contour. Thus, the -18 and -30 ft. NGVD samples were not included in the composites.

    b. Anomalous “Scatter” Samples. Sample mean grain diameter (for all samples) was plotted against sample standard deviation. Beach sediments plotted in this manner typically result in a very dense grouping, with few outliers. The few outlier samples (located significantly away from the central “cluster”) were omitted from beach model composites. Outliers may be comprised of a random shell or cobble, or a limited pocket of silts or clay making its way into the sample cup.

    c. Gravel Samples. Samples that contained more than 16% retained on the ASTM Mesh #10 sieve (i.e., 16% or more of the sample is coarser than 2mm) were omitted from the composites as well. The risk of including gravel samples in the models arose from the potential of having a beach model in the non-sand range (according to the Wentworth Sediment Classification Scale), or from having a bimodal beach model for which our current methods of compatibility analysis are not equipped to model.

15. **Borrow Source Screening.** The potential borrow sources included: upland (quarry), navigation channel maintenance dredging, shoal mining, and offshore. Table 2 shows a comprehensive matrix of all sources investigated. Table 3 shows the list of potential quarries. The following vibracore data sets were used: 1975 FIMP (USACE, 1979); 1976 ICONS (Williams, 1976); 1979 FIMP (OSSI, 1983); 1995 FIMP (MNE and OSI, 1995); 1997 FIMP (collected for this study); and 1998 FIMP (collected for this study) The compatibility is discussed further by beach model. Table 4 shows the result of the screening. Figure 4 shows a comprehensive map with all the potential sources shown.

Table 1

Summary of Native Beach Models

Model	1995 PL	1996 PL	Location	Mean Grain Size (phi units)	Standard Deviation (phi units)	Mean Grain Size (mm)
GSB-D1	P001-P007	F1-F12	Robert Moses State Park to Fire Island Lighthouse	1.34	0.58	0.39
GSB-D2	P007B-P012A	F13-F35	Kismet to Cherry Grove	1.33	0.64	0.40
GSB-D3	P013-P019	F36-F58	Cherry Grove to Watch Hill	1.26	0.58	0.42
GSB-D4	P022-P024	F64-F68	Fire Island Wilderness Area	1.25	0.68	0.42
MB-D1	P027-P029	F72-F79	Smith Point County Park	1.25	0.64	0.42
MB-D2	P031-P037	F81-W17	Moriches Inlet to Westhampton Groinfield	1.15	0.62	0.45
SB-D1	P039-P045	W20-W35	East of Westhampton Groins to Tiana Beach	1.33	0.62	0.40
SB-D2	P045C-P048	W38-P3	Vicinity of Shinnecock Inlet	1.14	0.61	0.45
SB-D3	P050-P052	P7-P11	Southampton Beach	1.26	0.57	0.42
P-D1	P056-P063	P20-P41	Agawam Lake to Amagansett	1.15	0.63	0.45
M-D1	P065-P077	M5-M32	Amagansett to Montauk Point	1.05	0.67	0.48

Table 2

Comprehensive Matrix of Evaluated Sources

		Screening Selections								
Location	Source	Insufficient Data	Insufficient Quantity	Incompatible Sediment Characteristics	Potential Adverse Wave Attenuation	Potential Adverse Geomorph-ological Effects	Overburden of Fines	Excessive Fines	Potential Environ-mental Impacts	Potential Cultural Impacts
Upland	Quarries (12)	3 Quarries	7 Quarries							
Maintenance Dredging	Moriches Inlet (max. 50,000 cy/yr)									Yes
	Shinnecock Inlet (max 60,000 cy/yr)									Yes
	Long Island Intracoastal Waterway			Incompatible						
Shoal Mining	Fire Island Inlet Ebb Shoal			Incompatible						
	Moriches Inlet Ebb Shoal			Incompatible						
	Shinnecock Inlet Ebb Shoal			3 Incompatible Cores	4 Core Locations					
	Fire Island Inlet Flood Shoal	Insufficient Data								
	Moriches Inlet Flood Shoal	Insufficient Data								
	Shinnecock Inlet Flood Shoal			Incompatible						
Offshore	1976 FIMP Reach 2 Cores (46)		2 Cores	20 Cores	12 Cores		1 Core			
	1976 ICONS Cores (56)			42 Cores	10 Cores	1 Core				
	1979 FIMP Cores (60)		4 Cores	36 Cores	2 Cores	3 Cores	1 Core			
	1995 FIMP Reach 1 Cores (15)		2 Cores	8 Cores		1 Core	3 Cores		1 Core	
	1996 FIMP Reach 2 Cores (15)			10 Cores	3 Cores					
	1997 FIMP Cores (10)			5 Cores	1 Core	1 Core				
	1998 FIMP Cores (39)			15 Cores	3 Cores	3 Cores		4 Cores		

Table 3

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Potential Upland Sources

Potential Upland Sources	Location	Contact	Quantity*	Grain Size Da
American Sand & Gravel	Dix Hills, NY	(631) 242-9485	Insufficient	
Bistrian	East Hampton, NY	(631) 324-1123	Insufficient	
Empire Sand & Stone	Westbury, NY	(516) 997-2246	Insufficient	
European Express Sand and Stone	Kings Park, NY	(631) 544-9370	Insufficient	
Guillo	Southampton, NY	(631) 283-7251	Insufficient	
Hubbard Sand & Gravel	Bay Shore, NY	(631) 665-1005	Insufficient	
Stone, Sand, Soil & Rock	Lindenhurst, NY	(631) 956-7645	Insufficient	
Horan Sand & Gravel	Syosset, NY	(516) 364-2972	Sufficient	5 samples (200
Ranco Sand & Stone	Manorville, NY	(631) 874-3939	Sufficient	5 samples (200
East Coast Mines & Materials	Quogue, NY	(631) 645-7005	Sufficient	TBD
Sagaponack	Bridgehampton, NY	(631) 537-2252	Sufficient	TBD
Wainscott	Bridgehampton, NY	(631) 537-4583	Sufficient	TBD
Note: * Specification was 150,000 cy within 2 to 4 months.				

16. Borrow Screening for Beach Model GSB-D1-Fire Island Robert Moses State Park to Fire Island Lighthouse.

    a. Quarries. Out of the six quarries within the range of Model GSB-D1, only Horan Sand and Gravel in Syosset could supply 150,000 cy within 2 to 4 months and provided grain size distributions. The distributions at the time of the sampling (2002) were compatible with the beach model (overfill factor 1.11). Trucked in fill has no wave, geomorphological, and when specified in a detailed enough manner, negligible fines. Environmental and cultural effects (detailed elsewhere in the report) are minimal. The round trip distance from the quarry to the site is over 40 miles, and would require over 10,000 trucks to travel over a minimum of two bridges each way, and would require extra cost to restore roads and bridge surfaces from premature wear.
    b. Maintenance Dredging. This area occasionally receives small amounts of fill from Fire Island Maintenance Dredging. This would be assumed to continue into the future. Historical dredging observations have described Long Island Intracoastal Waterway material as unsuitable for ocean beach placement and won't be considered any further as a source in this study, i.e., less than 90% sand.
    c. Shoal Mining. Fire Island Inlet flood shoal has no data available, but is likely to contain material unsuitable for ocean beach fill. The ebb shoal has coring data, but the characteristics of the sediment were unsuitable.
    d. Offshore. No offshore cores were found to be suitable for this fill area.

17. Borrow Screening for Beach Model GSB-D2- Fire Island Kismet to Point O'Woods.

    a. Quarries. Horan Sand and Gravel in Syosset was suitable with a similar overfill factor 1.11 as for the previous model. See above for screening details.

b. Maintenance Dredging. The maintenance dredging material from Fire Island Inlet meets greater erosion needs further downdrift, so maintenance dredging as fill placement is not considered for this reach.
c. Shoal Mining. Fire Island Inlet flood shoal has no data available, but is likely to contain material unsuitable for ocean beach fill. The ebb shoal has coring data, but the characteristics of the sediment are unsuitable.
d. Offshore. Five offshore cores were found to be suitable for this fill area; ICONS-71, FIMP 79-2-9, 1995 FIMP Core 2, FIMP 97-2 and 97-6. There was adequate data to determine the overfill factors (1.02, 1.02, 1.02, 1.06, and 1.02, respectively). None of the cores is shallower than -37 ft. NGVD so no wave attenuation effects are expected. Four of the cores are located on sand ridges hypothesized to provide transport between offshore and onshore depths in recent studies. It is assumed that with the shortage of borrow sources in the area, borrow sources on the sand ridges may be utilized in such a way, with much adaptive management, and in deeper areas first, to make any impact to on-offshore transport negligible.

18. Borrow Screening for Beach Model GSB-D3- Fire Island Cherry Grove to Davis Park.

a. Quarries. No quarries were within convenient distance from fill area.
b. Maintenance Dredging. Inlets are located outside of convenient fill range.
c. Shoal Mining. Inlets are located outside of convenient fill range.
d. Offshore. Seven offshore cores were found to be suitable for this fill area; ICONS-67, FIMP 79-2-1 and 2-12, FIMP 97-5 and VC98-3, 4, 5 and 6. There was adequate data to determine the overfill factors (1.19, 1.08, 1.02, 1.08, 1.23, 1.28 and 1.25, respectively). None of the cores is shallower than -37 ft. NGVD so no wave attenuation effects are expected. Six of the cores are located on sand ridges hypothesized to provide transport between offshore and onshore depths in recent studies. It is assumed that with the shortage of borrow sources in the area, borrow sources on the sand ridges may be utilized in such a way, with much adaptive management, and in deeper areas first, to make any impact to on-offshore transport negligible.

