NATIVE SEDIMENT CHARACTERISTICS OF NORTH CAROLINA BEACHES

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Introduction

The North Carolina oceanfront beach system varies in sedimentary characteristics, with the beaches in one part of the state often looking distinctly different than other beaches in the state. The characteristics of the beach sediments are an important engineering and ecological parameter for dredge and fill projects such as beach nourishment. No systematic survey and analysis of natural beach sediments has been performed to characterize the diversity of sediments of North Carolina beaches, requiring site-specific surveys and analyses for proposed dredge and fill projects.

The objectives of this study were to (1) determine the availability of sedimentary data for North Carolina oceanfront beaches; (2) compile the available data in a uniform format and database; (3) determine the variability of sedimentary characteristics within North Carolina; and (4) identify any variability of sedimentary characteristics between different regions within the state.

Methods

The technical literature available for sedimentary characterizations of North Carolina oceanfront beaches were reviewed and available data collated. The files of the Raleigh Ecological Services Field Office of the U.S. Fish and Wildlife Service (USFWS), Wilmington District of the U.S. Army Corps of Engineers (USACE), the Duck Field Research Facility of the USACE, North Carolina Department of Transportation (NC DOT) and North Carolina Division of Coastal Management (NC DCM) were also reviewed for sedimentary data. Data were also downloaded from the World Wide Web, specifically databases available from the Duck Field Research Facility of the USACE and the U.S. Geological Survey (USGS). Sedimentary data collected by the academic community were solicited and received from a variety of educational institutions.

The data were collected in both electronic and hard copy and include surveys from 1958 to 2002. All data were entered into an electronic spreadsheet database with the following parameters for each sample included (as available): location, station, sample number, elevation (in feet), distance from benchmark (in feet), geomorphic position, latitude, longitude, carbonate content (in percent), collection date, grain size distribution (percent retained on each sieve between 1.5 inches and 0.0625 millimeters), data source, and any comments on the sample data. The

spreadsheet was organized from north to south and includes data from the dune to 30 feet of water depth.

Some locations have been sampled on numerous occasions. Where multiple time periods of data were available for a specific location, the earliest occurrence of the largest dataset was selected for inclusion in the geographic database. For instance, if sedimentary data were collected on a profile at Bogue Banks, but the number of samples ranged from 1 to 17 on different collection dates, the earliest date with 17 sediment samples available in a dataset were selected. This maximized the data included to represent any given location and minimized any artificial disturbance of the sediments (assuming that beach fill, dredge disposal, and other manipulations of the beach have increased over time).

In order to compare the sedimentary characteristics of different locations, additional data fields for the percentage (by weight) of sediment within each grain size category (i.e., coarse sand, medium sand, fine sand on the Wentworth Classification scheme) were added. The grain size data varied by sieve sizes used for analysis, preventing direct comparisons of grain sizes for different sample sets. Table 1 identifies the sieve sizes summed to provide a percentage of each sediment sample within each grain size category.

Table 1. Sieve sizes and grain size ranges incorporated into summations of grain size categories, based on the Wentworth Classification scheme.

U.S. Standard Sieves	Size in millimeters (mm)	Phi Size	Grain Size Category
Greater than #10	Greater than 2 mm	Less than -1.00 ϕ	Coarser than 2 mm
#12 to #18	1.00 to 2.00 mm	- 0.75 to 0.00 ϕ	Very coarse sand
#20 to #35	0.50 to 1.00 mm	0.25 to 1.00 ϕ	Coarse sand
#40 to #60	0.25 to 0.50 mm	1.25 to 2.00 ϕ	Medium sand
#70 to #120	0.125 to 0.25 mm	2.25 to 3.00 ϕ	Fine sand
#140 to #230	0.0625 to 0.125 mm	3.25 to 4.00 ϕ	Very fine sand
Less than #230	Less than 0.0625 mm	Greater than 4.00 ϕ	Fines

Several assumptions were made in the compilation of the database. The first assumption is that all sediment sampling was conducted with accurate and unbiased methods. The sediment grain size analyses were assumed to be conducted with accurate and precise methods. Another assumption is that each sediment sample is representative of the environment in which it was taken. Next, it was assumed that sediment grain sizes determined to different degrees of accuracy are comparable (e.g., 0 to 3 decimal places). Sediment samples taken at different time periods are assumed to be geographically representative, and when multiple datasets are available for a given location the earliest occurrence of the largest dataset is assumed to be temporally

representative of each beach. Finally, the analysis assumes that no sediment samples included in the database are biased by beach fill, dredged material disposal or other artificial manipulation of the sediment source.

