APPENDIX C

Biological Survey

(Versar 2006)

Final Draft Report
GSA Contract No. GS-OOF-00071

YEAR ONE PRE-CONSTRUCTION ENVIRONMENTAL MONITORING FOR THE DARE COUNTY BEACH SHORELINE PROTECTION PROJECT, DARE COUNTY, NORTH CAROLINA

Prepared for

Frank Yelverton
U.S. Army Corps of Engineers
Wilmington District
P.O. Box 1890
Wilmington, NC 28402-1890

Prepared by

H. Ward Slacum Jr.
Jodi Dew
Lisa Scott
Ed Weber

Versar, Inc.
9200 Rumsey Road
Columbia, Maryland 21045

Prepared Under the Supervision of

____
William H. Burton
Program Manager

January 2006

ACKNOWLEDGEMENTS

There were many people who were essential throughout the first year of pre-construction monitoring. First and foremost, we thank David Wong of Versar for his above and beyond commitment during the first year. We also acknowledge the efforts of Abigail Porter who conducted the bird and creel surveys during the first year. We are grateful to Joe and Charles Wilson of Oregon Inlet Sea Tow for their insight and support of the fisheries sampling. We also thank all the Versar field staff members who contributed to this effort and the numerous crewmembers who assisted Sea Tow Oregon Inlet during the fisheries sampling activities. Thanks are also extended to Dr. Bob Diaz and Christina Tallent for their assistance in conducting the underwater video survey.

EXECUTIVE SUMMARY

Erosion along the Outer Banks has degraded public beaches and significantly damaged or destroyed both public and private properties. In particular, several beaches in Dare County, including the beaches of Nags Head, Kill Devil Hills, and Kitty Hawk have been severely eroded and are still rapidly eroding, raising concerns by the Dare County local government. To address this problem the Wilmington District of the U. S. Army Corps of Engineers (USACE) conducted an investigation reviewing several alternative protection measures for Dare County Beaches and property. Findings from that study concluded that the most practical plan of protection in the primary study area was a beach and shoreline protection project that would construct a primary sand dune and extend the beach seaward 15 m using sand from several offshore borrow sites located within three miles of the beach. However, the processes associated with beach nourishment can have negative impacts to biological communities. To address this concern, a five-year monitoring plan was designed to assess any impacts associated with the beach nourishment process. The biological monitoring plan recommends two years of pre-construction monitoring of biological resources. This report presents the first year of pre-construction monitoring.

Beginning in the spring of 2004, the fish, benthic, bird, and ghost crab communities at two beaches, and the fish and benthic communities at two offshore ocean sites, were monitored seasonally for one year. In addition, a roving creel survey was also implemented to monitor recreational fisherman activity at the beaches. Beach nourishment processes will impact one of the beaches and one of the ocean sites and the other sites are used as reference sites. The first year of pre-construction monitoring indicates significant temporal and spatial scale fluctuations in many of the biological recourses monitored. The beaches were characterized with low benthic diversity and high fish diversity. In contrast, the borrow site and borrow reference site exhibited high benthic community diversity and very low fish diversity and abundance. Bird use between the beaches was similar and bird diversity was low. Recreational fishing activity along the beaches was highest in the summer and fall and lowest in winter. The most commonly caught species were spot, bluefish, spotted sea trout, kingfish, and flounder. These results are consistent with other studies reported within the region.

The program is now three seasons into the second year of pre-construction monitoring in a continuing effort to characterize temporal and spatial baseline conditions at the project site. These data will be used to assess beach replenishment impacts and recovery as the program moves into construction and post-construction monitoring periods.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

Figure **Page**

LIST OF FIGURES

Figure **Page**

1.0 INTRODUCTION

The Outer Banks of North Carolina are just some of the nearly 300 barrier island systems along the East and Gulf Coasts of the United States that are experiencing long-term erosion due to sea level rise, increasing frequency and intensity of coastal storms, and other natural processes. Erosion along the Outer Banks has degraded public beaches and significantly damaged or destroyed both public and private properties. In particular, several beaches in Dare County, including the beaches of Nags Head, Kill Devil Hills, and Kitty Hawk have been severely eroded and are still rapidly eroding. Because of concerns raised by the Dare County local government, the United States House of Representatives adopted a resolution in 1990 requesting the Secretary of the Army to investigate hurricane and shore erosion protection measures for a portion of Dare County beaches. The Wilmington District of the U. S. Army Corps of Engineers (USACE) conducted the investigation and based upon an evaluation of several alternative protection measures, concluded that the most practical plan of protection in the primary study area was a beach and shoreline protection project (Feasibility Report 1999).

Beach and shoreline protection projects, also known as beach nourishment projects, generally build a beach seaward by pumping sand onto the beach from offshore sand resources. The recommended plan of improvement on the Dare County beaches is to construct a primary sand dune and extend the beach seaward 15 m using sand from several offshore borrow sites located within three miles of the beach. Based on the recommendation of the Feasibility Report (1999), two stretches of beach were identified as candidates for beach nourishment in Dare County, one in the Southern extent of the project limits and one to the North. Initial construction will entail placement of approximately 8,000,000 cubic yards of sand in the South Project Area, and 4,300,000 cubic yards in the North Project Area, for a total volume of 12,300,000 cubic yards. The construction phase is scheduled to begin in early 2006 for both the North Project Area, and the middle segment of the South Project Area.

The nourishment of these beaches is expected to protect and reduce damages associated with hurricane and storm events and beach erosion. Nourishment is also expected to enhance the overall value of the beaches by increasing the area available for recreation. However, the processes associated with beach nourishment can have negative impacts to biological communities and concerns were raised regarding to what extent the nourishment process may impact local biological resources.

In September 2000 the Final Impact Statement (FEIS) for the proposed beach nourishment project was completed. The findings of that document suggest that the project areas may provide high quality habitat to number of marine and terrestrial organisms and therefore impacts from long-term sand placement and sand dredging offshore could be detrimental to those resources. In recognition of this, the USACE made a commitment to develop an integrated a pre and post monitoring plan designed to "*demonstrate reasonable indication of expected recovery of benthic food sources in the borrow area and to identify any unforeseen significant impacts to biological resources residing in the borrow and beach placement areas*." The USACE also recognized the value of several years of pre and post monitoring and committed to a 5-year study. In addition, to ensure that two years of pre-monitoring could be completed it was recommended that all monitoring take place in the Northern Project, which is the last beach scheduled for nourishment.

To assist in the development of a comprehensive monitoring plan, the Wilmington District of the USACE contracted Versar, Inc in July 2003. Based upon previous experience and rigorous scientific protocol, a comprehensive monitoring plan was developed encompassing the following four major monitoring elements outlined below:

- Biological monitoring of the North Project Beach, inclusive of fisheries, benthic, and ghost crab surveys
- Biological monitoring of the N1/N2 borrow site, inclusive of fisheries, benthic, and underwater video surveys
- Shorebird monitoring on the subject and reference beach
- Recreational fishing surveys on the subject and reference beach

After the monitoring plan was completed and accepted, Versar, Inc was also contracted to implement the monitoring plan. This report summarizes the first full year of pre-construction biological monitoring of the beach and borrow sites scheduled for beach nourishment in the Northern Project area of Dare County, North Carolina.

2.0 MATERIALS AND METHODS

2.1 STUDY DESIGN

Beginning in the spring of 2004 we sampled two beaches and two offshore ocean sites seasonally for one year (Figure 2-1). Seasonal sampling was conducted during the spring (May-June), summer (July-September), fall (October-December), and winter (January-April). The sampling design consists of monitoring a beach, hereafter referred to as the "Impact Beach", and borrow site scheduled to be impacted by beach nourishment. In addition, a reference site of similar habitat was also chosen and monitored for the impact beach and borrow site. Monitoring will be conducted two years prior to beach nourishment, during the nourishment process, and two years post nourishment for a total of five years of monitoring. The monitoring program consists of sampling the densities of fish, benthos, ghost crabs, and birds at the beaches and only fish and benthos densities are monitored at the ocean sites. In addition, a creel survey is conducted at the beaches to monitor fisherman activity and fishing effort. A detailed description of the entire monitoring plan can be viewed at the following internet link: http://www.saw.usace.army.mil/Dare%20County/Finalmonitoringplan2_03.pdf.

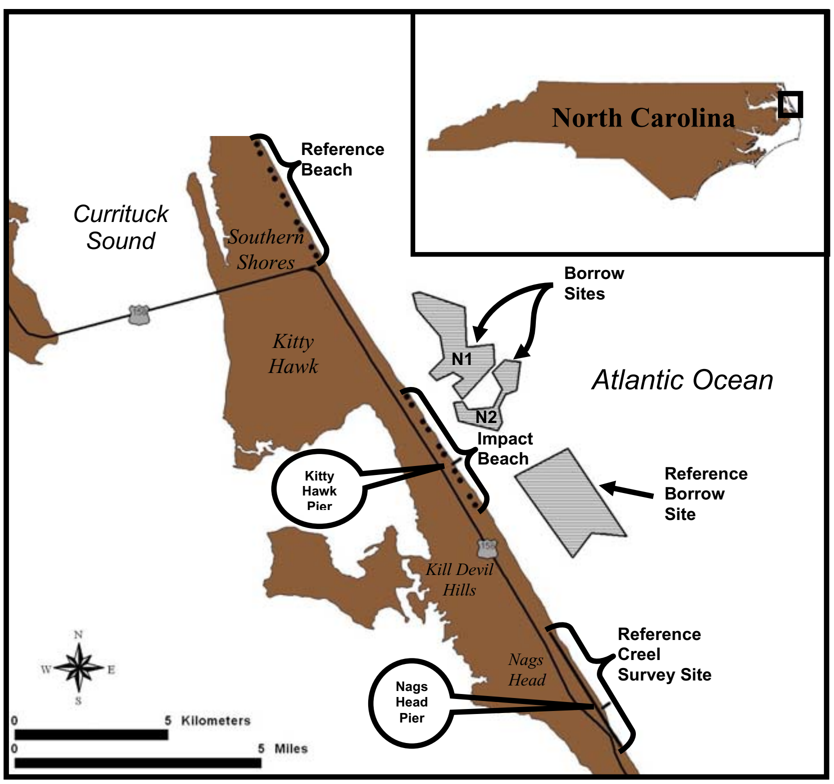

Figure 2-1. Map of several beaches and offshore sand borrow sites located in Dare County, N.C. that were sampled seasonally for one year as part of a biological monitoring project for the U.S. Army Corps of Engineers, Wilmington District.

2.2 BEACH SITES

The beach sites were located in Dare County, N.C., and consisted of one stretch of beach scheduled for beach nourishment and a reference stretch of beach sampled for data comparison. The impact beach is located in Kill Devil Hills, NC and is the Northern part of the Shoreline Protection Project scheduled for Dare County Beaches (Figure 2-1). This stretch of beach is approximately 4.8 km in length, and is an area that has been significantly eroded in recent years.