19. Borrow Screening for Beach Model GSB-D4- Fire Island Wilderness Area.

a. Quarries. No quarries were within convenient distance from fill area.
b. Maintenance Dredging. Inlets are located outside of convenient fill range.
c. Shoal Mining. Inlets are located outside of convenient fill range.
d. Offshore. Four offshore cores were found to be suitable for this fill area; FIMP 79-3-7 and 3-9, and VC98-7 and 8. There was adequate data to determine the overfill factors (1.10, 1.06, 1.04 and 1.21, respectively). None of the cores is shallower than -37 ft. NGVD so no wave attenuation effects are expected. Three of the cores are located on relict headland area hypothesized to provide transport between offshore and onshore depths in recent studies. It is assumed that with the shortage of borrow sources in the area, borrow sources on the sand ridges may be utilized in such a way, with much adaptive management, and in deeper areas first, to make any impact to on-offshore transport negligible.

20. Borrow Screening for Beach Model MB-D1- Fire Island Smith Point County Park.

a. Quarries. Out of the quarries within the range of Model MB-D1, only Ranco Sand and Stone in Manorville could supply 150,000 cy within 2 to 4 months and supplied grain size distributions. The distributions at the time of the sampling (2002) were compatible with the beach model (overfill factor 1.21). Trucked in fill has no wave, geomorphological, and when specified in a detailed enough manner, negligible fines. Environmental and cultural effects (detailed elsewhere in the report) are minimal. The round trip distance from the quarry to the site is over 40 miles, and would require over 10,000 trucks to travel over a minimum of two bridges each way, and would require extra cost to restore roads and bridge surfaces from premature wear.

b. Maintenance Dredging. Moriches Inlet Maintenance Dredging material is occasionally placed in this reach, and this practice is expected to continue.
c. Shoal Mining. Moriches Inlet flood shoal has no data available, but is likely to contain material unsuitable for ocean beach fill. The ebb shoal has coring data, but the characteristics of the sediment were unsuitable.
d. Offshore. No offshore cores were found to be suitable.

21. Borrow Screening for Beach Model MB-D2- Westhampton West of Groins.

a. Quarries. Out of the quarries within the range of Model MB-D2, none met the quantity available threshold. Samples therefore, were not collected.
b. Maintenance Dredging. Moriches Inlet Maintenance Dredging material is usually placed in this beach area at a rate of 50,000 cy/year at 5 years intervals, and this practice is likely to continue.
c. Shoal Mining. Moriches Inlet flood shoal has no data available, but is likely to contain material unsuitable for ocean beach fill. The ebb shoal has coring data, but the characteristics of the sediment were unsuitable.
d. Offshore. One offshore core were found to be suitable for this fill area; 1976 FIMP Cores CB-40. There was adequate data to determine adequate quantity, and overfill factor (1.22). The core is not shallower than -37 ft. NGVD so no wave attenuation effects are expected. No sensitive geomorphological areas were identified in the vicinity of this core.

22. Borrow Screening for Beach Model SB-D1- Westhampton Groins and East of Groins.

a. Quarries. Out of the quarries within the range of Model SB-D1, none met the quantity available threshold. Samples therefore, were not collected.
b. Maintenance Dredging. Shinnecock Inlet Maintenance Dredging material is occasionally placed in this beach area, and this practice is likely to continue.
c. Shoal Mining. Shinnecock Inlet flood shoal has data available, but contains material unsuitable for ocean beach fill. The ebb shoal is located closer to the updrift beachfill placement area, and is discussed there.
d. Offshore. Thirteen offshore cores were found to be suitable for this fill area; 1976 FIMP Cores CB-11, 12, 13, 14, 15, 22, 23 and 24, 1979 Core 5-1, 1998 FIMP Cores VC98-21, 22, 23, and 24. There was adequate data to determine adequate quantity, and overfill factors (1.17, 1.02, 1.02, 1.17, 1.27, 1.16, 1.20, 1.23, 1.26, 1.09, 1.17, 1.12, and 1.18, respectively). The cores are not located in areas shallower than -37 ft. NGVD so no wave attenuation effects are expected. No sensitive geomorphological areas were identified in the vicinity of these cores. Environmental and cultural analyses shall be performed to determine impacts prior to use, in the cases where it has not been done already.

23. Borrow Screening for Beach Model SB-D2- West of Shinnecock Inlet.

a. Quarries. Out of the quarries within the range of Model SB-D2, four met the quantity available threshold. Only one of the four provided sediment characterization data; Ranco Sand and Stone in Manorville. The overfill factor for Ranco was 1.21 for this fill area. Trucked in fill has no wave, geomorphological, and when specified in a detailed enough manner, negligible fines. Environmental and cultural effects (detailed elsewhere in the report) are minimal. The round trip distance from the quarry to the site is over 40 miles, and would require over 10,000 trucks to travel over a minimum of two bridges each way, and would require extra cost to restore roads and bridge surfaces from premature wear. Samples from the remaining three quarries may be collected in the future.

b. Maintenance Dredging. Shinnecock Inlet Maintenance Dredging material is commonly placed in this beach area, and this practice is likely to continue, at a rate of 60,000 cy/year placed at 5-year intervals.

c. Shoal Mining. Shinnecock Inlet flood shoal has data available, but contains material unsuitable for ocean beach fill. The ebb shoal has coring data, adequate volume, and one core was found to be suitable with an overfill ratio of 1.19; 1997 FIMP Core Alt-1. The grade of the shoal at the location of the core is shallower than -37 ft. NGVD, due to its nature of being located on the shoal, hence hydrodynamic and sediment transport modeling is recommended prior to dredging to evaluate potential wave attenuation and geomorphological effects. The core does not contain excessive fines or overburden. Environmental and cultural analyses shall be performed to determine negligible effects prior to use.

d. Offshore. No offshore cores were found to be suitable for this fill area.

24. Borrow Screening for Beach Model SB-D3- Southampton.

a. Quarries. Out of the quarries within the range of Model SB-D3, three met the quantity available threshold but none provided sediment characterization data. Trucked in fill has no wave, geomorphological, and when specified in a detailed enough manner, negligible fines. Environmental and cultural effects (detailed elsewhere in the report) are minimal. The round trip distance from the quarry to the site is over 40 miles, and would require over 10,000 trucks to travel over a minimum of two bridges each way, and would require extra cost to restore roads and bridge surfaces from premature wear. Samples from the three quarries may be collected in the future.

b. Maintenance Dredging. Shinnecock Inlet Maintenance Dredging material is rarely placed in this beach area, and this practice is likely to continue.

c. Shoal Mining. Shinnecock Inlet flood shoal has data available, but contains material unsuitable for ocean beach fill. The ebb shoal has coring data, but the down drift reach (SB-D2) was closer to the coring data, and was considered for placement there.

d. Offshore. Three offshore cores were found to be suitable for this fill area; 1979 FIMP Cores 79-6-17, 1996 FIMP Cores SHIN-12 and 15. There was adequate data to determine adequate quantity, and overfill factors (1.06, 1.24 and 1.26). The cores are not located on grades shallower than -37 ft. NGVD so no wave attenuation effects are expected. No sensitive geomorphological areas were identified in the vicinity of these cores. Environmental and cultural analyses shall be performed to determine negligible effects prior to use.

25. Borrow Screening for Beach Model P-D1- Ponds.

a. Quarries. Out of the quarries within the range of Model P-D1, four met the quantity available threshold but none provided sediment characterization data. Trucked in fill has no wave, geomorphological, and when specified in a detailed enough manner, negligible fines. Environmental and cultural effects (detailed elsewhere in the report) are minimal. The round trip distance from the quarry to the site is over 40 miles, and would require over 10,000 trucks to travel over a minimum of two bridges each way, and would require extra cost to restore roads and bridge surfaces from premature wear. Samples from the three quarries may be collected in the future.
b. Maintenance Dredging. Inlets are not in proximity of fill area.
c. Shoal Mining. Inlets are not in proximity of fill area.
d. Offshore. Eleven offshore cores were found to be suitable for this fill area; 1976 ICONS Core 34, 1979 FIMP Cores 79-6-2, 6-5, 6-8, 6-13, 7-3, 7-7, and 7-9, 1998 FIMP VC98-30, 32, and 33. There was adequate data to determine adequate quantity, and overfill factors (1.06, 1.10, 1.25, 1.16, 1.22, 1.19, 1.23, 1.09, 1.17, 1.16 and 1.10, respectively). The cores are not located on grades shallower than -37 ft. NGVD so no wave attenuation effects are expected. No sensitive geomorphological areas were identified in the vicinity of these cores. Environmental and cultural analyses determined negligible adverse impacts in the areas surrounding cores 1979 FIMP 6-13 and 1998 Core VC98-32. Environmental and cultural analyses shall be performed to determine negligible effects prior to use for the other potential areas.