Statistical analyses of the data were performed utilizing the built-in software mathematical functions of QuattroPro 10 by Corel Corporation. The mean, median, standard deviation, variance, skewness and kurtosis of each grain size category were calculated in this manner. The minimum, maximum, and various percentiles of the data were also calculated.

The data available on carbonate content (shell material) includes both visual percentage and the percentage calculated by acid digestion. The sedimentary analysis assumes that these two methodologies are comparable. Where less than one percent carbonate content was listed, the value was rounded up to one percent so that quantitative analyses could be performed. The datasets for carbonate content are not necessarily the same as those used in the geographic database, and all statistical analyses were performed using a separate carbonate database that included all available carbonate data. Where more than one time period of carbonate content data were available, the earliest occurrence of the largest dataset were selected. For instance, carbonate content data were collected during both July and September 2002 on Emerald Isle beaches. Neither of these datasets were utilized in the geographic database since earlier surveys of native sediments were available for all of Bogue Banks. The July 2002 dataset was included in the carbonate database as it was the earlier of the two time periods.

Results

Sediment collection and grain size analyses methods were found to be non-uniform, with significantly different methodologies used by academia, government agencies and private entities. Sufficient data exist (N = 1500) to geographically characterize the native sediment characteristics of North Carolina beaches from Currituck to Ocean Isle.

Sufficient data also exist to temporally characterize the native sediment characteristics of North Carolina beaches on daily, weekly, monthly and yearly time scales. In total, over 3000 sediment samples exist when multiple time periods are incorporated. Some locations like Duck and other Bodie Island beaches, Bogue Banks, and Onslow Beach have been sampled numerous times. Data have been gathered on certain Bodie Island beaches daily for several weeks at a time. Other locations have been sampled every few months (e.g., Bogue Banks), while others have been systematically sampled every few years (e.g., Duck). This study did not evaluate the temporal variation of sedimentary characteristics but did collect the available data.

Sedimentary data from beaches that have received beach fill or dredge disposal material for long periods of time do not have native sediment data available. These locations include Wrightsville Beach and Carolina Beach, which frequently have received beach fill since the 1950s or 1960s.

No data were found for some beaches. Locations with no native sediment data include Brown's Island, Lea-Hutaff Island, Masonboro Island, Smith Island, Bald Head Island, and Sunset Beach.

Privately gathered data may exist for Masonboro and Bald Head Islands, but data sources were not identified in this study. In other locations such as Surf City on Topsail Island, data are currently being collected by the USACE but are not available as of this time (additional data will become available for Topsail Beach and North Topsail Beach through this USACE study as well).

Table 2 describes the sedimentary characteristics of North Carolina's oceanfront beaches. The statewide average beach sediment is predominantly medium to fine sand with 2.89 % gravel (> 2 mm; by weight), 2.05 % fines (silt and clay), and 5.79 % shell material (using the Wentworth Classification). The carbonate content of North Carolina beaches is highly variable, ranging from 0 to 99.00 % (Table 3). The mean carbonate content statewide is 5.79 %, and the median carbonate content is 2.00 %.

The data analysis identified some variation in sedimentary characteristics for different regions within North Carolina. The capes were utilized as boundaries to identify coastal regions or compartments, based on underlying geology characteristics and longshore sediment transport patterns (which generally do not cross the shoal systems associated with the capes). Tables 4 through 7 describe the sedimentary characteristics of the northern Outer Banks (Table 4), southern Outer Banks (Table 5), Onslow Bay (Table 6), and Brunswick County (Table 7).

The beaches of the northern Outer Banks (north of Cape Hatteras) are slightly coarser than the statewide average. On the other hand, Brunswick County beaches are finer grained than the statewide average. The average native sediments of Onslow Bay and the southern Outer Banks (Cape Hatteras to Cape Lookout) beaches are similar to the statewide averages.