To compare temporal differences in bird, fish and benthos abundances before, during, and after beach nourishment, we chose a reference site of similar length located approximately 4.8 km north of the impact beach in Southern Shores (Figure 2-1). This site was chosen as the reference beach because it was located far enough away so that it would not be affected during the re-nourishment processes, but was close enough to assume it exhibited similar habitat characteristics as the impact beach.

Because the impact beach has an active fishing pier and the reference site does not, a separate 4.8 km stretch of beach in Nags Head was chosen as the reference site for monitoring fisherman activity and fishing effort (Figure 2-1). Although there are several fishing piers in the area, none were situated on beaches far enough away from the influence of the nourishment project to justify having the biological monitoring and the creel reference at the same beach. Rather than disregard the pier, because pier's represents an important resource to recreational fisherman, we chose a separate reference beach for the creel survey that had an active fishing pier.

2.3 OCEAN BORROW SITES

The two ocean sites consist of a combination of two sand borrow sites and a reference site used for comparison. The two borrow sites are located between .8 and 3.2 km offshore of the impact beach and are known as N1 and N2 (Figure 2-1). Several past geological investigations have identified these sites as having good quality sand for beach nourishment and therefore these sites are scheduled to be mined for sand to nourish the Northern Project Beach in early 2006.

For comparison we also chose an ocean borrow reference site. This site was chosen based on video imagery collected from an underwater video mapping survey conducted prior to biological sampling. The objective of this survey was to provide data to select a reference site for benthic and fisheries monitoring that had similar surface sediment features as the borrow site. By selecting a reference site with similar physical features we can assume that differences in biological responses observed during borrow site impact and post impact years will be attributed to the dredging activity not inherent differences due to bottom type (e.g., sand, gravel, shell, rock).

Using existing bathymetry data and several summary reports describing bottom habitat near the borrow sites (e.g., Boss and Hoffman 2001), several potential reference areas to the south of the borrow sites were delineated prior to conducting the video survey (Figure 2-2). After these areas were identified, Dial Cordy and Associates Inc. from Jacksonville Beach Florida were subcontracted to conduct this initial video survey. A towed video camera in conjunction with a Differential Global Positioning System (DGPS) and navigation software was used to image bottom features at the borrow sites and the potential reference sites. Transects were established within the survey area to best represent the habitats within the timeframe allotted for the survey. Transects were spaced at 150 to 300 m intervals, because this spacing was determined to provide adequate coverage to characterize the sediment composition within the proposed borrow sites.

During the survey, a video sled was towed along each transect in the borrow sites to document physical habitat features. Once the borrow sites were mapped with the video, both potential reference areas were investigated in efforts to locate habitat types similar to those encountered within the borrow sites. All video images were then post processed and physical features noted and categorized. A total of 66 km of video transects were recorded during this survey (Figure 2-2). Within the borrow areas, 35 km of video were recorded and analyzed. Investigations to identify a suitable reference area included over 31 km of video transect. The final borrow reference site was chosen based upon the best combination of similar habitat features seen in the video from both potential reference sites (Figure 2-1).

2.4 SAMPLING METHODS

2.4.1 Benthic Sampling

2.4.1.1 Beach Sites

Benthic invertebrate species composition, abundance, and biomass was collected using a Ponar Grab sampler in the swash zone and shallow sub-tidal habitats at a series of 10 fixed sites along the impact beach and at 10 sites along the reference beach (Figure 2-1). Fixed sites at both beaches were chosen to coincide with physical habitat survey transects previously established by researchers from the Army Corps of Engineers Research Duck Pier. A total of 15 USACE physical transect stations are located within the subject beach and 15 at the reference beach. To ensure that the entire beach is characterized and that all stations had an equal probability of being selected for sampling, we separated the physical transect stations into five groups of three per beach. Within those groups two stations out of the three were selected at random. We then selected those station positions for all subsequent groups within that beach for a total of 10 sampling sites per beach (Table 2-1 and 2-2).

During each seasonal sampling event, one sample per habitat (swash and shallow sub-tidal) is taken at each of the sites along a beach. All sampling is conducted during daylight hours as close to low tide as possible. Grab samples are preserved in the field and transported back to Versar, Inc for processing.

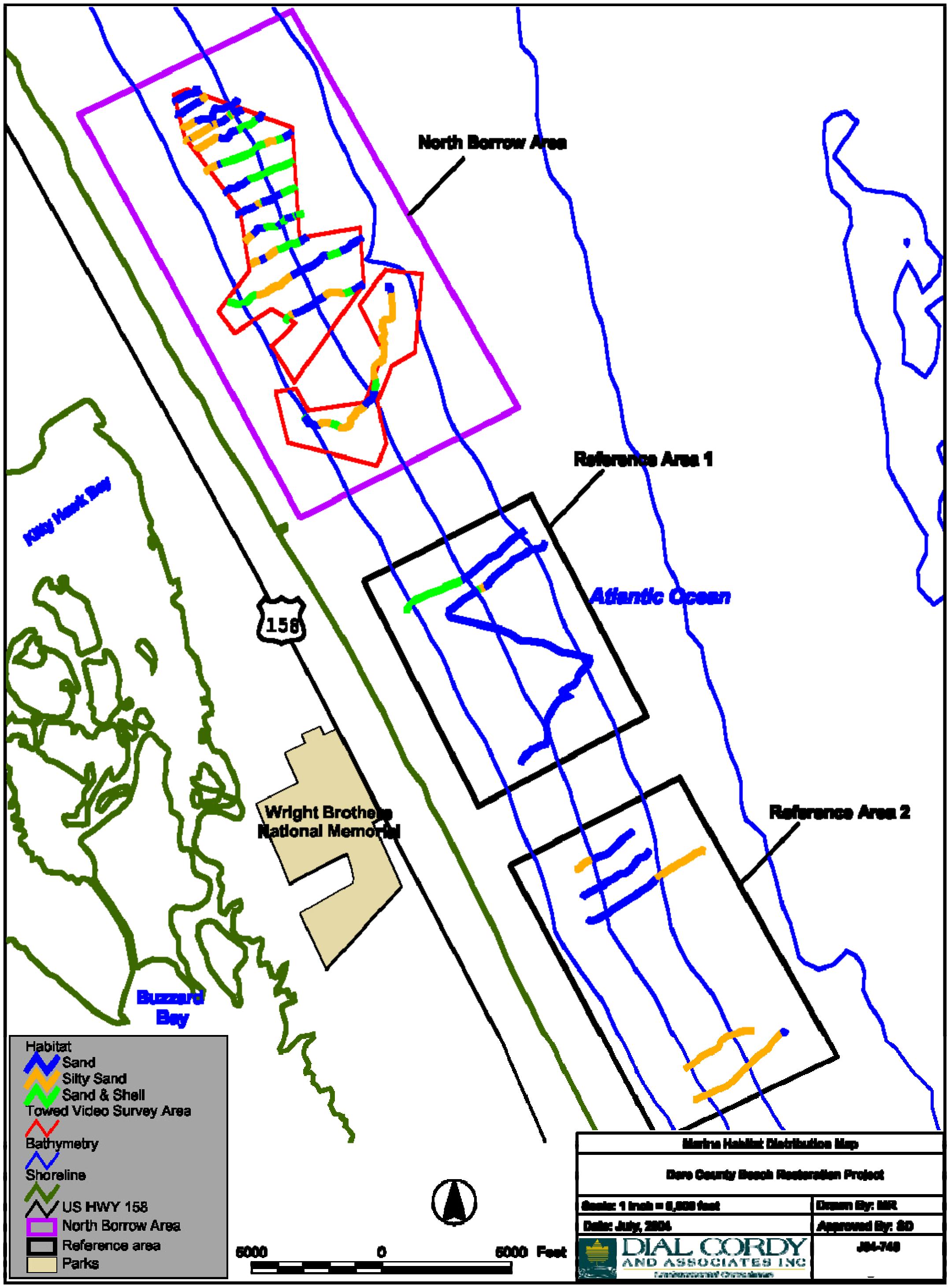

Figure 2-2. Map of two ocean borrow sites and two potential reference sites surveyed with an underwater video sled to identify a suitable reference borrow site for the biological monitoring project in Dare County, N.C. Lines show actual video transects and substrate type.

Table 2-1. Impact beach benthic stations. Bolded physical station numbers were selected for benthic sampling and physical monitoring.

USACE Physical Station #'s	Group	Sediment	Benthic
289	1	X	X
279		X	X
269			
260	2	X	X
249		X	X
240			
229	3	X	X
219		X	X
209			
199	4	X	X
189		X	X
179			
169	5	X	X
159		X	X
149			

Table 2-2. Reference beach benthic stations. Bolded physical station numbers were randomly selected for benthic sampling and physical monitoring.

USACE Physical Station #'s	Group	Sediment	Benthic
-10	1	X	X
-20		X	X
-30			
-40	2	X	X
-50		X	X
-60			
-70	3	X	X
-80		X	X
-90			
-100	4	X	X
-110		X	X
-120			
-130	5	X	X
-140		X	X
-150			

In the laboratory, the samples were re-sieved to remove the preservative. Under a dissecting microscope, all macroinvertebrate organisms were removed from the debris, enumerated, and identified to lowest practical taxon (species in most cases). The laboratory followed a strict 10% QA/QC protocol to assure accuracy in both the sorting and identification procedures (Versar 1999). After identification and enumeration, ash-free dry weight (AFDW) biomass was measured for each taxon. AFDW biomass was determined by (1) drying and weighing each taxonomic group to a constant weight at 60 °C, (2) ashing in a muffle furnace at 500 °C for 5 hours, and (3) weighing the remains.

2.4.1.2 Borrow Sites

Benthic invertebrate species composition, abundance, and biomass was collected from a research vessel using a Young Grab at the borrow sites and borrow site reference during each seasonal sampling event (Figure 2-1). Using a random point generator in a GIS, a total of 10 randomly chosen sites were generated and sampled in each season within the borrow (7 sites in N1 and 3 in N2) and reference sites (Figure 2-3). At each sample site the exact latitude and longitude were documented, and bottom water quality readings (dissolve oxygen, PH, temperature, and salinity) were also taken. Benthic samples are sieved through a 0.5 mm screen in the field and all organisms present on the screen are preserved and transported back to Versar, Inc for processing. Benthic samples are processed in the laboratory in same manner as the beach benthic samples.

2.4.2 Sediment Grain Size

Sediment grain size samples were collected concurrent with benthic samples during each seasonal sampling event. For the beaches, one composite sample from all 10 sites was collected for each habitat zone (swash and sub-tidal) at each beach. At the borrow sites, grain size was collected at each station for a total ten individual grain size samples per site.