26. Borrow Screening for Beach Model M-D1- Montauk.

a. Quarries. Out of the quarries within the range of Model M-D1, one met the quantity available threshold but didn't provide sediment characterization data. Trucked in fill has no wave, geomorphological, and when specified in a detailed enough manner, negligible fines. Environmental and cultural effects (detailed elsewhere in the report) are minimal. The round trip distance from the quarry to the site is over 40 miles, and would require over 10,000 trucks to travel over a minimum of two bridges each way, and would require extra cost to restore roads and bridge surfaces from premature wear. Samples from the quarry may be collected in the future.
b. Maintenance Dredging. Inlets are not in proximity of fill area.
c. Shoal Mining. Inlets are not in proximity of fill area.
d. Offshore. Six offshore cores were found to be suitable for this fill area; 1976 ICONS Core 29, 1979 FIMP Cores 79-8-1, 8-8 and 8-9, 1998 FIMP VC98-34 and 35. There was adequate data to determine adequate quantity, and overfill factors (1.06, 1.09, 1.16, 1.29 and 1.13, respectively). The cores are not located on grades shallower than -37 ft. NGVD so no wave attenuation effects are expected. No sensitive geomorphological areas were identified in the vicinity of these cores. Environmental and cultural analyses determined negligible adverse impacts in the areas surrounding cores 1979 FIMP 8-9 and 1998 Core VC98-34. Environmental and cultural analyses shall be performed to determine negligible effects prior to use for the other potential areas.

Table 4

Results of Screening Analysis

Beach Model	Suitable Quarries	Maintenance Dredging	Suitable Shoal Mining Source	Suitable Offshore Sources
GSB-D1	Horan	Fire Island Inlet occasional		
GSB-D2	Horan			5 cores
GSB-D3				7 cores
GSB-D4				4 cores
MB-D1	Ranco	Moriches Inlet regular		
MB-D2		Moriches Inlet occasional		1 core
SB-D1		Shinnecock Inlet occasional		15 cores
SB-D2	Ranco	Shinnecock Inlet regular	1 core	
SB-D3				3 cores
P-D1				11 cores
M-D1				6 cores

27. **Borrow Source Recommendations.** Modern reworked deposits formed from erosion of eastern Long Island were targeted as having the highest likelihood of compatibility with beach sediment based on textural characteristics, based on preliminary vibracore data correlation (see Figure 2). While hundreds of miles of seismic data was collected, ease of use was not found. Therefore, Holocene thickness maps (derived by the USGS from the seismic and other data) were utilized for the delineation. Where suitable cores were located in groupings of two or more, a borrow area delineation was drawn to contain the group. Where suitable cores were isolated, it was assumed that the core has a horizontal influence of 2000' by 2000' and a vertical influence equal to the extent of the suitable material in the core. During the pre-construction phase, seismic interpretive profiles can be examined to refine the delineation, and more cores collected for verification purposes. The recommended borrow sources for each beach model area is described below. Borrow Areas are shown on Figures 5, 6, and 7. Borrow source recommendations are summarized in Table 5. Estimated volumes available in each beach model are detailed in Table 6.

27. Recommended Borrow Sources for Beach Model GSB-D1-Fire Island Robert Moses State Park to Fire Island Lighthouse.

    a. Initial Fill. Offshore. While no offshore cores were found to be suitable for this fill area in the immediate vicinity, cores suitable for Beach Model GSB-D2 were found to be suitable for this reach as well (the models were virtually identical). So an area was drawn around Cores ICONS-71, FIMP 79-2-9, 1995 FIMP Core 2 and FIMP 97-2, following the Holocene boundaries called Borrow Area 2C. This area covers 522 acres with an average depth of 12.7 feet. This area is recommended for initial fill. Environmental surveying was completed on this area.
    b. Future Renourishments. Navigation Channel Maintenance Dredging, Quarry or Offshore. Fire Island Inlet Maintenance dredging will be used in this reach for all

future operations. In addition, quarry may be utilized. Further, additional cores may be collected in Borrow Area 2C to confirm its suitability and if material is still shown to be compatible, Borrow Area 2C may be utilized. And environmental surveying may be performed on Borrow Area 1A (2000' by 2000' by 10.5 feet depth, surrounding core 1997 FIMP 97-6), and if negligible impacts are found, Borrow Area 1A may be specified.

28. Borrow Sources for Beach Model GSB-D2- Fire Island Kismet to Point O'Woods.

    a. Initial Fill. Offshore. Borrow Area 2C.
    b. Future Renourishments. Offshore. Borrow Area 2C.

29. Borrow Sources for Beach Model GSB-D3- Fire Island Cherry Grove to Davis Park.

    a. Initial Fill. Offshore. Borrow Area 2C was found to be suitable for this fill area as well and is recommended for initial fill (very similar models).
    b. Future Renourishments. Offshore. Additional vibracoring is recommended and if areas are shown to be still compatible, then the suitable borrow areas delineated surrounding core couple 1979 FIMP 79-2-12 and 1998 FIMP encompassing 500 acres at an average depth of 5 feet, called Borrow Area 2B, and two borrow areas of 165 and 200 acres with average depths of 15 and 10.1 feet, respectively, called 2A and 2D are recommended for future renourishments. Environmental and cultural surveys have already been completed on these areas. And/or environmental and cultural surveys may be completed on three additional areas, each 2000' by 2000', by 9.5, 4.3, and 17.2 feet depths, respectively, called 2F, 2G, and 2H, and if no adverse impacts are found, these areas may be utilized.

30. Borrow Sources for Beach Model GSB-D4- Fire Island Wilderness Area. No fill is recommended for this area.

31. Borrow Sources for Beach Model MB-D1- Fire Island Smith Point County Park.

    a. Initial Fill. Offshore. Although no offshore cores were found to be suitable for this reach in the immediate vicinity, cores from model areas MB-D2 and SB-D1 were found to be suitable (very similar models). A borrow area was delineated surrounding cores 1975 CB-12 and 13, 1979 FIMP Core 5-1, 1998 FIMP Cores VC98-21, 22, 23 and 24 covering 610 acres with an average depth of 13 feet, called Borrow Area 5B. Environmental and cultural surveys have been performed in this area, and it is thus recommended for use.
    b. Future Renourishments. Offshore or Quarry. Borrow Area 5B is recommended, or quarry, or environmental and cultural surveys may be performed on a 2000' by 2000' area with an average depth of 20 feet called Borrow Area 4C surrounding core 1975 FIMP Core CB-40 may have environmental and cultural surveys performed and if no adverse impact is found, then Borrow Area 4C can be utilized.

32. Borrow Sources for Beach Model MB-D2- Westhampton West of Groins.

    a. Initial Fill. No initial fill is recommended.

b. Future Renourishments. Maintenance Dredging and/or Offshore. Moriches Inlet Maintenance Dredging material is occasionally placed in this beach area, and this practice is likely to continue at a rate of 50,000 cy/year. Additional material may be obtained from Borrow Area 5B.

33. Borrow Sources for Beach Model SB-D1- Westhampton Groins and East of Groins.

    a. Initial Fill. Initial fill from an existing stockpile will be placed.
    b. Proactive Breach Contingency Plan Fill. Fill will be placed as needed as part of a Proactive BCP. Should fill be needed, Navigation Channel Maintenance Dredging material from Shinnecock Inlet may be utilized, or Offshore Borrow Area 5B may be used (similar models and similar suitability).

34. Borrow Sources for Beach Model SB-D2- West of Shinnecock Inlet.

    a. Initial Fill. Initial fill is not recommended for this reach.
    b. Proactive Breach Contingency Plan Fill. Fill will be placed as needed as part of a Proactive BCP. Should fill be needed, Navigation Channel Maintenance Dredging material from Shinnecock Inlet may be utilized, or Quarry or modeling studies and environmental and cultural surveys performed, and if no adverse impact is found, then a 2000’ by 2000’ by 17.8 feet depth, called Ebb Shoal Borrow Area 6B may be used.

35. Borrow Sources for Beach Model SB-D3- Southampton. No fill is recommended for this reach.

36. Borrow Sources for Beach Model P-D1- Ponds.

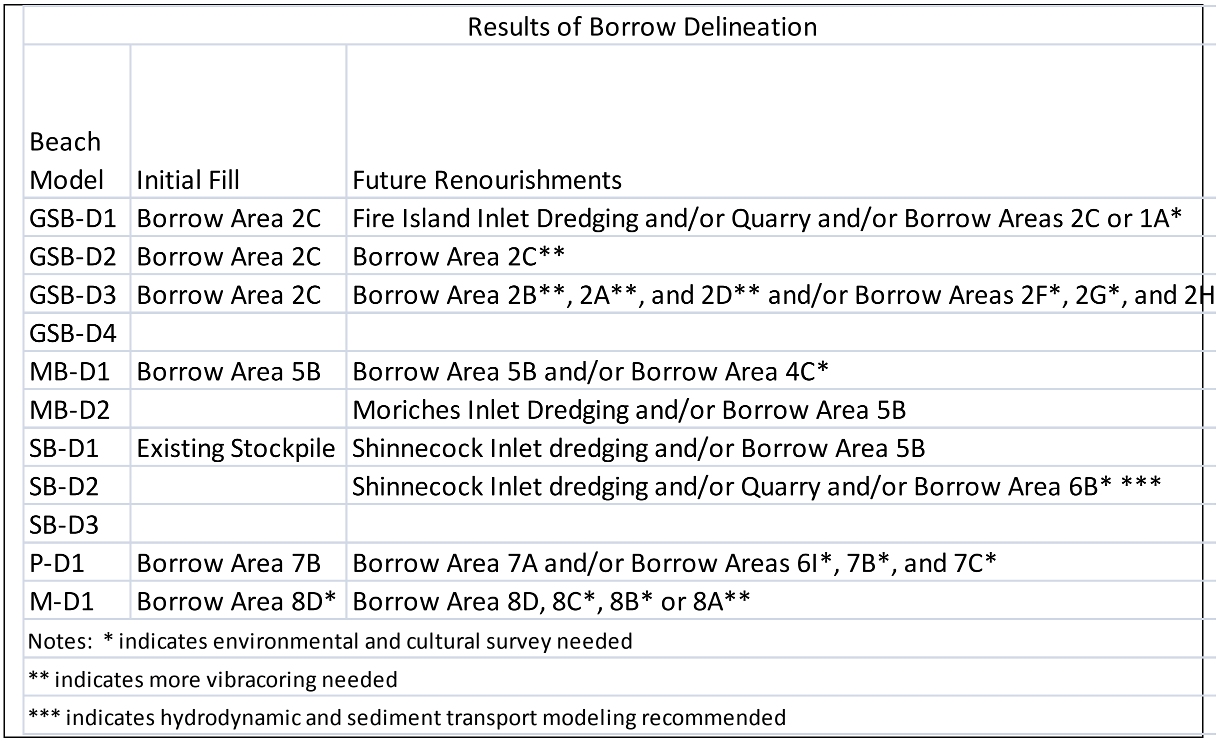
    a. Initial Fill. Offshore. An area 4000’ by 2500’ with an average depth of 8 feet, called Borrow Area 7B is recommended for use for initial fill. All environmental and cultural survey work has been performed on this area.
    b. Future Renourishments. Offshore. Borrow 7A is recommended. Or any of three 2000’ by 2000’ by 15, 12, or 11 feet depth, surrounding cores 1998 FIMP VC98-30, 1979 FIMP Core 7-9 and 7-7, respectively, called Borrow Areas 6I, 7B, and 7C may have environmental and cultural surveys performed, and if no adverse impacts are determined, then these areas may be utilized.