Site-specific sedimentary characteristics are provided in Table 8. The majority (95 %) of native beach sediments contain less than or equal to 16.84 % coarse sediments (greater than 2 mm; Table 2). Portions of Kure Beach, North Topsail Beach, Topsail Beach, Onslow Beach, Bogue Banks, Shackleford Banks and Hatteras Island contain significant portions of gravel, though (numerous samples occurring in percentages greater than the 90th percentile). Kure Beach and Topsail Beach show coarser sediments with deeper water depth on the shoreface (> 18 ft). Onslow Beach exhibited concentrations of gravel material at both the mid-intertidal to mean low water area as well as at deeper water depths on the shoreface (> 20 ft). The presence of coarser materials in these locations probably reflect the underlying geology, which include hardbottoms near each of these beaches. Insufficient data are available at this time to evaluate this potential correlation at North Topsail Beach (available sediment samples are limited to elevations above wading depth, or approximately 3 feet of water) and Surf City, where hardbottoms also are known.

The distribution of fine sediments (less than 0.0625 mm in size) ranges from 0 to 98.6 % by weight of the sediment samples (Table 2). The majority of the sediment samples contain minimal levels of fines, however (Mode = 0 %). Almost all (95 %) of the native beach sediments in the state contain less than or equal to 7.72 % fine sediments (silt and clay). In addition, 90 % of the samples contain less than or equal to 4.00 % fines and 75 % contain less than or equal to 1.29 % fines. The sediment samples that contain a large proportion of fines are almost

exclusively from deeper water depths on the shoreface (12 to 30 ft) and are found at Onslow Beach and in Brunswick County. Concentrations of fines (those occurring in percentages greater than the 95th percentile) are not uniformly distributed across all deep water samples, however, and probably reflect the underlying geology which may contain outcroppings of mud or peat. Shallow water sediments are also subject to more reworking by wave energy as compared to the deeper waters, which winnows fines from the substrate more readily.

Discussion

The native sediments of North Carolina's oceanfront beaches have been characterized well over the last 50 years. While some data gaps still exist (e.g., Sunset Beach, Brown's Island), sedimentary analyses are ongoing (e.g., North Topsail Beach, Surf City, Topsail Beach) and the database of sedimentary characteristics will increase in the near future.

The scope of this study precluded an analysis of the temporal variation in native sediment characteristics of North Carolina beaches, but sufficient data exist at multiple locations to identify any patterns or trends in variation on several time scales.

The scientific characterization of native beach sediments in North Carolina is a valuable tool for both ecological and engineering applications. The macroinvertebrate benthic community of sandy beach ecosystems is sensitive to grain size and other sedimentary parameters (Alexander et al. (1993), Bowman and Dolan (1985), Donoghue (1999), Manning (2003), McLachlan et al. (1995), McArdle and McLachlan (1992), Peterson et al. (2001)). These macroinvertebrate species are an important link in the food web, providing the prey base for migratory shorebirds and surf zone fish. Adverse environmental impacts to the sandy beach ecosystem resulting from dredge and fill projects can thus be minimized by using fill material that is compatible with the native sedimentary characteristics of the project beach.

The results of this study indicate that, statewide, compatible beach fill material can be described. Using the 95th percentile of native sediment characteristics (Tables 2 and 3), compatible beach fill should contain an average of less than or equal to 16.84 % material (by weight) greater than 2 mm in size, less than or equal to 7.72 % fines, and less than or equal to 25.00 % carbonate material. Additional environmental protection may be provided by using the 90th percentile of native sediments, which would contain less than or equal to 5.89 % material greater than 2 mm in size, 4.00 % fines, and 15.00 % carbonate material. In some areas of high resource value, sufficient data often exist to utilize site specific sedimentary characteristics to further minimize ecological impacts (Table 8).

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Table 2. Statewide Native Sediment Characteristics
(using the Wentworth Classification)