Grain-size analysis was performed according to ASTM Method D422-63. Sieve sizes ranged from 4.75 mm (U.S. Standard Sieve No. 4) to 63 µm (U.S. Standard Sieve No. 230). Sediments were categorized by Wentworth's classifications (Table 2-3). Total organic content (TOC) was measured by weight loss upon ignition at 500 °C for 4 hours.

Table 2-3. Sieve sizes used for sediment particle distribution and the Wentworth sediment size categories (Buchanan 1984)

Sieve Number	Sieve Size	Wentworth Size Category
4	4.75-mm	Pebble
10	2.00-mm	Granule
20	850-µm	Very Coarse Sand
40	425-µm	Coarse Sand
60	250-µm	Medium Sand
140	106-µm	Fine Sand
200	75-µm	Undefined
230	63-µm	Very Fine Sand
	< 63-µm	Silt-Clay

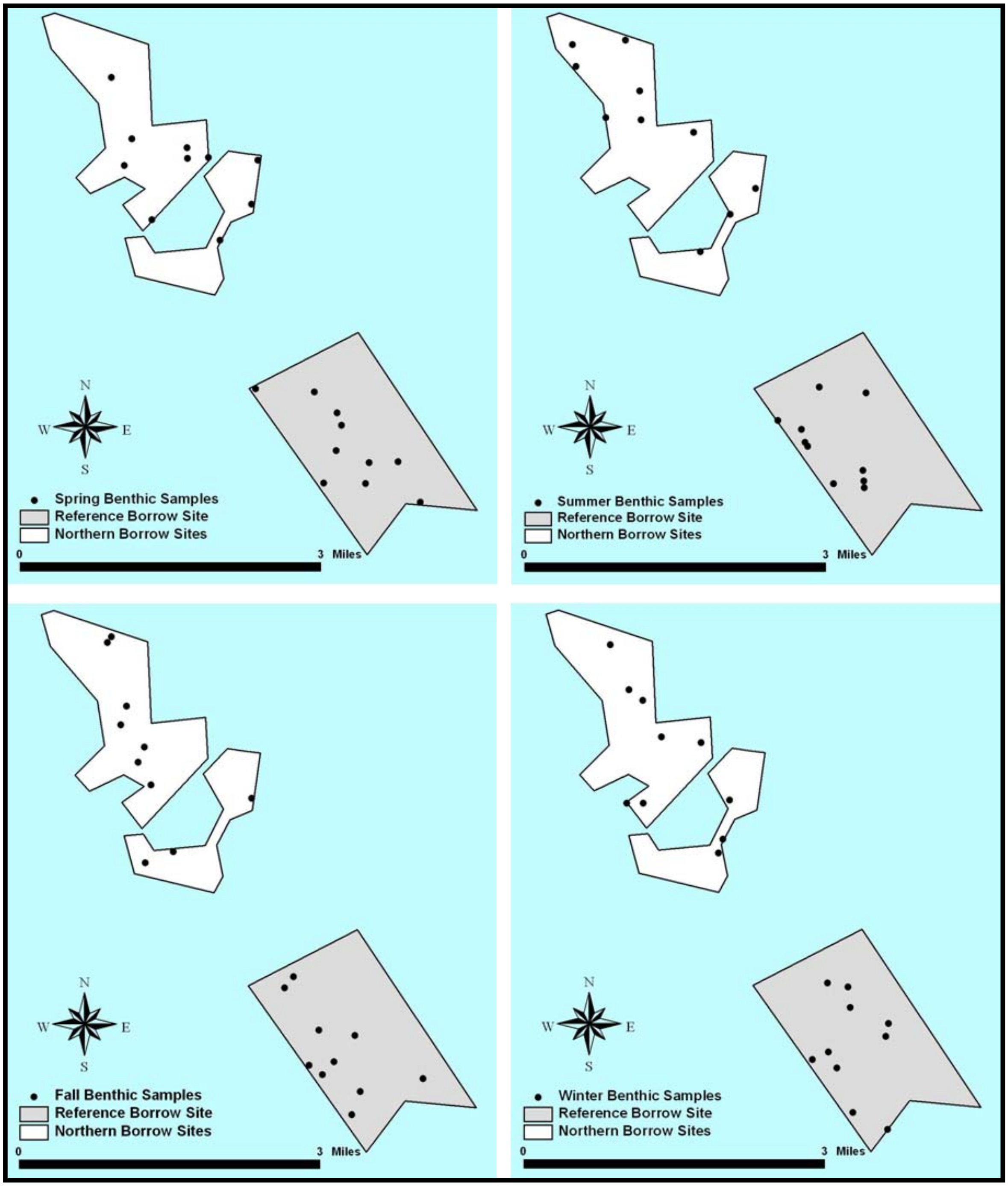

Figure 2-3. Maps showing the locations of seasonal benthic samples collected in a ocean borrow site and a reference borrow site located offshore of Kitty Hawk, N.C.

2.4.3 Fish collections

2.4.3.1 Haul Seines (Beach Sites)

A 183 m modified commercial beach seine was used to target large fish and invertebrates inhabiting the surf zone. The seine consists of a 146 m x 3 m monofilament "wing", made of 8 cm mesh transitioning into a 37 m x 4 m nylon "bunt" end of similar mesh size. Seines are deployed into the surf zone out of a 6 m seining skiff provided by Oregon Inlet Sea Tow. A total of 10 seines are conducted during each season at both the impact and reference beaches. However, because of weather conditions only seven seines were conducted at each beach in the summer season. Attempts are also made to conduct seining over the entire length of each beach, but since the boat must be transported by a vehicle, seines are restricted to certain portions of the beaches (Figure 2-4), because of localized beach replenishment efforts and significant storm and erosion damage which has restricted vehicle traffic.

Seines are deployed from the stern of the skiff by anchoring the bunt end of the seine to the beach and driving the skiff from the beach into and around the surf zone. The net is then brought to shore farther up the beach, generally in a North to South direction, and then retrieved by hand. All organisms brought to the beach in the net are identified to species level, enumerated, and a sub-set of up to 25 specimens are measured for each species.

2.4.3.2 Trawls (Ocean Borrow Sites)

Large benthic and pelagic fish and invertebrate sampling was conducted at the borrow and reference sites using semi-balloon otter trawls with 8 cm mesh webbing. Due to logistical constraints, a 9.7 m trawl with 1.2 m x 0.6 m wooden doors was used during the first (spring of 2004) seasonal sampling event. All subsequent sampling was conducted using a 12.7 m trawl with 1.5 m X 0.8 m aluminum doors. The use of two separate trawls will not impact this analysis, because trawl samples are presented as the square area covered by the trawl and the relative densities of organisms collected are reported to a standardized catch value, in this case 10,000 m^2. Therefore, even though the smaller trawl may have covered less square area, that area would be negligible and is scaled to the equivalent of 10,000 m^2.

During each seasonal sampling event a total of 12 daytime trawls were conducted at the combined N1 (9) and N2 (3) borrow sites and 12 at the reference borrow site. However, during the first event, only ten trawls were conducted between the two borrow sites and ten trawls in the reference site (Figure 2-5). Each trawl is generally towed for 10-minutes and the starting and ending latitude and longitude coordinates are documented to determine the length of the trawl. All fish and invertebrate species collected in the trawls were identified to species level, 25 representatives of each species were measured to total length and all species were enumerated.

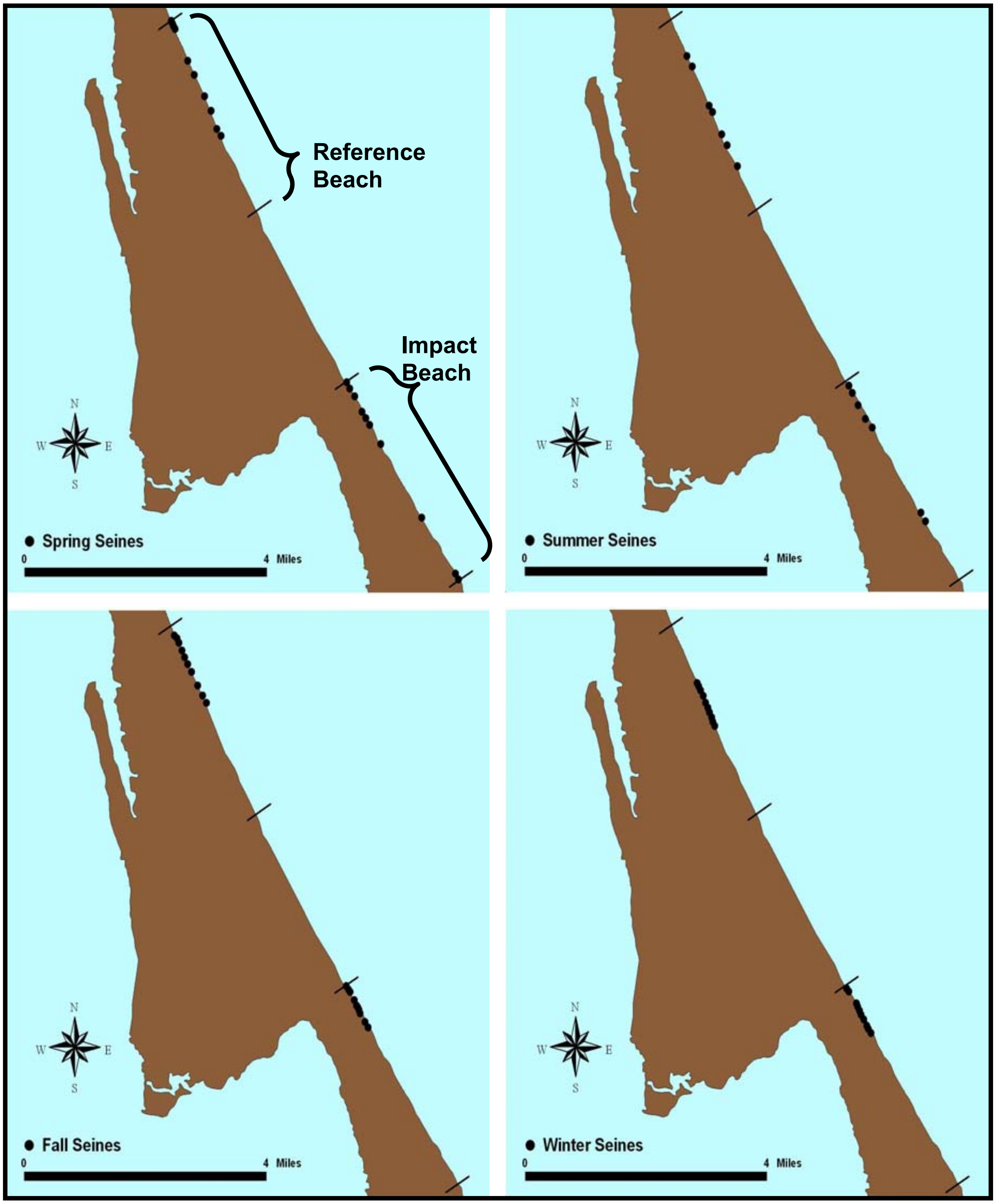

Figure 2-4. Maps showing the locations of seasonal beach seines pulled in the surf zone at the impact beach and reference beach located in Kill Devil Hills and Southern Shores, N.C.