37. Borrow Sources for Beach Model M-D1- Montauk.

    a. Initial Fill. Offshore. Environmental and cultural survey shall be undertaken on an area 2000’ by 2000’ with a average depth of 13.3 feet, called Borrow Area 8D, surrounding core 1998 FIMP VC98-35, if found to have no adverse impact will be utilized.
    b. Future Renourishments. Offshore. Borrow Area 8D. Or vibracoring, environmental and cultural survey shall be undertaken on an area 4000’ by 1500’ with a average depth of 8 feet, called Borrow Area 8C, surrounding core 1979 FIMP VC 8-1 and 8-8, if found to have no adverse impact will be utilized. Or, environmental and cultural survey shall be undertaken on an area 2000’ by 2000’ with a average depth of 11 feet, called Borrow Area 8B, surrounding core 1976 ICONS-29, if found to have no adverse impact will be utilized. Or, vibracoring, survey shall be undertaken on an area 10000’ by 3000’ with an average depth of

15 feet, called Borrow Area 8A, surrounding cores 1979 FIMP VC 8-1 and 8-8, if found to have suitability confirmed, will be utilized.

Table 5



Results of Borrow Delineation

Beach Model	Initial Fill	Future Renourishments
GSB-D1	Borrow Area 2C	Fire Island Inlet Dredging and/or Quarry and/or Borrow Areas 2C or 1A*
GSB-D2	Borrow Area 2C	Borrow Area 2C**
GSB-D3	Borrow Area 2C	Borrow Area 2B**, 2A**, and 2D** and/or Borrow Areas 2F*, 2G*, and 2H
GSB-D4		
MB-D1	Borrow Area 5B	Borrow Area 5B and/or Borrow Area 4C*
MB-D2		Moriches Inlet Dredging and/or Borrow Area 5B
SB-D1	Existing Stockpile	Shinnecock Inlet dredging and/or Borrow Area 5B
SB-D2		Shinnecock Inlet dredging and/or Quarry and/or Borrow Area 6B* ***
SB-D3		
P-D1	Borrow Area 7B	Borrow Area 7A and/or Borrow Areas 6I*, 7B*, and 7C*
M-D1	Borrow Area 8D*	Borrow Area 8D, 8C*, 8B* or 8A**

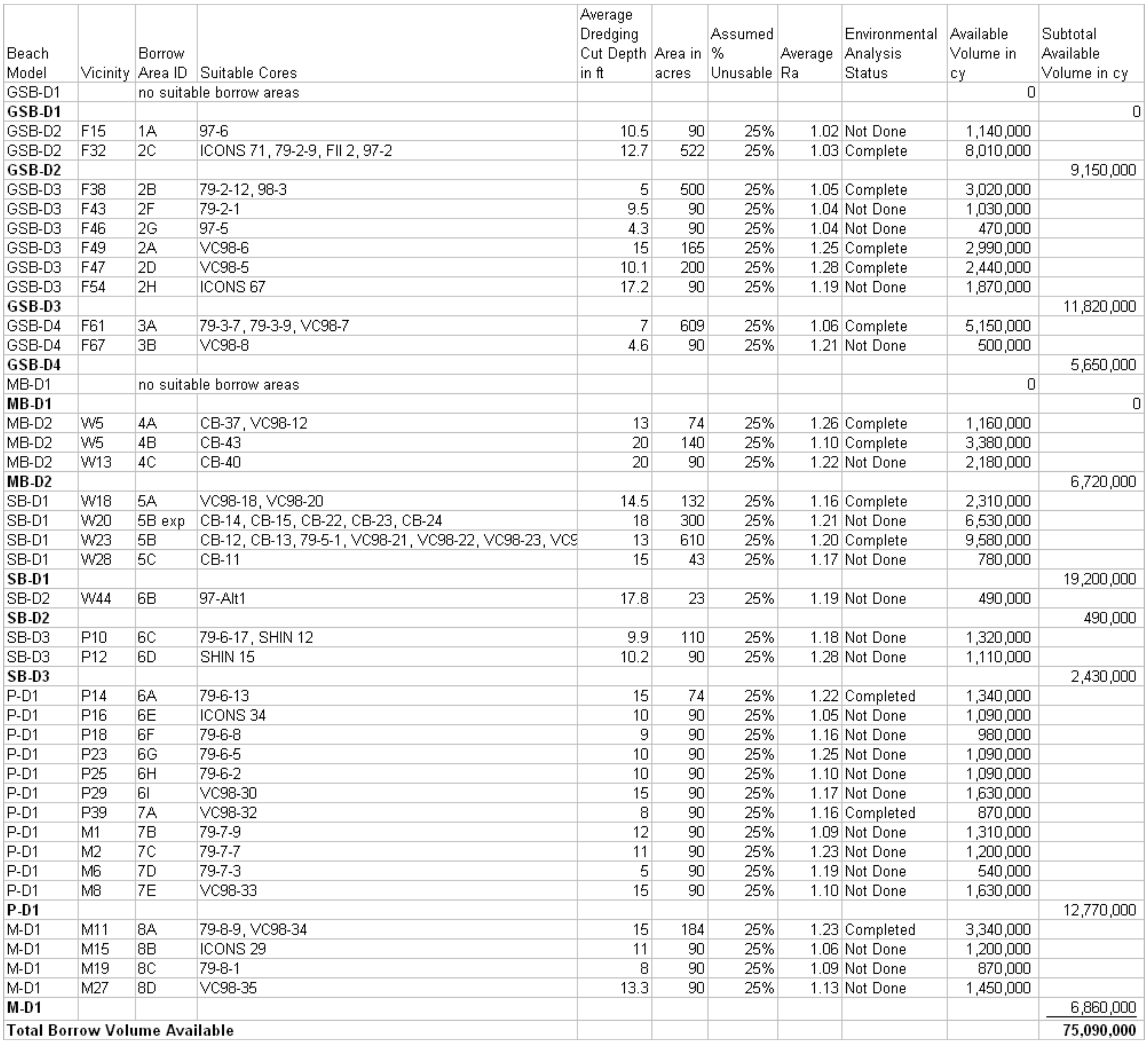
Notes: * indicates environmental and cultural survey needed