	Coarser than 2 mm	*Very coarse sand*	*Coarse sand*	*Medium sand*	*Fine sand*	*Very fine sand*	*Fines*
Size range	2.0 mm - 1.5" 10 sieve + < -1.00 ϕ	1.0 - 2.0 mm sieves 12 - 18 -0.75 - 0.00 ϕ	0.5 - 1.0 mm sieves 20 - 35 0.25 - 1.00 ϕ	0.25 - 0.5 mm sieves 40 - 60 1.25 - 2.00 ϕ	0.125 - 0.25 mm sieves 70-120 2.25 - 3.00 ϕ	0.0625 - 0.125 mm sieves 140-230 3.25 - 4.00 ϕ	< 0.0625 mm < 230 sieve > 4.00 ϕ
Mean	2.89 %	2.32 %	8.26 %	34.39 %	39.38 %	11.87 %	2.05 %
Median	0.15 %	1.00 %	3.30 %	32.98 %	36.46 %	3.83 %	0.20 %
Mode	–	–	–	–	–	–	0 %
Variance	70.40	21.60	129.52	536.46	484.82	285.31	52.72
Standard Deviation	8.39	4.65	11.38	23.16	22.02	16.89	7.26
Minimum	0 %	0 %	0 %	0.10 %	0 %	0 %	0 %
Maximum	68.53 %	67.00 %	88.00 %	93.00 %	95.00 %	80.20 %	98.6 %
Skewness	4.74	5.89	2.45	0.22	0.37	1.71	8.33
Kurtosis	25.13	54.90	7.84	- 1.13	- 0.70	2.00	82.28
N	1500	1140[‡]	1391[§]	1500	1500	1500	1500

	Coarser than 2 mm	*Very coarse sand*[‡]	*Coarse sand*[§]	*Medium sand*	*Fine sand*	*Very fine sand*	*Fines*
Percentile[†]							
10	0	0	0	3.05 %	9.58 %	0	0
20	0	0	0.02 %	8.20 %	17.34 %	0.22 %	0
25	0	0	0.62 %	11.40 %	21.00 %	0.58 %	0
30	0	0	1.00 %	15.00 %	24.00 %	1.00 %	0
40	0	0	1.80 %	23.00 %	29.59 %	2.00 %	0.02 %
50	0.10 %	0.19 %	2.84 %	32.00 %	35.72 %	3.50 %	0.20 %
60	0.50 %	0.90 %	4.49 %	41.00 %	42.61 %	6.09 %	0.65 %
70	1.00 %	1.10 %	7.40 %	49.00 %	49.90 %	10.61 %	1.00 %
75	1.32 %	1.80 %	9.92 %	53.00 %	54.59 %	14.75%	1.29 %
80	2.00 %	2.00 %	12.59 %	57.04 %	59.78 %	21.06 %	1.90 %
90	5.89%	4.89 %	21.75 %	66.08 %	71.00 %	40.85 %	4.00 %
95	16.84%	8.06 %	30.00 %	72.68 %	78.88 %	50.96 %	7.72 %
100	68.53%	67.00 %	88.00 %	93.00%	95.00 %	80.20 %	98.60 %

[†] The percentiles are the proportion of the sediments less than or equal to a given weight percentage. For example, 90 % of the samples contain less than or equal to 5.89 % gravel (sediments coarser than 2 mm). Or 95% of the samples contain less than or equal to 7.72 % fines (silt and clay on the Wentworth Classification).

[‡]Note that the dataset for very coarse sand does not include some locations.

[§] Note that the dataset for coarse sand does not include some locations.

Table 3. Native Sediment Characteristics

Carbonate Content (using both visual and acid testing)

	Statewide[1]		*North OBX*[2]	*South OBX*[3]	*Onslow Bay*[4]	*Brunswick Co.*[5]
Mean	5.79 %		0.69 %	5.41 %	7.83 %	2.67 %
Median	2.00 %		0.26 %	2.00 %	2.00 %	1.00 %
Variance	122.48		0.64	72.62	203.22	8.48
Standard Deviation	11.07		0.80	8.52	14.26	2.91
Minimum	0 %		0 %	0 %	0 %	0 %
Maximum	99.00 %		2.50 %	54.60 %	99.00 %	14.00 %
Skewness	4.53		0.80	2.82	3.92	2.07
Kurtosis	27.58		- 0.74	9.91	18.70	4.57
N	548		47	201	243	57
75 % Percentile	15.04 %		1.30 %	6.00 %	10.00 %	4.00 %
90 % Percentile	15.00 %		1.86 %	15.00 %	20.00 %	6.40 %
95 % Percentile	25.00 %		2.18 %	25.00 %	30.00 %	8.20 %

[1] Data used for these statistics do not include many areas where data are unavailable. Published literature (N = 17) indicate an average carbonate content of 3.43 % for North Carolina beaches. [2] Data are from Duck and Kitty Hawk only. [3] Note that sampling techniques may have biased the data to underestimate the carbonate content; some data sources note purposefully excluding surface shell hash from the samples (e.g., brushing the surface shell away before taking the sample). [4] Data are from Shackleford Banks, Bogue Banks, Onslow Beach and Topsail Beach only, and most are from Onslow Beach. [5] Data are from Ocean Isle only.