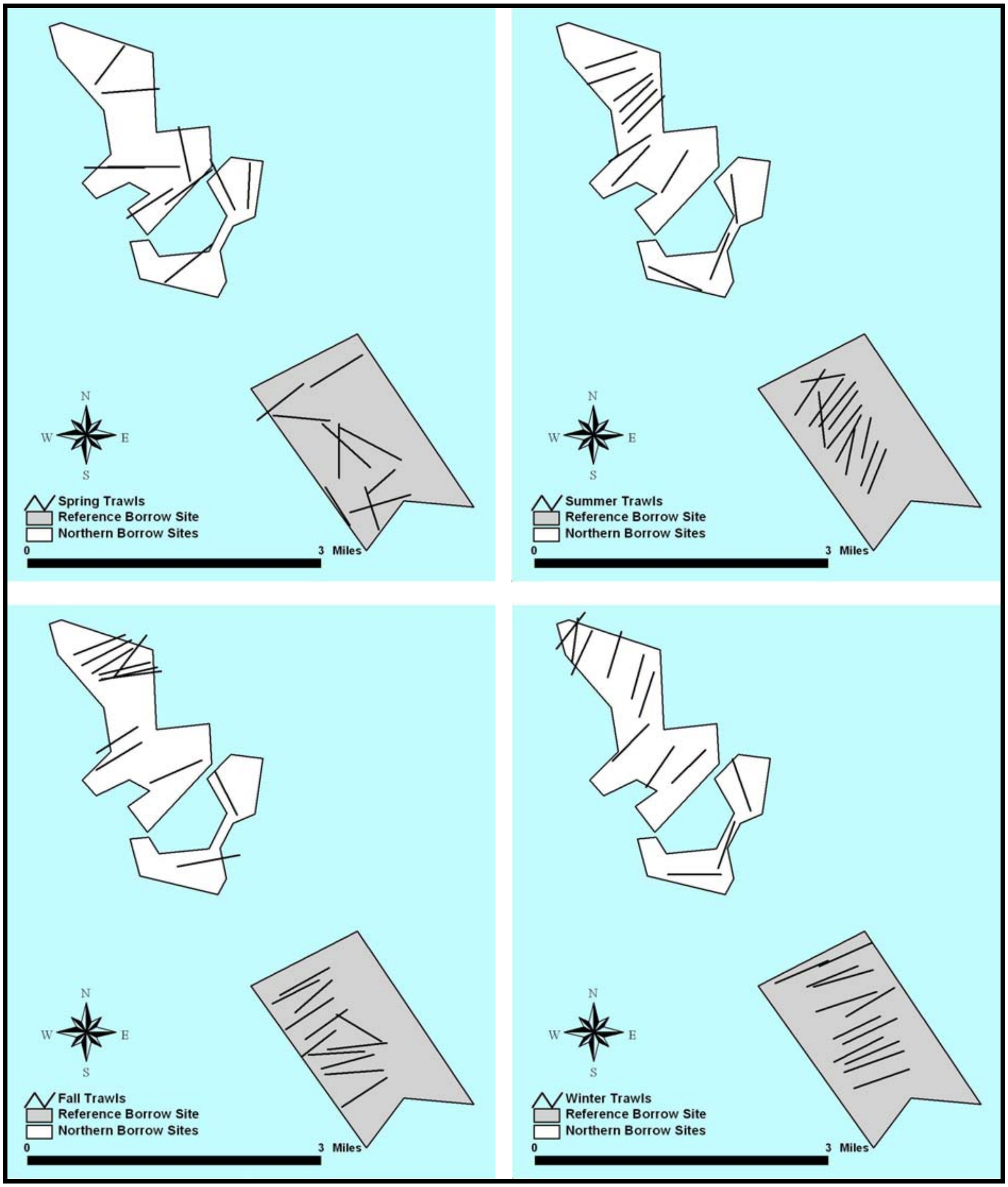

Figure 2-5. Maps showing the locations of seasonal trawls conducted in a ocean borrow site and a reference borrow site located offshore of Kitty Hawk, N.C.

2.4.3.3 Stomach Contents

To obtain baseline diet information for fish residing at the beaches and the borrow sites, up to five individuals of several select (benthic feeders) fish species were preserved from each seine (n=10) and trawl (n=12) conducted during each seasonal sampling event. Initial samples were preserved on ice in the field and later frozen until dissection. However, some of those samples did not preserve well and later samples were preserved in the field using 10% formalin. Fish collected in the field are euthanized on ice, and either preserved whole after injecting formaldehyde solution into the gut, or for larger individuals (e.g. red drum), the stomach is removed and preserved. Fish that have stomachs removed are measured to total length and weighed to the nearest 0.1 grams on hanging scales before stomachs are removed.

After the field collections, whole fish are measured, weighed and the stomachs are extracted. All stomachs are then dissected and the contents are flushed from the stomach and collected through filtration on a 63 micron nytex filter. The filter is allowed to air dry for a short period and then the total contents are weighed collectively to the nearest ±0.001 g. Contents are then sorted to the lowest practical taxon, counted, oven-dried separately by taxon at 60^{o}C, and then weighed to the nearest ±0.001 g.

2.4.4 Ghost Crab Survey

The densities of ghost crabs were sampled by counting ghost crab holes at the impact and reference beach benthic stations during each sampling event. Area counts of ghost crab holes were conducted between the beach wrack line and the toe of the primary dune. Counts were taken along a series of 10 transects spaced apart such that the total covered distance between the first and last transect was 18.2 m (Figure 2-6). The distance between the wrack line and the toe of the dune was also noted so the total square area that was sampled could be calculated. Ghost crab holes were counted by walking along each transect and documenting all the holes directly on either side.

2.4.5 Creel and Bird Survey

2.4.5.1 Creel Survey

A recreational creel survey was conducted to obtain baseline fishing effort and catch information at the impact beach and the designated reference creel survey beach (Figure 2-1). A description of why the creel survey reference beach was different from the benthic survey reference beach is presented in section 2.2. A roving creel survey with a progressive count of anglers was conducted during the day (8 am to 5 pm) every six to eight days throughout the first year of monitoring. The sampling schedule was set so that each beach was sampled separately over two consecutive days and the start day of the next weekly sample progressed one to three days ahead each week (Figure 2-7). In the spring of 2004 the initial sampling day was chosen randomly and the survey progressed systematically throughout the year from that point on. This allowed each day within a season to have the best chance of being surveyed throughout each season.

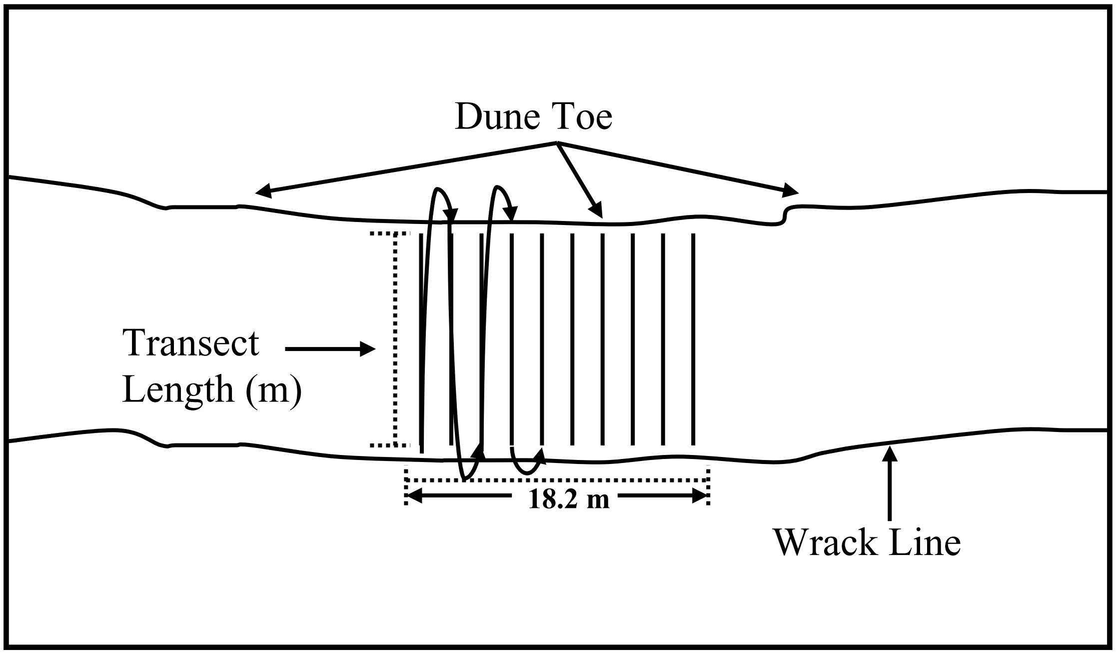

Figure 2-6. Diagram of ghost crab hole transect counts which were conducted at 10 stations at the impact beach (Kitty Hawk) and 10 stations at the reference beach (Southern Shores).

	Weeks	**Days of the Week**						
		1	2	3	4	5	6	7
Season	1	Bird	Creel	Creel				
	2			Creel	Creel	Bird		
	3					Bird	Creel	Creel
	4							Creel
	5	Creel	Bird					
	6		Bird	Creel	Creel			
	7				Creel	Creel	Bird	
	8						Bird	Creel
	9	Creel						
	10	Creel	Creel	Bird				
	11			Bird	Creel	Creel		
	12					Creel	Creel	Bird

Figure 2-7. Progressive sampling schedule for the creel and bird surveys being conducted at the impact beach and two reference beaches located at Kill Devil Hills, Southern Shores and Nags Head, N.C.

Two strata were sampled at each of the beaches; a pier and the beach. Beaches were surveyed throughout the year and the piers were surveyed during the time they were open, from March to November. The first beach to be surveyed in the two day weekly survey window was chosen randomly and the beach that was not chosen was surveyed the following day. Both the beach and pier strata are surveyed at the beach during each daily survey. The survey begins at one randomly chosen stratum (beach or pier) in the morning and the second stratum for that beach is surveyed in the afternoon. The daily survey start time is chosen at random from a choice of times between 8 am to 12 pm. The second daily survey time is dependent upon the initial time choice by adding approximately four hours to the initial start time (Figure 2-8). For example, if 8 am is chosen as the start on the pier, then the beach will be surveyed beginning at noon on that day. This technique allowed the beach and pier to have the same probability of being chosen for surveys either in the morning or the afternoon (Figure 2-8). Angler interviews were conducted either before or after instantaneous counts were performed.