** indicates more vibracoring needed

*** indicates hydrodynamic and sediment transport modeling recommended

Available Borrow Volumes

Table 6



Beach Model	Vicinity	Borrow Area ID	Suitable Cores	Average Dredging Cut Depth in ft	Area in acres	Assumed % Unusable	Average Ra	Environmental Analysis Status	Available Volume in cy	Subtotal Available Volume in cy
GSB-D1		no suitable borrow areas							0	
GSB-D1										0
GSB-D2	F15	1A	97-6	10.5	90	25%	1.02	Not Done	1,140,000	
GSB-D2	F32	2C	ICONS 71, 79-2-9, FII 2, 97-2	12.7	522	25%	1.03	Complete	8,010,000	
GSB-D2										9,150,000
GSB-D3	F38	2B	79-2-12, 98-3	5	500	25%	1.05	Complete	3,020,000	
GSB-D3	F43	2F	79-2-1	9.5	90	25%	1.04	Not Done	1,030,000	
GSB-D3	F46	2G	97-5	4.3	90	25%	1.04	Not Done	470,000	
GSB-D3	F49	2A	VC98-6	15	165	25%	1.25	Complete	2,990,000	
GSB-D3	F47	2D	VC98-5	10.1	200	25%	1.28	Complete	2,440,000	
GSB-D3	F54	2H	ICONS 67	17.2	90	25%	1.19	Not Done	1,870,000	
GSB-D3										11,820,000
GSB-D4	F61	3A	79-3-7, 79-3-9, VC98-7	7	609	25%	1.06	Complete	5,150,000	
GSB-D4	F67	3B	VC98-8	4.6	90	25%	1.21	Not Done	500,000	
GSB-D4										5,650,000
MB-D1		no suitable borrow areas							0	
MB-D1										0
MB-D2	W5	4A	CB-37, VC98-12	13	74	25%	1.26	Complete	1,160,000	
MB-D2	W5	4B	CB-43	20	140	25%	1.10	Complete	3,380,000	
MB-D2	W13	4C	CB-40	20	90	25%	1.22	Not Done	2,180,000	
MB-D2										6,720,000
SB-D1	W18	5A	VC98-18, VC98-20	14.5	132	25%	1.16	Complete	2,310,000	
SB-D1	W20	5B exp	CB-14, CB-15, CB-22, CB-23, CB-24	18	300	25%	1.21	Not Done	6,530,000	
SB-D1	W23	5B	CB-12, CB-13, 79-5-1, VC98-21, VC98-22, VC98-23, VC9	13	610	25%	1.20	Complete	9,580,000	
SB-D1	W28	5C	CB-11	15	43	25%	1.17	Not Done	780,000	
SB-D1										19,200,000
SB-D2	W44	6B	97-Alt1	17.8	23	25%	1.19	Not Done	490,000	
SB-D2										490,000
SB-D3	P10	6C	79-6-17, SHIN 12	9.9	110	25%	1.18	Not Done	1,320,000	
SB-D3	P12	6D	SHIN 15	10.2	90	25%	1.28	Not Done	1,110,000	
SB-D3										2,430,000
P-D1	P14	6A	79-6-13	15	74	25%	1.22	Completed	1,340,000	
P-D1	P16	6E	ICONS 34	10	90	25%	1.05	Not Done	1,090,000	
P-D1	P18	6F	79-6-8	9	90	25%	1.16	Not Done	980,000	
P-D1	P23	6G	79-6-5	10	90	25%	1.25	Not Done	1,090,000	
P-D1	P25	6H	79-6-2	10	90	25%	1.10	Not Done	1,090,000	
P-D1	P29	6I	VC98-30	15	90	25%	1.17	Not Done	1,630,000	
P-D1	P39	7A	VC98-32	8	90	25%	1.16	Completed	870,000	
P-D1	M1	7B	79-7-9	12	90	25%	1.09	Not Done	1,310,000	
P-D1	M2	7C	79-7-7	11	90	25%	1.23	Not Done	1,200,000	
P-D1	M6	7D	79-7-3	5	90	25%	1.19	Not Done	540,000	
P-D1	M8	7E	VC98-33	15	90	25%	1.10	Not Done	1,630,000	
P-D1										12,770,000
M-D1	M11	8A	79-8-9, VC98-34	15	184	25%	1.23	Completed	3,340,000	
M-D1	M15	8B	ICONS 29	11	90	25%	1.06	Not Done	1,200,000	
M-D1	M19	8C	79-8-1	8	90	25%	1.09	Not Done	870,000	
M-D1	M27	8D	VC98-35	13.3	90	25%	1.13	Not Done	1,450,000	
M-D1										6,860,000
Total Borrow Volume Available										**75,090,000**

35. **Wave Attenuation Avoidances.** In order to evaluate wave attenuation effects from potential borrow dredging, wave shoreline change modeling was performed utilizing wave conditions developed on the existing conditions bathymetry, and a post-dredge hypothetical bathymetry where the full dredged quantity is assumed to be excavated all at once in order to evaluate wave attenuation effects. Bathymetric data for the numerical domain was acquired from the NOAA bathymetric database. Areas not covered by the NOAA database were defined using beach profile surveys collected in 1995 for this study. The post excavation bathymetry was estimated assuming a cutterhead dredge operation, which results in a fixed cutting depth, and 1V:37.5H final adjusted side slopes, over a 1.85 square mile area. RCPWAVE is the wave model utilized as input to the

GENESIS shoreline change model to determine the shoreline changes. The results of the GENESIS modeling without project (without dredging and without fill placement) and with project (with dredging and with fill placement) future net longshore transport rates show decreased or stable net transport rate within 3 miles down drift of Cherry Grove. This indicates that the dredged borrow depressions do not adversely impact the down drift shoreline. As an added safety factor, borrow areas did not extend landward of -37 ft. NGVD which is seaward of the “depth of closure” for the majority of storm events.

36. Cultural Resource Avoidance. Buffer zones surrounding significant cultural resources have not been delineated and concordant volume reductions in the borrow areas have not been incorporated. These will be accomplished prior to construction.

37. Geomorphologic Impact Avoidance. Towards gaining an understanding of the geomorphologic processes that we shall minimize impacts to, a literature review of onshore sediment movement on Western Fire Island was performed. A summary of the hypothesis of onshore sediment transport from sand ridges offshore of Fire Island appears below.

- In 1961 (a and b) Taney proposed onshore sand transport as the source to balance the sediment transport deficit from Moriches Inlet to Fire Island Inlet.
- In 1972, Duane et al identified sand ridges offshore of Fire Island.
- In 1975, Kumar and Sanders proposed that west of Watch Hill the island was drowning in place.
- In 1976, Williams in “Geomorphology of Long Island” identified cretaceous strata on subbottom profiles.
- In 1977, Williams and Meisberger in “Sand Sources for the Transgressive Barrier Coast of Long Island” propose material migrating onshore from the Continental Shelf.
- In 1983, Kana suggested relic Fire Island Inlet shoals as the onshore source, though presently exhausted.
- In 1985, Leatherman proposed that inlet breaching provided the majority of sediment into the bays east of Watch Hill.
- In 1985, Leatherman and Allen connected frequent inlet breaching east of Watch Hill with landward island migration.
- In 1989, Leatherman identified historical inlet sites along the barrier island system east of Watch Hill.
- In 1999, Rosati et al acknowledged the possibility of onshore transport, although no transport to 160,000 cubic meters/year of onshore transport is still within the level of uncertainty of the data making up the balanced sediment budget. In other words, if no transport exists, the budget is balanced, and if 160,000 m3/year of onshore transport occurs, the budget is still balanced to the accuracy of the supporting data.
- Also in 1999, Schwab et al in “Geological Mapping of the Nearshore Area Offshore Fire Island” propose that the geologic framework influences the shoreline, and describe the side scan sonar, subbottom profiling, and surface sampling performed between 1997 and 1998 for the purpose of mapping the geologic framework. Approximately 6 km offshore of Watch Hill, a large outcrop of Cretaceous strata was proposed, and outside of Watch Hill, the outcrop is proposed to be buried by

Quaternary sediments. And the field of sand waves oriented 30 to 40 degrees with respect to the shoreline were revealed in the data.

- Also in 1999, Foster et al proposed that the thickness of the sand ridges varies from 5 m immediately west of the outcrop, thinning to the west, to less than 1 m offshore of Fire Island Inlet.
- In 2000, Schwab et al in “Seafloor Sediment Distribution off Southern Long Island, New York” concluded that the ridges west of Watch Hill provide sediment to the shoreline west of Watch Hill, contributing to the island stability in that region (as opposed to the drowning-in-place shoreline east of Watch Hill).
- In 2008, Lentz, Hapke and Schwab in “Review of Sediment Budget Estimates at Fire Island National Seashore, New York” propose that removal of sediment from nearshore regions have the potential to alter wave refraction and diffraction patterns, and result in changes in the wave energy reaching the beach.
- In 2008, a two-day technical workshop on offshore sand resources south of Long Island was held at Stony Brook University’s School of Marine and Atmospheric Sciences. The workshop was intended to review what is known, or unknown about the volume of offshore sand reserves, the potential for onshore transport, and the character of offshore sand ridges. Workshop attendees included researchers from federal agencies, academia and the private sector as well as federal, state local agency representatives involved in coastal resource management. Bokuniewicz and Tanski summarize the workshop in, “White Paper: Long Island Offshore Sediment Resources”. (provided as a sub-appendix). Some of the workshop recommendations include the following:
    - Collection of high-resolution bathymetry of the proposed borrow pits and surrounding areas before and after dredging
    - Collection of periodic bathymetry and sidescan sonar from the 0 m to the 10 m contours
    - Collection of wave, water level, and current data via bottom-mounted instrumentation

    A conclusion of the workshop included the following: adverse impacts on the shoreline can be minimized by project design (such as borrow area size, orientation, and distance offshore).
- In 2013, Schwab et al. in “Geologic Evidence for Onshore Sediment Transport from the Intercontinental Shelf, Fire Island, NY” compare high-resolution mapping (sidescan sonar, seismic profiling and bathymetry) collected in 2011 with that collected in 1996-1997. The conclusion of “outcropping” was changed to “erosion outwash lobe”, as the data reveals it is buried by 15 m of Quaternary sediments. The 1996-1997 data was not able to resolve layers less than 50 cm thick. The 2011 data revealed that southeast of the outwash lobe are linear Pleistocene gravely-lag ridges less than 50 cm in height. These ridges extend from the 5m contour offshore 20 km to greater than the 35 m contour, and they vary in height from 6 m at the Watch Hill end to 1m at the Fire Island Inlet end. Net westward transport of fine to medium sand was suggested (as evidenced by low backscatter of the sonar), leaving medium to coarse material in the troughs and on the east-facing flanks (as evidenced by high backscatter). It was proposed that the southwest flanks of the

larger attached ridges have eroded, leaving high scarps, and that these scarps may be migrating landward. Older borrow sites were seen to have filled in, and in some cases the sand ridge systems reformed.

- And more recently, Schwab et al., in "Modification of the Quaternary stratigraphic framework of the inner-continental shelf by Holocene marine transgression: An example offshore of Fire Island, New York", assert more firmly that the morphology of the inner-continental shelf region is the result of ongoing erosion of the Pleistocene glaciofluvial sediments. The outwash lobe is concluded to define a past Fire Island headland, east of which has eroded for the past 8,000 years providing material west of the lobe, in a sand wave formation. And finally that the comparison of the seafloor mapping between 1996-1997 and 2011 indicate that the nearshore sediment zone has received sediment at the expense of deflation of the sand waves.