Table 4. Northern Outer Banks Native Sediment Characteristics

North of Cape Hatteras

(using the Wentworth Classification)

	Coarser than 2 mm	*Very coarse sand*	*Coarse sand*	*Medium sand*	*Fine sand*	*Very fine sand*	*Fines*
Size range	2.0 mm - 1.5" 10 sieve + < -1.00 ϕ	1.0 - 2.0 mm sieves 12 - 18 -0.75 - 0.00 ϕ	0.5 - 1.0 mm sieves 20 - 35 0.25 - 1.00 ϕ	0.25 - 0.5 mm sieves 40 - 60 1.25 - 2.00 ϕ	0.125 - 0.25 mm sieves 70-120 2.25 - 3.00 ϕ	0.0625 - 0.125 mm sieves 140-230 3.25 - 4.00 ϕ	< 0.0625 mm < 230 sieve > 4.00 ϕ
Mean	0.88 %	3.31 %	13.11 %	48.18 %	30.57 %	3.79 %	0.16 %
Median	0 %	1.04 %	6.57 %	50.00 %	28.00 %	1.00 %	0 %
Variance	13.14	202.55	202.55	356.20	308.19	43.60	0.45
Standard Deviation	3.62	14.23	14.23	18.87	17.56	6.60	0.67
Minimum	0 %	0 %	0 %	7.00 %	0 %	0 %	0 %
Maximum	41.00 %	67.00 %	65.49 %	93.00 %	77.00 %	34.00 %	6.00 %
Skewness	7.38	1.45	1.45	- 0.24	0.51	2.59	5.85
Kurtosis	63.57	1.72	1.72	- 0.74	- 0.51	6.84	38.53
N	326	326	326	326	326	326	326

	Coarser than 2 mm	*Very coarse sand*	*Coarse sand*	*Medium sand*	*Fine sand*	*Very fine sand*	*Fines*
Percentile†							
10	0	0	0	12.00 %	4.00 %	0	0
20	0	0	1.58 %	26.39 %	12.19 %	0	0
25	0	0	2.00 %	30.46 %	14.83 %	0	0
30	0	0.55 %	3.00 %	33.91 %	16.05 %	0	0
40	0	1.00 %	4.00 %	42.00 %	21.00 %	0	0
50	0	1.00 %	5.24 %	48.16 %	26.80 %	1.00 %	0
60	0	2.00 %	9.65 %	54.00 %	31. 80 %	1.00 %	0
70	0	2.00 %	16.30 %	59.00 %	36.00 %	3.00 %	0
75	0	3.00 %	19.02 %	61.02 %	40.75 %	4.00 %	0
80	1.00 %	3.65 %	23.20 %	64.88 %	46.74 %	5.00 %	0
90	1.00 %	7.00 %	33.60 %	72.00 %	56.00 %	11.00 %	0
95	3.00 %	12.85 %	40.53 %	75.57 %	61.00 %	18.00 %	1.00 %
100	41.00 %	67.00 %	65.49 %	93.00 %	77.00 %	34.00 %	6.00 %

† The percentiles are the proportion of the sediments less than or equal to a given weight percentage. For example, 90 % of the samples contain less than or equal to 1.00 % gravel (sediments coarser than 2 mm). Or 95% of the samples contain less than or equal to 1.00 % fines (silt and clay on the Wentworth Classification).

Table 5. Southern Outer Banks Native Sediment Characteristics

Cape Lookout to Cape Hatteras

(using the Wentworth Classification)

	Coarser than 2 mm	*Very coarse sand*	*Coarse sand*	*Medium sand*	*Fine sand*	*Very fine sand*	*Fines*
Size range	2.0 mm - 1.5" 10 sieve + < -1.00 ϕ	1.0 - 2.0 mm sieves 12 - 18 -0.75 - 0.00 ϕ	0.5 - 1.0 mm sieves 20 - 35 0.25 - 1.00 ϕ	0.25 - 0.5 mm sieves 40 - 60 1.25 - 2.00 ϕ	0.125 - 0.25 mm sieves 70-120 2.25 - 3.00 ϕ	0.0625 - 0.125 mm sieves 140-230 3.25 - 4.00 ϕ	< 0.0625 mm < 230 sieve > 4.00 ϕ
Mean	0‡	0.80 %	10.46 %	28.88 %	52.60 %	7.10 %	0.16 %
Median	0	0 %	4.00 %	27.00 %	56.00 %	1.00 %	0 %
Variance	–	6.55	227.87	357.42	527.12	191.88	0.35
Standard Deviation	–	2.56	15.10	18.91	22.96	13.85	0.60
Minimum	0	0	0	1.00 %	0	0	0
Maximum	0	16.00 %	88.00 %	82.00 %	95.00 %	77.00 %	4.00 %
Skewness	–	4.13	2.42	0.60	- 0.39	2.89	4.29
Kurtosis	–	17.30	7.00	- 0.34	- 0.81	9.11	19.20
N	201	201	201	201	201	201	201