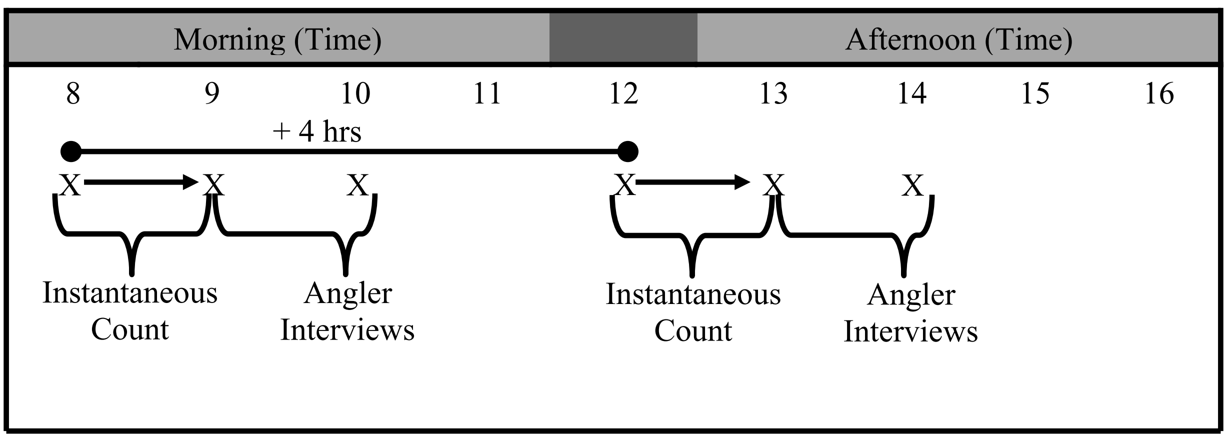

Figure 2-8. Diagram describing the schedule and timing of daily angler counts and interviews conducted at the impact (Kitty Hawk) and reference creel (Nags Head) survey beaches.

During each daily survey, an instantaneous count of anglers was conducted by walking the length of the beach and pier counting the number of anglers (and poles per person) actively fishing. Instantaneous counts on the beaches generally took ~ 1 hour and pier instantaneous counts took ~ .5 hours. Before or after completing the initial count of anglers, the field technician interviewed actively fishing recreational fishermen. Because it was not possible to interview fishermen at the end of their fishing day, fisherman were approached while they were fishing and asked when they began fishing and when they expected to complete their fishing day. The mean catch per hour for each season could then be combined with the independent effort estimate to obtain an estimate of total catch, following methods described in Pollock et al. (1994). Fishermen were also asked what they were targeting and what species and how many were caught and discarded. All angler caught fish were identified to species level when possible, but for discarded fish and other infrequent species, fish were sometimes grouped to family level. In addition to angler and catch effort, demographic information such as state and county of residence, and age and gender were also documented to provide information on angler characteristics.

2.4.5.2 Bird Survey

Shore and water bird counts were conducted throughout the year at the impact and reference beaches (Figure 2-1). The sampling schedule followed the same rotation as the creel survey, but the bird surveys were conducted on one day which alternated to begin before and after the creel surveys every other week (Figure 2-8). This was done because one day of the week would not have the chance of being surveyed if the bird survey day remained fixed, either in front or behind the creel days throughout the year. Both beaches were surveyed on the same day beginning in the morning. Once the morning survey was complete, generally 2 to 3 hours, the second beach was then surveyed. Every week the morning survey beach was alternated to get a representative sample of all times for both beaches during the seasons. Surveys were conducted throughout the year; however the amount of winter surveys was reduced because of reduced bird use on the beaches.

Bird counts were conducted by walking the entire length of each beach in a linear or zigzag fashion (depending on the width of the beach). Beaches were divided into 10 equal transect lengths and three separate microhabitat zones defined as: 1) the beach (the physical habitat residing between the dune and present swash/intertidal zone), 2) the dune (the part of the dune that is facing the ocean and is observed from walking the beach), and 3) the intertidal zone (the area within the present swash zone out to 10 meters). During a survey, bird species, total numbers, bird activity (i.e., feeding, resting, flying, or breeding), and bird location was documented within each of the 10 transects. Additional information on the number people using the beach area, whether any local beach construction activities was occurring (e.g., dune building) and other pertinent information such as tide state, wind speed and direction, air temperature was also noted.

2.4.6 Underwater Video Survey

An under water video survey was conducted between the 8th and 9th of December to gather baseline information on the physical and biological features residing on the substrate at the borrow and reference sites. During the survey a benthic video sled, provided by the Virginia Institute of Marine Science was towed at all the sites following a transect survey design outlined by Versar. The sled was towed off the stern of the 12 m Oregon Inlet sea tow vessel moving at speed of 1.5 to 2.8 knots. Approximately 48 km of bottom habitat was covered during the survey (Figure 2-9). During the two day field effort 24 km of transects were covered in the N1 & N2 borrow site and 24 km at the reference site.

The video sled was equipped with three video cameras mounted in three different configurations to provide: 1) a broad overview of the bottom, 2) near bottom horizontal view to

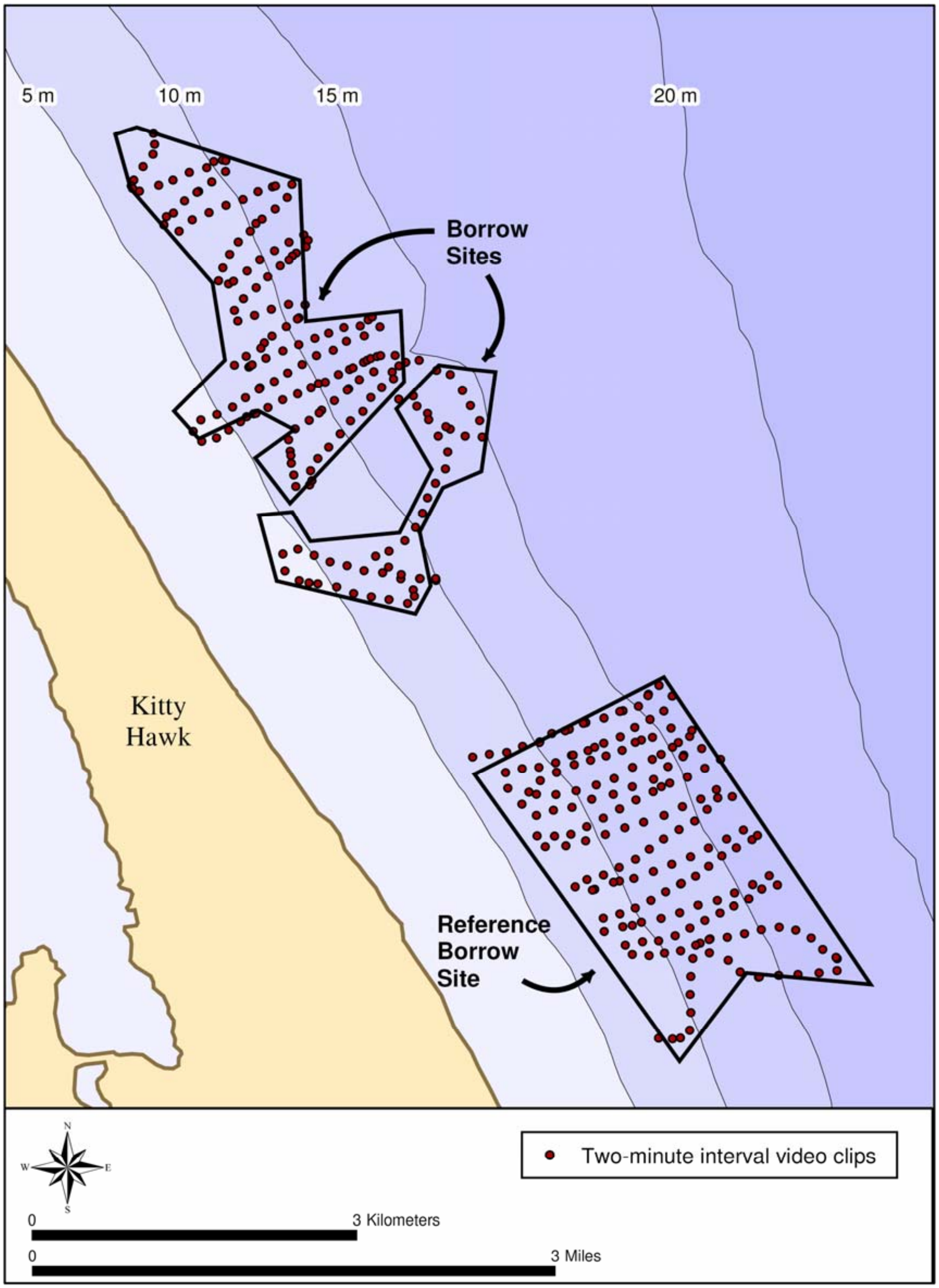

Figure 2-9. Video sled transect lines covered during the December 2004 bottom survey of the Dare County beach replenishment borrow sites N1 and N2 and a nearby reference area. Points represent locations of 2-minute video clips analyzed from the video.