38. In summary, more data is needed to quantify these processes, and then modeling is needed to more fully understand them. In order to have sufficient fill for Fire Island, it is impossible with the data currently existing to avoid use of the borrow areas on the ridges. However, steps shall be taken to select the lowest impact areas first, and use the lowest impact portions of that borrow area, collecting data before and after use, and repeatedly. This data can be used for quantification analyses and for modeling prior to the future renourishment cycles. The resulting recommended borrow source for western Fire Island is offshore Borrow Area 2C (the deepest borrow area on the sand ridges), and to dredge the deepest portion of the area for the initial operation. Use of Borrow Areas 1A, 2A, 2B, 2D, 2F, 2G, 3A, and 3B will be deferred until future renourishment operations, at which time, a better understanding of the sediment transport processes will have been gained through pre and post dredging monitoring of Borrow Area 2C.

28. **Borrow Area Monitoring.** Borrow areas 2B, 2C, and 2D have been proposed in the region with the largest sediment thicknesses contained in shore face connected sand ridges. USACE is looking at historic infilling between shore face attached sand ridges. The findings of the historic infilling study will be used for adaptive borrow area management to minimize impacts to the shoreline. Adaptive borrow area management practices include, but are not limited to: dredging in shallow lifts, managing the order that the ridge borrow areas are accessed during the project life, allowing further time in between operations of the borrow areas allow for infilling, minimizing the surface area impacted individual borrow areas. USACE welcomes further collaboration on future research from the community of coastal sedimentation scientists.

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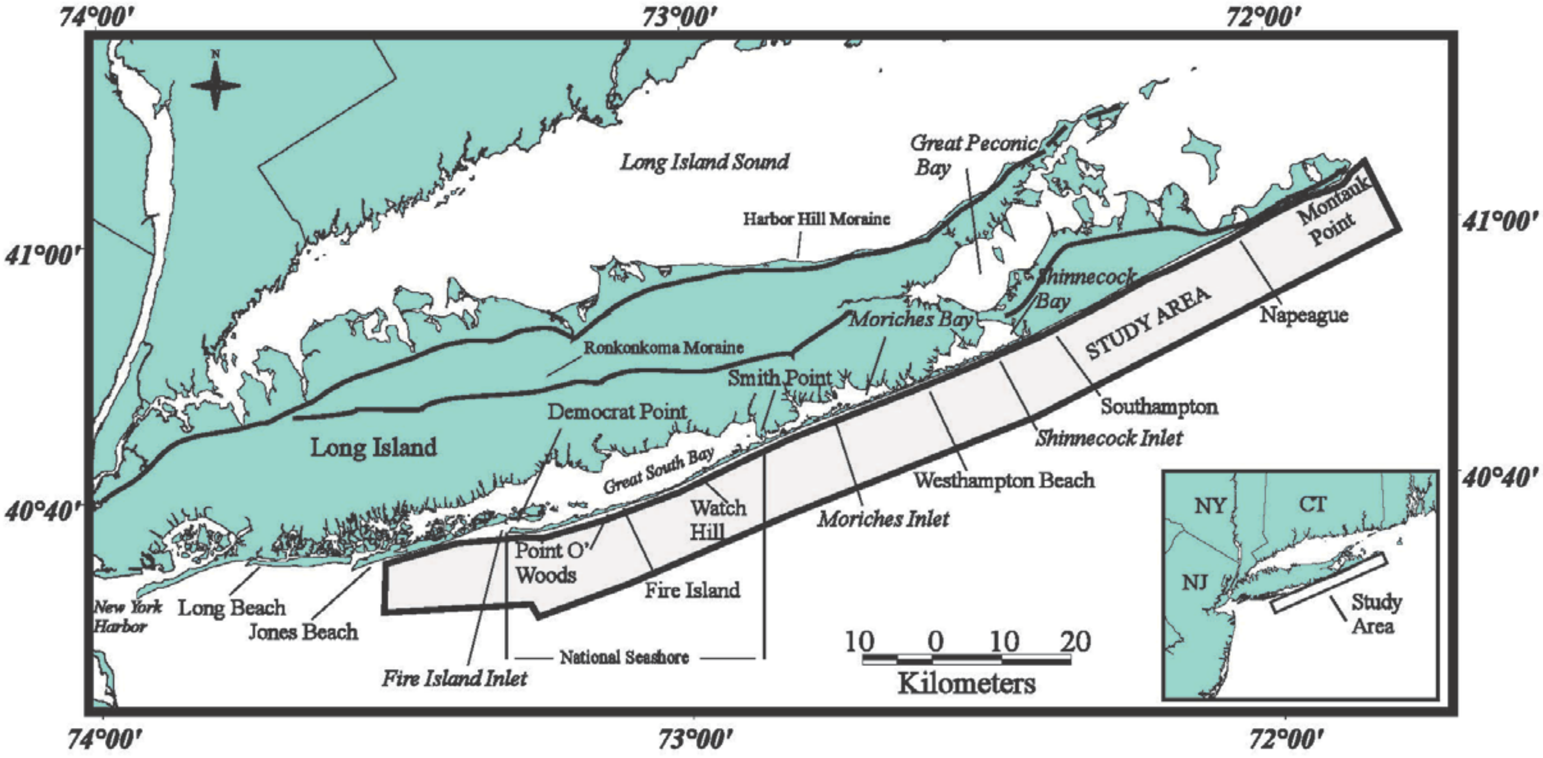


Figure1. Location figure showing the study area and location of late Pleistocene terminal moraines on Long Island, NY.

DRAFT

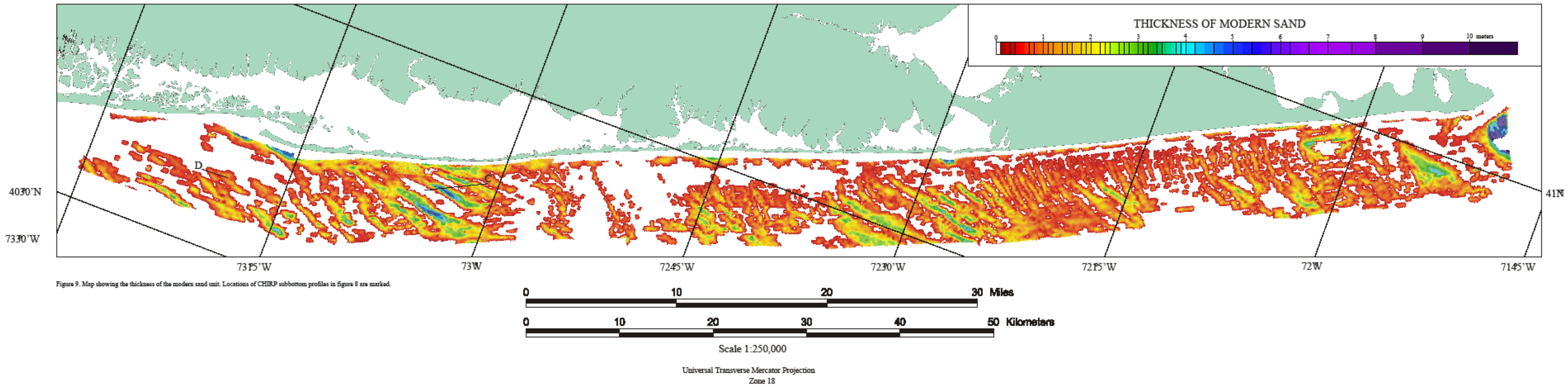
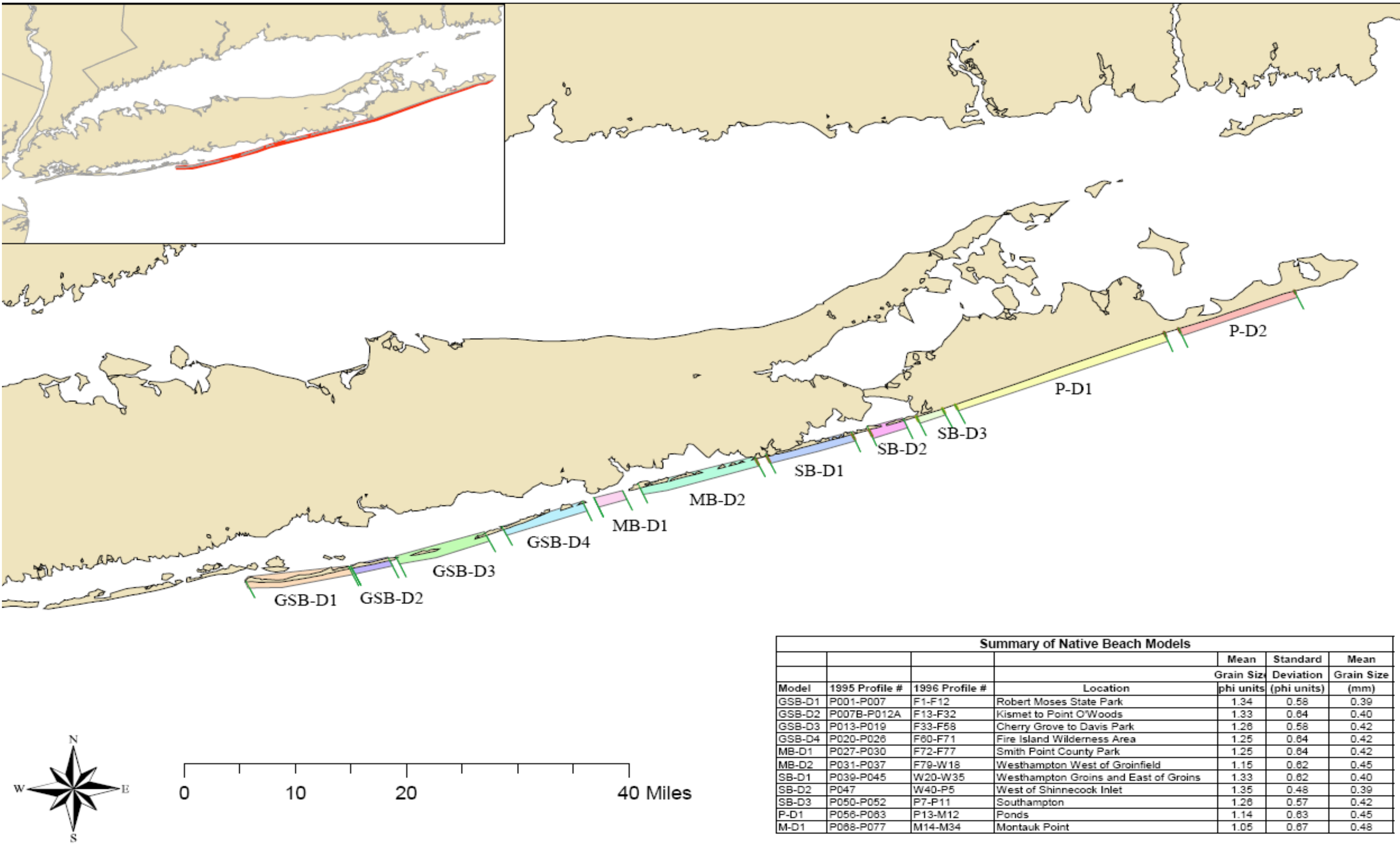