	Coarser than 2 mm	*Very coarse sand*	*Coarse sand*	*Medium sand*	*Fine sand*	*Very fine sand*	*Fines*
Percentile[†]							
10	0 [‡]	0	0	5.00 %	16.00 %	0	0
20	0	0	1.00 %	10.90 %	29.00 %	0	0
25	0	0	1.00 %	13.00 %	32.00 %	0	0
30	0	0	2.00 %	14.60 %	37.20 %	0	0
40	0	0	3.00 %	19.00 %	48.00 %	0	0
50	0	0	4.00 %	26.00 %	56.00 %	1.00 %	0
60	0	0	6.00 %	32.00 %	62.00 %	2.00 %	0
70	0	0	9.00 %	36.90 %	68.00 %	5.00 %	0
75	0	0	11.00 %	41.00 %	70.00 %	6.50 %	0
80	0	0	17.20 %	45.30 %	73.20 %	8.30 %	0
90	0	2.00 %	29.60 %	54.80 %	79.60 %	23.60 %	0
95	0	4.80 %	42.80 %	63.40 %	84.80 %	35.00 %	1.00 %
100	0	16.00 %	88.00 %	82.00 %	95.00 %	77.00 %	4.00 %

[†] The percentiles are the proportion of the sediments less than or equal to a given weight percentage. For example, 95 % of the samples contain less than or equal to 1.00 % fines (silt and clay on the Wentworth Classification).

[‡] Note that sampling techniques may have biased the data to exclude coarser materials such as shell hash; some data sources note purposefully excluding surface shell hash from the samples (e.g., brushing the surface shell away before taking the sample).

Table 6. Onslow Bay Native Sediment Characteristics

(using the Wentworth Classification)

	Coarser than 2 mm	*Very coarse sand*	*Coarse sand*	*Medium sand*	*Fine sand*	*Very fine sand*	*Fines*
Size range	2.0 mm - 1.5" 10 sieve + < -1.00 ϕ	1.0 - 2.0 mm sieves 12 - 18 -0.75 - 0.00 ϕ	0.5 - 1.0 mm sieves 20 - 35 0.25 - 1.00 ϕ	0.25 - 0.5 mm sieves 40 - 60 1.25 - 2.00 ϕ	0.125 - 0.25 mm sieves 70-120 2.25 - 3.00 ϕ	0.0625 - 0.125 mm sieves 140-230 3.25 - 4.00 ϕ	< 0.0625 mm < 230 sieve > 4.00 ϕ
Mean	5.86 %	2.34 %	7.08 %	27.84 %	42.17 %	12.30 %	2.83 %
Median	1.00 %	0.92 %	3.51 %	24.48 %	40.14 %	3.97 %	0.90 %
Variance	144.61	13.69	69.92	492.75	532.37	269.22	65.41
Standard Deviation	12.03	3.70	8.34	22.20	23.07	16.41	8.09
Minimum	0 %	0 %	0 %	0.20 %	0 %	0 %	0 %
Maximum	68.53 %	33.93 %	67.00 %	89.00 %	92.11 %	78.00 %	80.26 %
Skewness	3.06	3.57	2.06	0.46	0.22	1.52	6.43
Kurtosis	9.56	19.20	6.92	- 1.00	- 0.84	1.28	47.94
N	620	507[§]	620	620	620	620	620