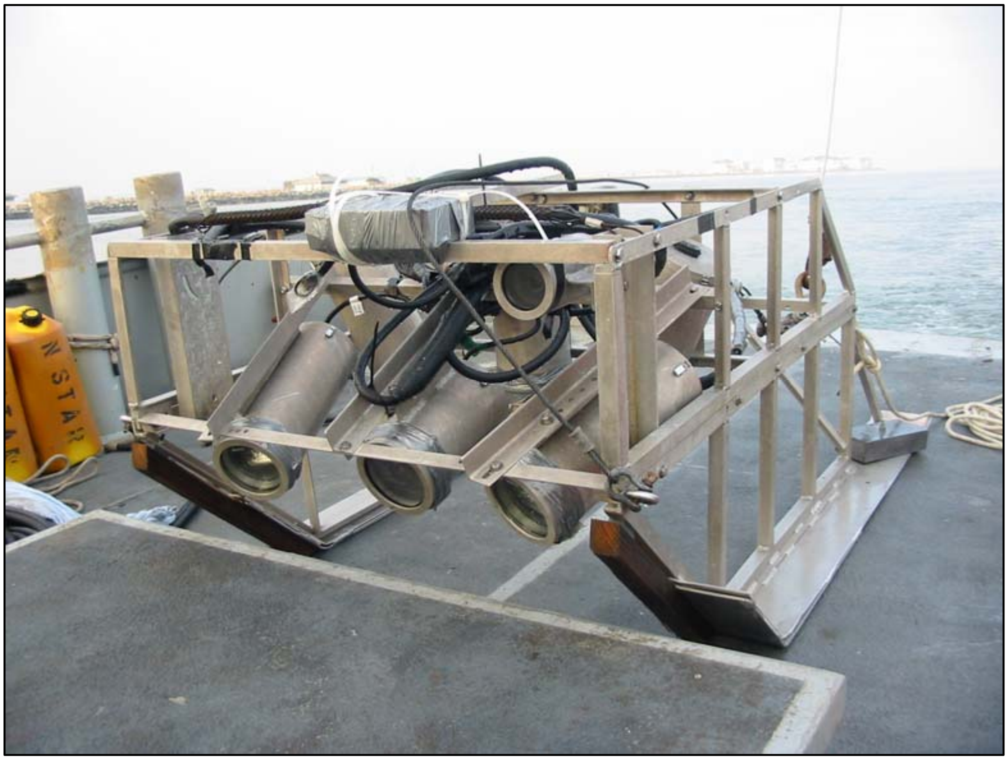

Figure 2-10. Video sled used to characterize benthic habitats. Overview camera is at the top right corner of the sled, horizontal camera is in the front center and flanked by two electronic video strobes, close-up vertical camera is in the center of the sled, behind the horizontal camera. Sled runners are 0.8 m apart.

see fish over the bottom and bed form types, and 3) a vertical high resolution view for sediment type and biogenic features (Figure 2-10). The broad overview camera was mounted about 0.5 m off the bottom and angled to view the bottom out in front of the sled from 2 to 10 m. The near bottom horizontal camera was mounted 0.2 m off the bottom at an oblique angle of 20^o to provide a close-up view of bottom morphology and the presence of juvenile fish and other mobile fauna from 0.2 to 1.0 m in front of the sled. Its field of view was a trapezoid with an area of approximately 0.9 to 1.0 m^2 being about 0.25 m near the sled and about 1.5 m at a distance of about 1.0 m from the sled. The vertical camera was mounted perpendicular to the bottom at a distance of 0.3 m from the sediment surface and had a field of view of 28 cm x 21 cm or 588 cm^2 (0.06 m^2). Illumination for the vertical and horizontal cameras was provided by electronic video strobes.

The video sled was linked to the surface via two cables that provided power to the cameras and strobes. The video signals were transmitted to the surface where sled performance and bottom features could be viewed in real-time. All the bottom video footage was recorded on Sony 8mm video cassettes and DGPS data was collected simultaneously so each video frame could be georeferenced. Video signals from the horizontal and vertical cameras were also recorded on higher resolution digital recorders for later analysis.

2.5 DATA ANALYSIS

2.5.1 Benthic

Counts of benthic invertebrates were expressed in numbers per square meter of bottom area for all subsequent data analyses. When completing taxonomic identifications, some organisms cannot be completely identified to the species level, particularly if they are immature/juveniles or in poor condition. The taxonomist made a note in the database when it was the opinion of the taxonomist that such an organism should not be considered a separate taxon when tallying total number of taxa. All the statistical analyses and calculation of diversity indices accounted for these taxonomic identification notations. Summaries of community composition, mean total abundance of infuanal and epifuanal organisms, and the mean number of species were calculated and presented. Total community diversity was also calculated on the CPUE data using the Shannon-Wiener Index of diversity, which is calculated using the following equation:

$$H = -\sum_{i=1}^{s} (p_i)(\log_2 p_i)$$

where

H = index of species diversity
S = number of species
p_i = proportion of total sample belonging to *i*th species

2.5.2 Fish

2.5.2.1 Fish Collections

Fisheries catch data were standardized to catch per unit effort (CPUE) for analysis. Units are the number of organisms collected per square meter for seines and trawls. The total swept area of a typical seine is approximately 5,330 m and seine data was standardized to catch per 10,000 m^2. The CPUE for the trawls was calculated as the linear distance a trawl traveled multiplied by the trawl mouth opening, which was then standardized to 10,000 m^2. The first year of data was summarized by season and site (impact and reference beach, and northern borrow and reference borrow site). Summaries of community composition, mean total CPUE, and the mean number of species were calculated and presented. Total community diversity was also calculated on the CPUE data using the Shannon-Wiener Index of diversity, which is calculated using the following equation:

$$H = -\sum_{i=1}^{s} (p_i)(\log_2 p_i)$$

where

H = index of species diversity
S = number of species
p_i = proportion of total sample belonging to *i*th species

2.5.2.2 Stomach Contents

Stomach content data was summarized by fish species and analysis was performed separately for each site and each season. Stomach contents were categorized by determining the frequency of occurrence (%F), the percent composition by number (%N), and the percent composition by dry weight biomass (%W) for each major prey item. Since these methods contain biases that limit the usefulness of any one method (Hyslop 1980), these data were combined in a modified index of relative importance (IRI) (Pinkas et al. 1971). IRI determines the quantitative importance of a particular prey group *i* (IRI_i) and is expressed as:

$$IRI_i = (\%N + \%W) \times \%F \ ,$$

where:
$\%N$ = frequency of mean abundance of prey item,
$\%W$ = frequency of mean dry weight of prey item, and
$\%F$ = frequency of occurrence of the prey item.

Because the IRI are not expressed as a percentage, comparisons between prey types can be difficult, therefore IRI were calculated as percent IRI (Cortez 1997). The percent IRI is expressed as:

$$\%IRI_i = \left(\frac{IRI_i}{\sum_{i=1}^{n} IRI_i} \right) \times 100$$

where:
n = total number of prey groups considered.

2.5.3 Ghost Crab Survey

To evaluate seasonal trends in ghost crab abundance (inferred from ghost crab hole counts), ghost crab hole counts conducted at beach station transects were summarized and the seasonal mean abundances was calculated for each beach. Mean abundance of ghost crabs per square meter was calculated using the following equation:

$$Abundance\ m^2 = \frac{Count}{\left(Length \times \left(\frac{9.144}{5}\right)\right)}$$

where:

Abundance m^2 = ghost crab abundance per square meter,
Count = number of ghost crabs per transect, and
Length = length of each transect (meters).

2.5.4 Creel Survey

Catch rates were calculated for the total number of fish of any species, and for the five most commonly captured species or more general taxonomic group – spot *Leiostomus xanthurus*, bluefish *Pomatomus saltatrix*, kingfish *Menticirrhus spp*., spotted seatrout *Cynoscion nebulosus*, and flounder *Pleuronectiform spp*.

Total fishing effort (hours/season), catch (fish/hour), and catch per unit of effort (CPUE; fish/hour) were estimated for beach or pier, type of treatment (impact or reference), and season, for Spring 2004 (incomplete) through Spring 2005. Estimates were made using procedures similar to those described by Pollock et al. (1994) for roving creel surveys from incomplete fishing trips, when the probability of being selected was independent of trip length. We modified the procedure slightly by weighting the catch per hour estimate ($\hat{R}$) by angler effort to better represent catch rates that fluctuated greatly within a season. The mean and variance of $\hat{R}$ were calculated using the jackknife procedure (Efron 1982). Estimators are described below.

Effort for day *i* was calculated as:

$$e_i = I_i \times 9 \text{ hours},$$

where I_i = the number of anglers observed on day *i*

Mean daily effort was calculated as:

$$\overline{e} = \sum_{i=1}^{n} e_i \ ,$$

$$\text{with variance } \hat{\text{var}}(\overline{e}) = \frac{\sum_{i=1}^{n} \left(e_i - \overline{e}\right)^2}{n-1} \left(\frac{1}{n} - \frac{1}{N}\right)$$

where n = the number of days sampled and N = the number of days in the season.

Total effort for a season, $\hat{E}$, was calculated as:

$$\hat{E} = N\overline{e} ,$$

$$\text{with variance } N^2 \, \hat{\text{var}}(\overline{e}) ,$$

The mean daily catch per hour of fishing was calculated as:

$$r_i = \sum_{j=1}^{m} \frac{c_j}{L_j} ,$$

where c_j is the catch for angler j. and L_j is the length of angler j's fishing trip at the time of the interview, and m is the number of anglers interviewed on day i.

The seasonal catch per hour of fishing $\hat{R}$ was calculated as:

$$\hat{R} = \frac{\sum_{k=1}^{n} \left(\hat{R}_k - \overline{\hat{R}} \right)^2}{n} ,$$

$$k = (1,2,\ldots\text{n})$$

$$\text{where } \hat{R}_k = \frac{r_i m_i}{\sum_{i=1}^{n} m_i} , \text{ with one observation } i \text{ omitted from each } k,$$

$$\text{and variance } \hat{\text{var}}(\hat{R}) = \frac{n-1}{n} \sum_{k=1}^{n} \left(\hat{R}_k - \hat{R} \right)^2$$

Total catch per season, Chat, was estimated as:

$$\hat{C} = \hat{R}\hat{E} ,$$

$$\text{with variance } \hat{\text{var}}(\hat{C}) = \hat{E}^2 \, \hat{\text{var}}(\hat{R}) + \hat{R}^2 \, \hat{\text{var}}(\hat{E}) - \hat{\text{var}}(\hat{E}) \, \hat{\text{var}}(\hat{R})$$

All standard errors (SE) were calculated as the square root of the variance of a given variable, and approximate 95% confidence intervals were calculated as variable means ±1.96*SE.

2.5.5 Bird Survey

Daily bird counts from beach transects were summarized and averaged to calculate the mean abundance of each species per sampling day at each beach. The mean total abundance, mean number of species, and the mean community diversity were calculated to examine seasonal trends at the beaches. Community diversity was calculated using the Shannon-Wiener diversity index, which is calculated using the following equation:

$$H = -\sum_{i=1}^{s} (p_i)(\log_2 p_i)$$

where:

H = index of species diversity,
S = number of species, and
p_i = proportion of total sample belonging to *i*th species.

Shore and waterbird species were also grouped to examine the seasonal trends for those two bird groupings. The mean total abundance, mean number of species, and group diversity were calculate for each beach and season.

2.5.6 Underwater Video Survey

The video imagery was analyzed by documenting physical and biological features in the video. Initially, the video data was decimated by taking video clips at 2.0-minute intervals and at locations where fish were seen in the recorded videotape. If video images were not visible because of poor near-bottom visibility at the 2.0-minute interval, than the last instance the bottom was visible and the first moment the bottom reappeared was analyzed. All fish visible from the forward or downward cameras were identified to the lowest possible taxon and physical and biological features of the benthic habitats at that instance was also noted and recorded. Data on bed roughness, sediment type, shell hash, biogenic structures, epi-faunal and infaunal organisms, and fishes and rays were collected and entered into an excel spreadsheet.