Figure 9. Map showing the thickness of the modern sand unit. Locations of CHIRP subbottom profiles in figure 8 are marked.

Figure 1

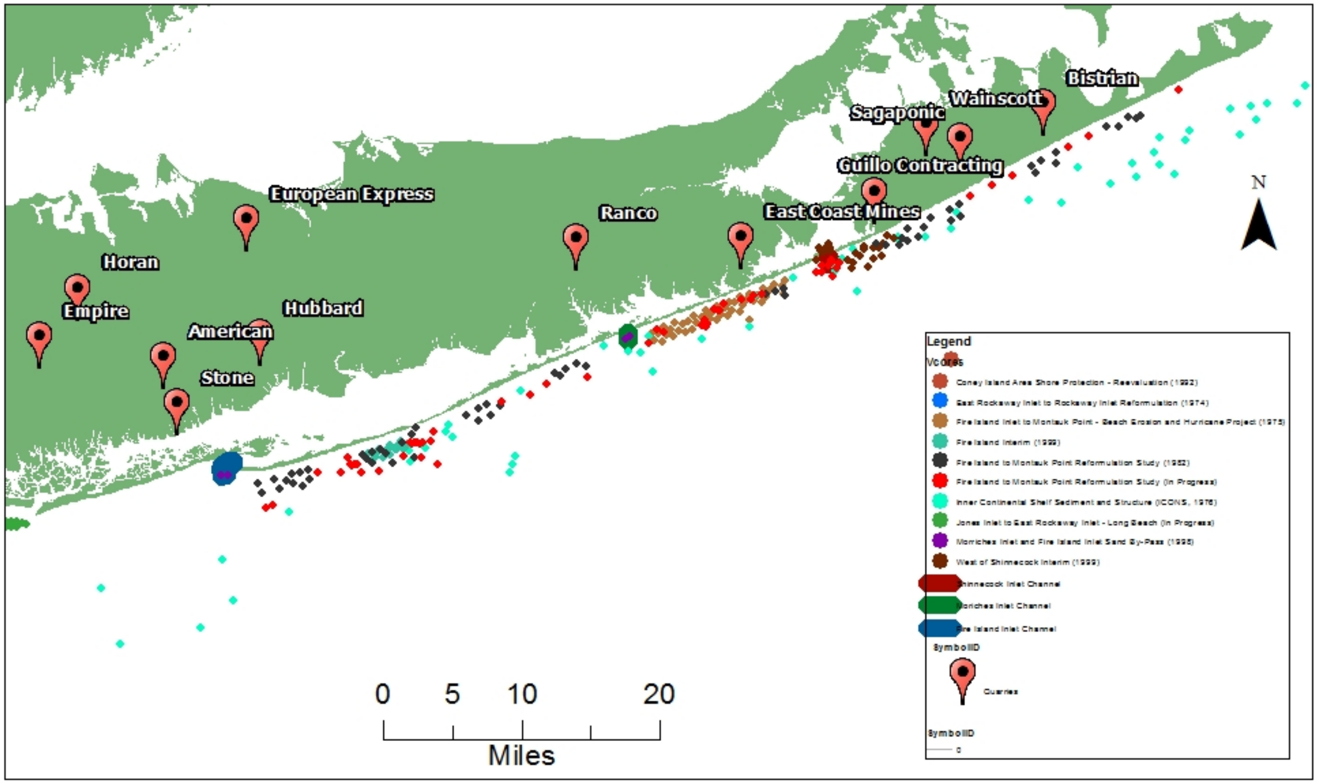
Map of Modern Sediment Thicknesses



Summary of Native Beach Models

				Mean	Standard	Mean
				Grain Size	Deviation	Grain Size
Model	1995 Profile #	1996 Profile #	Location	phi units	(phi units)	(mm)
GSB-D1	P001-P007	F1-F12	Robert Moses State Park	1.34	0.58	0.39
GSB-D2	P007B-P012A	F13-F32	Kismet to Point O'Woods	1.33	0.64	0.40
GSB-D3	P013-P019	F33-F58	Cherry Grove to Davis Park	1.26	0.58	0.42
GSB-D4	P020-P026	F60-F71	Fire Island Wilderness Area	1.25	0.64	0.42
MB-D1	P027-P030	F72-F77	Smith Point County Park	1.25	0.64	0.42
MB-D2	P031-P037	F79-W18	Westhampton West of Groinfield	1.15	0.62	0.45
SB-D1	P039-P045	W20-W35	Westhampton Groins and East of Groins	1.33	0.62	0.40
SB-D2	P047	W40-P5	West of Shinnecock Inlet	1.35	0.48	0.39
SB-D3	P050-P052	P7-P11	Southampton	1.26	0.57	0.42
P-D1	P056-P063	P13-M12	Ponds	1.14	0.63	0.45
M-D1	P068-P077	M14-M34	Montauk Point	1.05	0.67	0.48

Figure 2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Guillo Contracting
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Coney Island Area Shore Protection - Reevaluation (1992)
East Rockaway Inlet to Rockaway Inlet Reformulation (1974)
Fire Island Inlet to Montauk Point - Beach Erosion and Hurricane Project (1975)
Fire Island Interim (1999)
Fire Island to Montauk Point Reformulation Study (1982)
Fire Island to Montauk Point Reformulation Study (In Progress)
Inner Continental Shelf Sediment and Structure (ICONS, 1976)
Jones Inlet to East Rockaway Inlet - Long Beach (In Progress)
Moriches Inlet and Fire Island Inlet Sand By-Pass (1998)
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Figure 3