	Coarser than 2 mm	*Very coarse sand*[§]	*Coarse sand*	*Medium sand*	*Fine sand*	*Very fine sand*	*Fines*
Percentile[†]							
10	0	0.02 %	0.10 %	1.90 %	10.23 %	0.26 %	0.01 %
20	0.06 %	0.13 %	0.77 %	4.32 %	19.81 %	0.58 %	0.03 %
25	0.10 %	0.20 %	1.00 %	6.01 %	22.87 %	0.82 %	0.04 %
30	0.20 %	0.31 %	1.27 %	8.15 %	26.68 %	1.10 %	0.07 %
40	0.50 %	0.56 %	2.07 %	14.76 %	33.23 %	2.10 %	0.30 %
50	1.00 %	0.90 %	3.25 %	23.19 %	39.36 %	3.73 %	0.85 %
60	1.75 %	1.34 %	5.59 %	32.05 %	46.37 %	6.74 %	1.10 %
70	3.61 %	2.11 %	9.00 %	41.44 %	55.30 %	13.42 %	1.65 %
75	4.53 %	2.81 %	10.90 %	45.79 %	59.95 %	17.61 %	2.00 %
80	6.71 %	3.80 %	13.05 %	51.16 %	64.21 %	22.89 %	2.70 %
90	17.76 %	6.38 %	17.77 %	60.07 %	74.73 %	40.49 %	5.73 %
95	31.63 %	9.66 %	23.05 %	65.01 %	81.65 %	49.18 %	10.62 %
100	68.53 %	33.93 %	67.00 %	89.00 %	92.11 %	78.00 %	80.26 %

[†] The percentiles are the proportion of the sediments less than or equal to a given weight percentage. For example, 90 % of the samples contain less than or equal to 17.76 % gravel (sediments coarser than 2 mm). Or 95% of the samples contain less than or equal to 10.62 % fines (silt and clay on the Wentworth Classification).

[§] Note that the very coarse sand dataset does not include data for Topsail Beach, Figure 8 Island, or Kure Beach.

Table 7. Brunswick County Native Sediment Characteristics

(using the Wentworth Classification)

	Coarser than 2 mm	*Very coarse sand*	*Coarse sand*	*Medium sand*	*Fine sand*	*Very fine sand*	*Fines*
Size range	2.0 mm - 1.5" 10 sieve + < -1.00 ϕ	1.0 - 2.0 mm sieves 12 - 18 -0.75 - 0.00 ϕ	0.5 - 1.0 mm sieves 20 - 35 0.25 - 1.00 ϕ	0.25 - 0.5 mm sieves 40 - 60 1.25 - 2.00 ϕ	0.125 - 0.25 mm sieves 70-120 2.25 - 3.00 ϕ	0.0625 - 0.125 mm sieves 140-230 3.25 - 4.00 ϕ	< 0.0625 mm < 230 sieve > 4.00 ϕ
Mean	1.17 %	2.08 %	2.86 %	36.28 %	35.10 %	21.28 %	3.50 %
Median	0.30 %	1.00 %	1.05 %	33.00 %	33.00 %	10.90 %	1.00 %
Variance	6.32	7.41	36.74	613.38	340.59	429.64	100.31
Standard Deviation	2.51	2.72	6.06	24.77	18.46	20.73	10.02
Minimum	0 %	0 %	0 %	0.10 %	0.20 %	0 %	0 %
Maximum	20.90 %	14.00 %	59.89 %	87.90 %	86.30 %	80.20 %	98.60 %
Skewness	4.61	–	5.82	0.23	0.60	0.87	6.91
Kurtosis	25.36	–	44.51	-1.32	0.09	- 0.57	54.12
N	353	106[§]	252[‡]	353	353	353	353

	Coarser than 2 mm	*Very coarse sand*[§]	*Coarse sand* [‡]	*Medium sand*	*Fine sand*	*Very fine sand*	*Fines*
Percentile[†]							
10	0	0	0	5.70 %	12.78 %	1.50 %	0.20 %
20	0	0	0	10.02 %	19.00 %	3.62 %	0.30 %
25	0	1.00 %	0	12.50 %	21.00 %	4.50 %	0.50 %
30	0.02 %	1.00 %	0	15.84 %	23.88 %	5.26 %	0.60 %
40	0.10 %	1.00 %	0.01 %	21.08 %	27.09 %	7.44 %	0.77 %
50	0.30 %	1.00 %	0.33 %	32.50 %	32.68 %	10.70 %	1.00 %
60	0.70 %	1.56 %	0.80 %	44.78 %	39.09 %	19.33 %	1.21 %
70	1.00 %	2.00 %	1.50 %	52.56 %	43.00 %	29.70 %	2.00 %
75	1.00 %	2.00 %	1.80 %	58.00 %	46.00 %	38.65 %	2.70 %
80	1.40 %	2.00 %	2.30 %	63.23 %	48.84 %	44.05 %	3.60 %
90	2.50 %	4.78 %	5.14 %	71.18 %	59.82 %	54.54 %	6.38 %
95	4.60 %	9.00 %	7.96 %	75.00 %	73.50 %	60.45 %	11.38 %
100	20.90 %	14.00 %	59.89 %	87.90 %	86.30 %	80.20 %	98.60 %