Bottom habitats were classified based on both physical and biological characteristics. Physical characteristics included variables for bedforms type and size, which were primarily wavelength and form, and sediment grain size. Biological characteristics included variables for shell fragment cover, mobile fauna, sedentary fauna, and other biogenic structures (Table 2-4). These analyses were conducted using a Sony editing deck and high-resolution video monitor.

Table 2-4. Physical and biological features sampled from horizontal camera videotapes

Physical	Biological
Silt & Clay: 0 = absent 1 = present	Count of: Sessile epifauna
Fine-Medium Sand: 0 = absent 1 = present	Count of: Fishes
Coarse Sand & Gravel: 0 = absent 1 = present	Count of: Skates/Rays
Bedforms: 0 = absent 1 = present	Count of: Burrow opening
Size of bedforms 0 = <30 cm wavelength 1 = >30 cm wavelength	Count of: Biogenic mounds or pits Count of: Tubes
Waveform of bedforms 0 = smooth rounded crest 1 = sharp peaked crest	Count of: Mobile epifauna
Shape of bedforms 0 = straight 1 = asymmetric	
Secondary ripples: 0 = absent 1 = present	
Shell fragments 0 = 0-5% coverage of bottom 1 = 5-10% coverage of bottom 2 = 10-25% coverage of bottom 3 = >25% coverage of bottom	
Whole shell: 0 = absent 1 = present	

3.0 RESULTS

3.1 GENERAL OVERVIEW

The following summaries are provided to describe the general trends in species distributions at the impact beach, borrow sites, and associated reference sites. Although some differences were observed between the sites, those differences were not highlighted, as the purpose of this report was to describe the living resources that may be impacted by beach replenishment activities. As the dredging and shoreline development advances in the upcoming years, differences displayed between the sites will be used to help determine potential loss of living resources as a result of beach replenishment activities and subsequent recovery of the communities.

3.2 BENTHIC

3.2.1 Swash Area

Only 20 infauna and epifauna macrobenthic taxa were collected from the swash beach area from both the impact and reference beach (Table 3-1). Seasonal differences in the benthic community composition were apparent (Figure 3-1). In general, however, differences in community composition between the study and reference beaches within seasons were minimal (Figure 3-1). Most of the differences between the two beaches were in the counts or biomass of specific taxa (Figures 3-2 and 3-3). Both measures of diversity were very similar between the reference and impact beaches in all seasons sampled (Figures 3-4 and 3-5).

Some of the taxa collected within the swash area were extremely abundant but contributed little biomass. For example, oligochaete worms were overall the most abundant taxa collected within the swash area, sometimes with a mean in excess of over 1000 organisms/m^2 (Table 3-1). The mean biomass contribution of oligochaetes, however, was less than a mean of 1 g/m^2 (Table 3-2). Nemertina worms were also highly abundant in all seasons but again contributed little to biomass within the swash zone (Tables 3-1 and 3-2). Oligochaete worms appeared to have an abundance pattern of extremely high numbers in spring and summer with a decline in the fall to a very low number in winter. Nemertina worm abundances in the swash zone did not appear to follow a pattern, as they were numerous, but small in all seasons (Table 3-1).

Overall, more infauna organisms were collected in spring and mean infauna abundance declined through the summer into the fall and winter (Figure 3-2). Mean infauna biomass did not follow the same pattern as abundance. Biomass was highest in both spring and fall, and lowest in summer and winter (Figure 3-3). Mean number of infauna taxa collected within the seasons was low and ranged from a mean of about 3/station in spring and summer, to a low of about 1.25/station in winter (Figure 3-4). The Shannon Weiner diversity index (H') was very low in all seasons but was lowest in winter (Figure 3-5).

Some taxa considered key prey items to shorebirds, fish, and megabenthic species were collected from the swash zone and contributed to both abundance and biomass. The mole crab, *Emerita talpoida*, was numerically dominant in the summer compared to the other seasons. This species contributed the most biomass of any taxa within the swash zone (Table 3-1). *Emerita* showed a clear pattern of high abundance in the summer decreasing to no individuals collected in the winter. Biomass of this species was highest in spring and fall, however, indicating that although numerically abundant in summer, larger individuals were collected in spring and fall (Table 3-2). The amphipod, *Amphiporeia virginiana*, was abundant in the spring and decreased in abundance throughout the summer and fall to no individuals collected in the winter. The bean clam, *Donax variabilis*, typically a dominant in shore zone habitats along the Atlantic coast, was not abundant in the swash area at either the impact or reference beach (Table 3-1).

3.2.2 Shallow Area

Thirty-six distinct infauna and epifauna macrobenthic taxa were collected from the shallow beach area from both the impact and reference beach. Although the number of taxa collected from within the shallow beach area was greater than at the swash habitat, abundance of infauna organisms in the shallow habitat was lower than in the swash habitat (Figures 3-2 and 3-7). Many of the dominant taxa were abundant overall all seasons, such as nemertean and oligochaete worms, and the amphipod, *Amphiporeia virginiana* (Table 3-3). Other dominant taxa had very patchy abundance (i.e., amphipods *Atylus* cf. *minikoi* and *Haustorius candensis*). Table 3-4 provides the list of dominant taxa by weight. Most of the taxa dominant by count were also dominant by weight with a few exceptions.

In contrast to the swash habitat, differences in community composition between the impact and reference beaches within seasons were apparent and will need to be taken into account when assessing beach replenishment impacts (Figure 3-6). During the spring, the impact beach had a greater number polychaetes and miscellaneous organisms, whereas the reference beach had a greater number of crustacean organisms. In the summer, the impact beach had higher numbers of crustaceans and molluscs and the reference beach had higher numbers of miscellaneous species. In the fall, all of the major taxonomic groups were different in terms of counts and composition (Figure 3-6). As a consequence of the overall low abundance in the fall, minor differences in counts related to big differences in community composition (Figure 3-7). During the winter sampling period, more polychaetes were present at the impact beach than at the reference beach (Figure 3-6).

Table 3-1. Mean abundance (#/m^2) of macrobenthic taxa collected in the swash area of the impact and reference beach in Dare County, NC.

Taxonomic Group	Taxonomic Name	Spring		Summer		Fall		Winter	
		Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.
Nemertina	Nemertina	2312	2516	220	1648	816	764	5176	1204
Annelida : Oligochaeta	Oligochaeta	16464	12124	812	4924	712	364	4	4
Annelida : Polychaeta	*Amastigos caperatus*			28			312		
	Microphthalmus aberrans					4			
	Paraprionospio pinnata		4						
	Polydora spp.			4		20		4	
	Polygordius spp.			4			4		
	Scolelepis squamata								4
	Tharyx sp. *A Morris*			28			312		
Arthropoda : Amphipoda	*Ampelisca abdita*		4						
	Amphiporeia virginiana	592	4	24	4		12		
	Atylus cf. *minikoi*			8					
	Haustorius canadensis	4							
	Phoxocephalidae						4		
Arthropoda : Decapoda	*Emerita talpoida*	44	36	1520	936	72	88		
	Pagurus spp.								4
Mollusca : Bivalvia	*Donax variabilis*		4		20				
	Mytilus edulis	4	4						
Mollusca : Gastropoda	*Acteocina canaliculata*							4	
	Crepidula spp.			4					

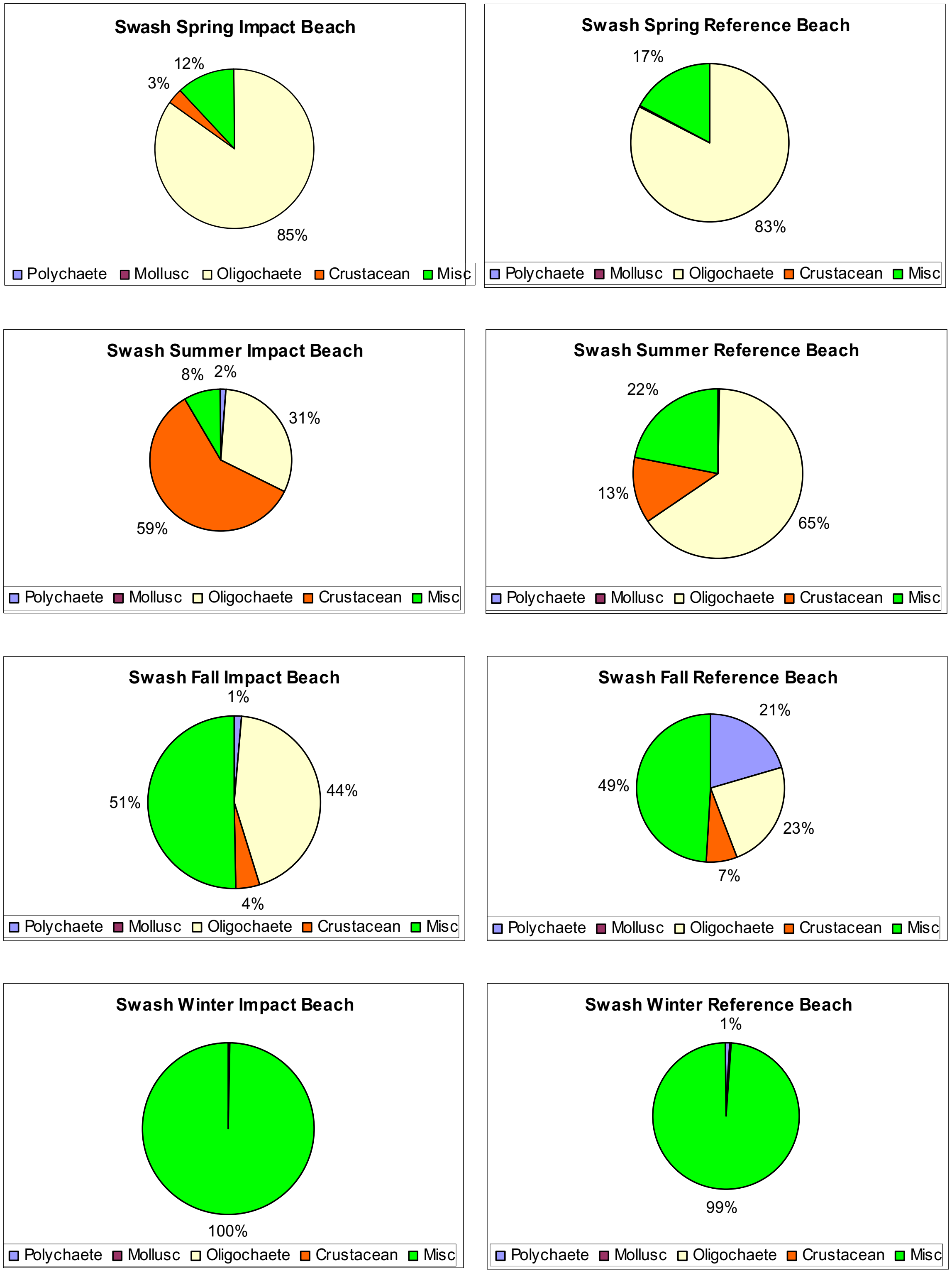

Figure 3-1. Community composition of benthic organisms collected in the swash habitat of the impact and reference beaches in Dare County, NC.