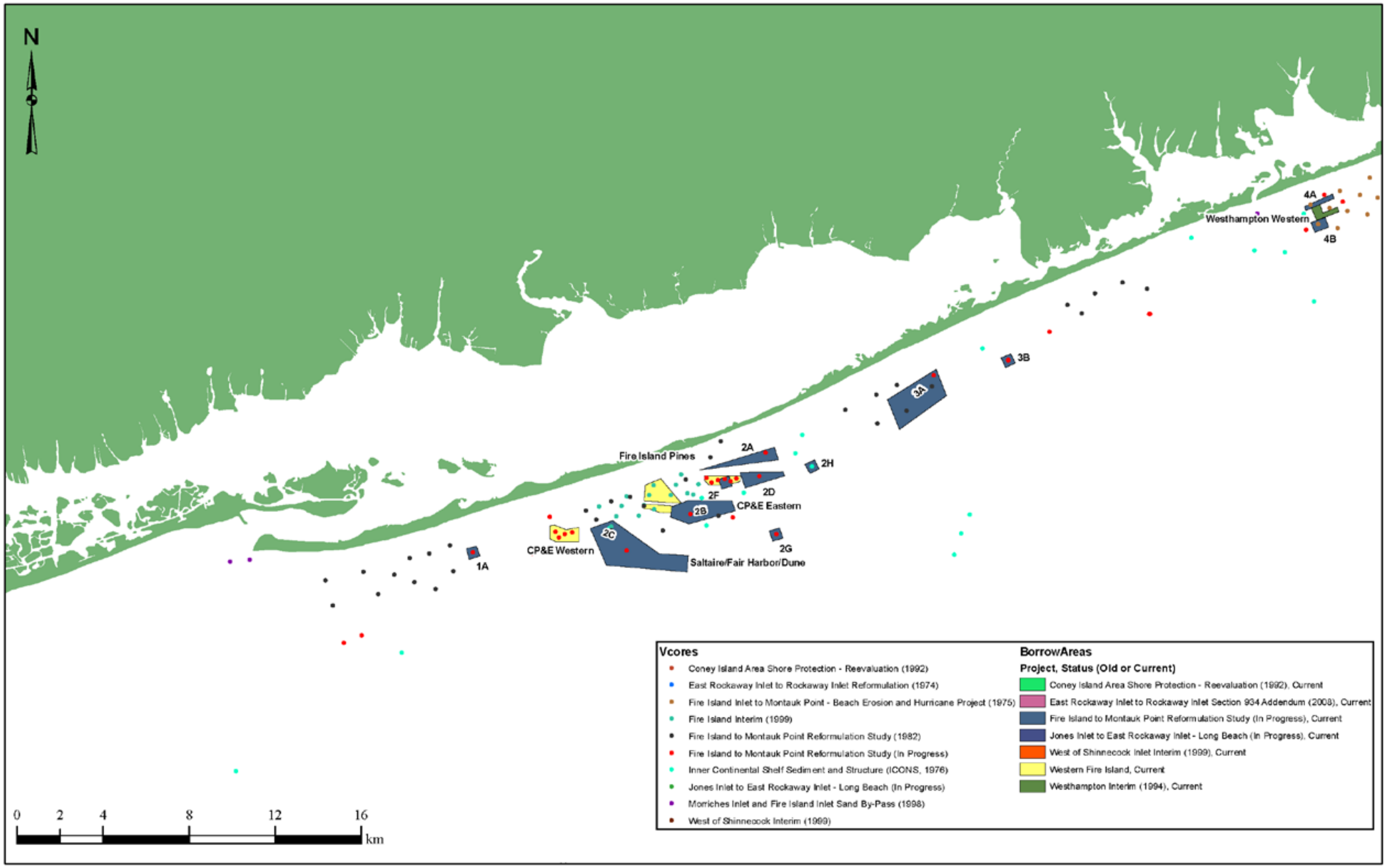

Figure 4 Active Borrow Sites for Fire Island

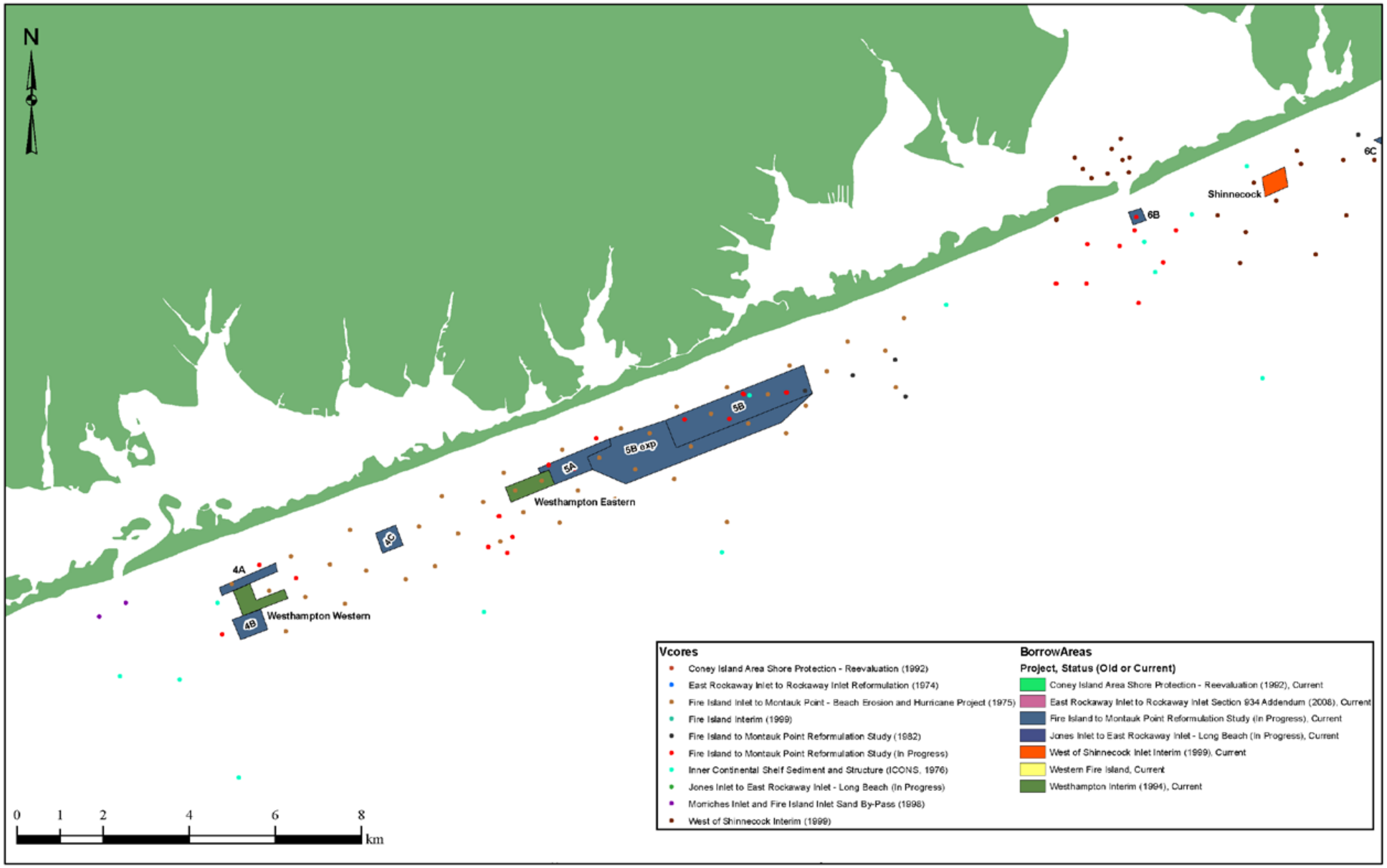

Figure 5: Active Borrow Sites for Westhampton

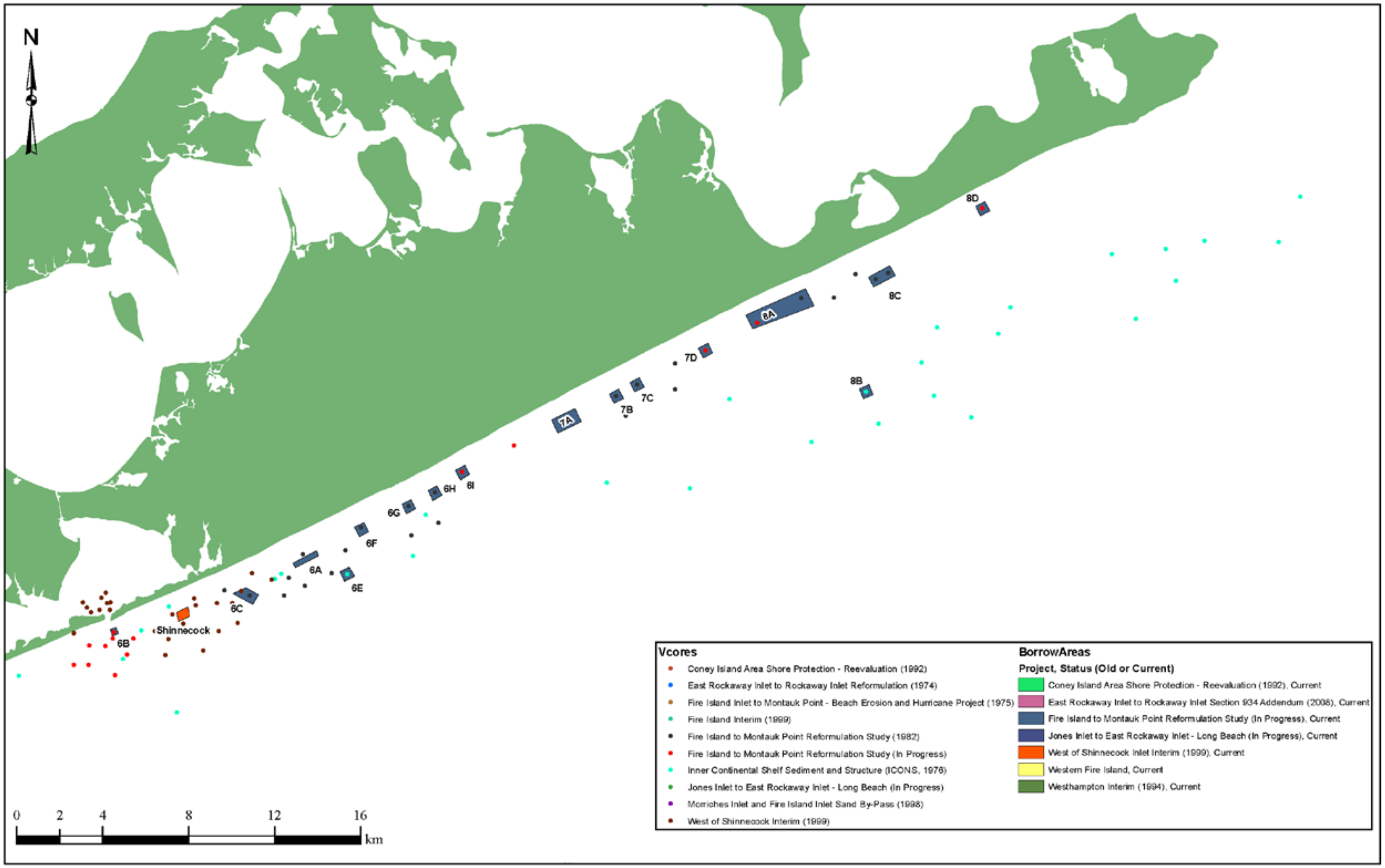

Figure 6: Active Borrow Sites for Montauk