[†] The percentiles are the proportion of the sediments less than or equal to a given weight percentage. For example, 95 % of the samples contain less than or equal to 4.60 % gravel (sediments coarser than 2 mm). Or 90 % of the samples contain less than or equal to 6.38 % fines (silt and clay on the Wentworth Classification).

[§] Note that the dataset for very coarse sand only includes data for Holden Beach.

[‡] Note that the dataset for coarse sand does not include data for Holden Beach.

Table 8. Site-specific sedimentary characteristics for the native beach sediments for various locations in North Carolina. The mean weight percent of gravel (sediments exceeding 2 mm in size) and fines (silt and clay, or sediments smaller than 0.0625 mm) are given, as is the dominant sand size. Based on the Wentworth Classification system for sediment grain size. Where data are available, the mean shell content is also listed.

Location	Sample Date	Data Source(s)	No. of Samples	Gravel (> 2 mm)	Dominant Sand Size	Fines (< 0.0625 mm)	Shell Content
Currituck County	1973	USACE	16	0	medium	0	
Duck	1976	USACE	17	0	medium	0	0.24 % (N = 500)[1]
Southern Shores to Nags Head	1976, 1978	USACE	65	0	medium	0	1.54 % (N = 18)[2]
Bodie Island, Cape Hatteras NS	1976	USACE	16	0	medium	0	
Pea Island NWR	1973	USACE	5	0	medium	0	
Hatteras Island	1973, 2002	USACE, NC DOT	207	1.39 %	medium	0.25 %	
Ocracoke Island	1958	USACE	113	0	fine	0.22 %	4.12 % (N = 113)[3]
Portsmouth Island	1961	USACE	35	0	fine	0.04 %	3.28 % (N = 35)[3]
South Core Banks	1961	USACE	45	0	fine	0.12 %	10.07 % (N = 45)[3]
Cape Lookout	1961	USACE	8	0	fine	0	6.70 % (N = 8)[3]

Shackleford Banks	1997	UNC-CH	12	7.80 %	medium	0	22.27 % (N = 12)
Bogue Banks	1972, 1998	USACE, UNC-CH, CSA*i*	251	4.89 %	medium to fine	0.59 %	12.41 % (N = 83)[4]
Bear Island	2002	UNC-CH	28	0.25 %	fine	0.03 %	
Onslow Beach	2000	USACE	186	4.48 %	fine	7.57 %	
North Topsail Beach	1999	UNC-CH	30	29.66 %	medium	0.05 %	
Topsail Beach	1985	USACE	42	6.31 %	fine	1.67 %	23.25 % (N = 4)
Figure 8 Island	1990	Literature	8	0.02 %	fine	0.88 %	
Kure Beach	1991	USACE	63	5.05 %	medium	1.93 %	
Caswell Beach - Oak Island	1999	USACE	180	1.69 %	medium to fine	4.40 %	
Holden Beach	1973, 1998	USACE	106	0.79 %	medium	2.52 %	
Ocean Isle	1994, 2001	USACE, ATM, Inc.	67	0.36 %	fine	2.63 %	

[1] Carbonate data are from 1984-85 from the Duck Field Research Facility of the USACE. [2] Carbonate data are from a 2003 NC DOT dataset for Kitty Hawk only. [3] Note that sampling techniques may have biased the data to underestimate carbonate content; some data sources note purposefully excluding surface shell hash from the samples (e.g., brushing the surface shell away before taking the sample). [4] Data are from 2002 from UNC-CH.

Data sources: USACE: U.S. Army Corps of Engineers; NC DOT: North Carolina Department of Transportation; UNC-CH: University of North Carolina at Chapel Hill, Institute of Marine Sciences; CSA*i*: Coastal Science Associates, Inc.; ATM, Inc.: Applied Technology & Management, Inc.