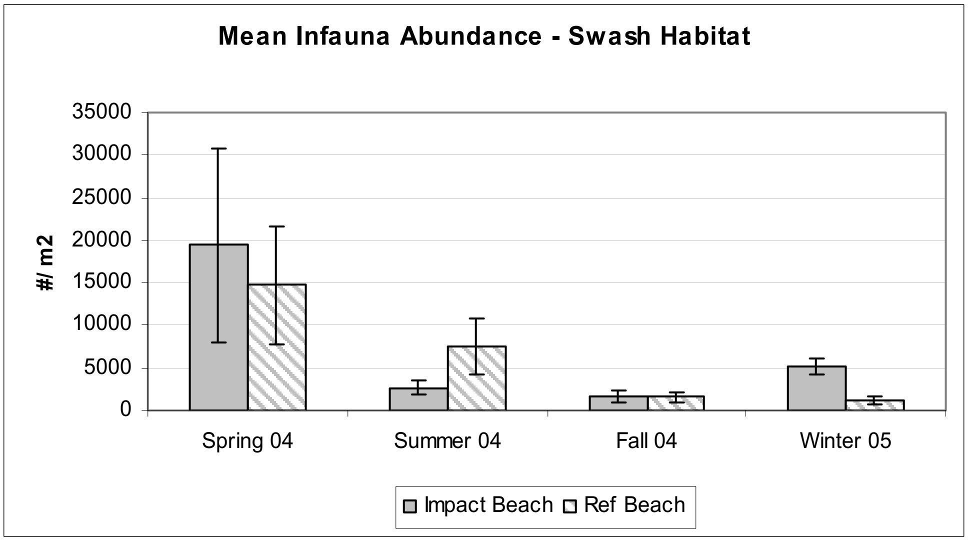

Figure 3-2. Mean total infauna abundance collected from the swash habitat at the impact and reference beaches in Dare County, NC.

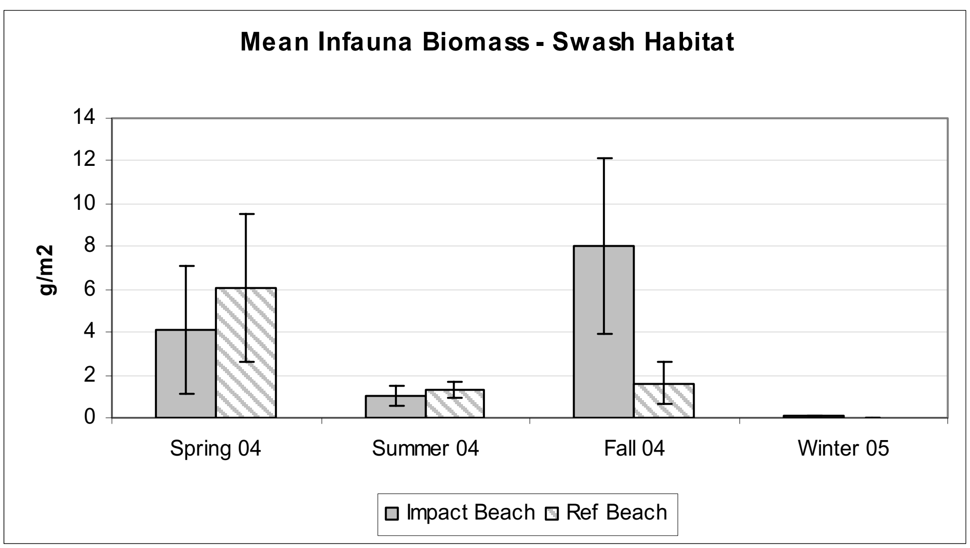

Figure 3-3. Mean total infauna biomass collected from the swash habitat at the impact and reference beaches in Dare County, NC.

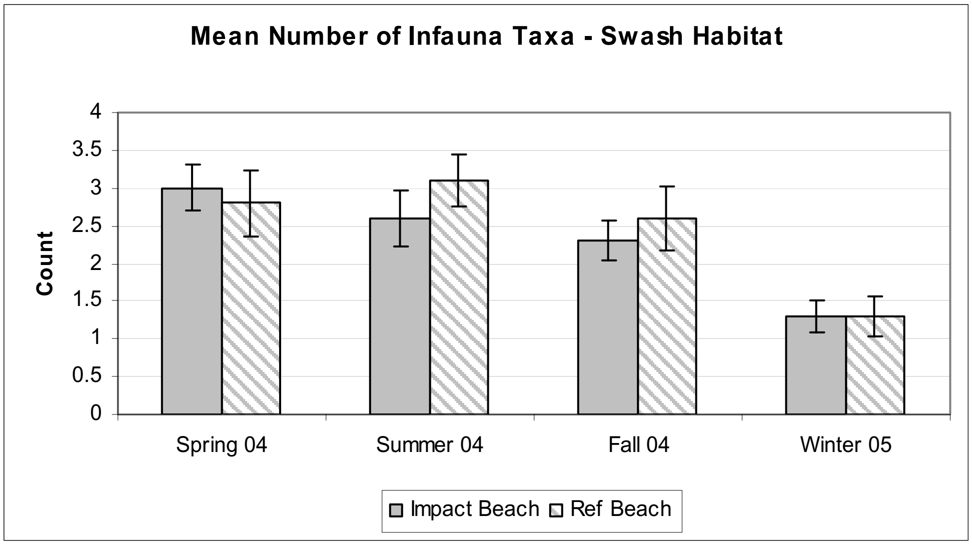

Figure 3-4. Mean number of infauna taxa collected from the swash habitat at the impact and reference beaches in Dare County, NC.

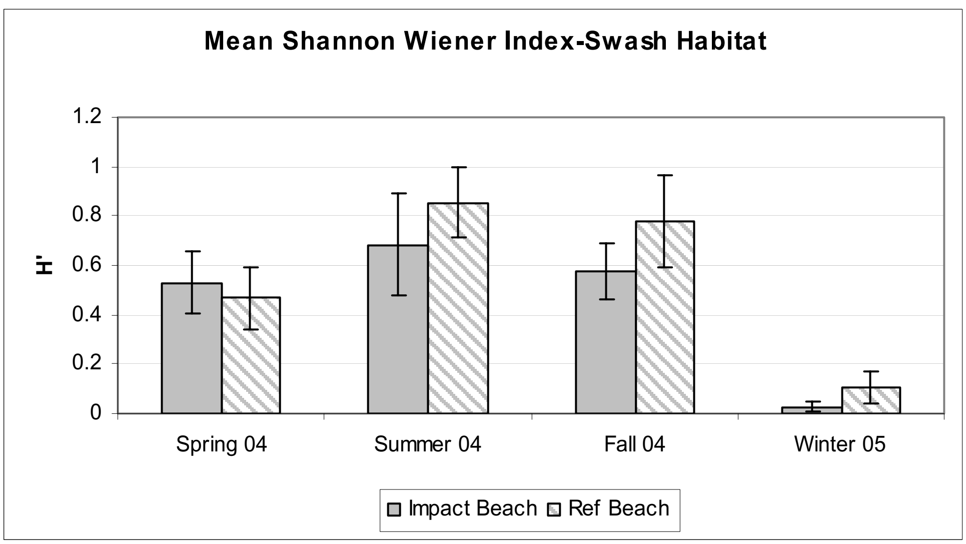

Figure 3-5. Mean Shannon Wiener Diversity Index measured from the swash habitat at the impact and reference beaches in Dare County, NC.

Table 3-2. Mean biomass (g/m^2) of macrobenthic taxa collected in the swash area of the impact and reference beaches in Dare County, NC.

Taxonomic Group	Taxonomic Name	Spring		Summer		Fall		Winter	
		Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.
Nemertina	Nemertina	0.0286	0.0356	0.0040	0.0142	0.0126	0.0150	0.0884	0.0176
Annelida : Oligochaeta	Oligochaeta	0.0512	0.0508	0.1310	0.0134	0.0024	0.0034	0.0002	0.0002
Annelida : Polychaeta	*Amastigos caperatus*			0.0002			0.0002		0.0010
	Microphthalmus aberrans			0.0004			0.0032		
	Paraprionospio pinnata					0.0002			
	Polydora spp.		0.0002						
	Polygordius spp.			0.0002		0.0004		0.0002	
	Scolelepis squamata			0.0004			0.0032		
	Tharyx sp. *A Morris*								0.0008
Arthropoda : Amphipoda	*Ampelisca abdita*		0.0002						
	Amphiporeia virginiana	0.1412	0.0020	0.0016	0.0004		0.0036		
	Atylus cf. minikoi			0.0004					
	Haustorius canadensis	0.0272							
	Phoxocephalidae						0.0002		
Arthropoda : Decapoda	*Emerita talpoida*	3.8728	5.9876	0.8852	1.1084	8.0024	1.5680		
	Pagurus spp.								0.0008
Mollusca : Bivalvia	*Donax variabilis*		0.0002		0.1708				
	Mytilus edulis	0.0004	0.0002						
Mollusca : Gastropoda	*Acteocina canaliculata*							0.0002	
	Crepidula spp.			0.0002					

Table 3-3. Mean abundance (#/m^2) of the top ten macrobenthic taxa collected in the shallow area of the impact and reference beaches in Dare County, NC.

Taxonomic Group	Taxonomic Name	Spring		Summer		Fall		Winter	
		Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.
Nemertina	Nemertina	112	32	196	492	68	16	152	464
Annelida : Oligochaeta	Oligochaeta		28	28	4	80	8	8	4
Annelida : Polychaeta	*Microphthalmus aberrans*	228	32	8	8		32		
	Scolelepis squamata		8	80	144		4		
Arthropoda : Amphipoda	*Amphiporeia virginiana*	112	32	196	492	68	16	152	464
	Atylus cf. *minikoi*			100					
	Haustorius canadensis		40	12			24		
Arthropoda : Decapoda	*Emerita talpoida*	4		76	40	20	52		
Arthropoda : Mysidacea	*Neomysis americana*	4		84	20	8			
Mollusca : Bivalvia	*Donax variabilis*	80	116	120	28		4		

Table 3-4. Mean biomass (g/m^2) of the top ten macrobenthic taxa (based on biomass) collected in the shallow area of the impact and reference beaches in Dare County, NC.

Taxonomic Group	Taxonomic Name	Spring		Summer		Fall		Winter	
		Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.
Nemertina	Nemertina	0.0036	0.0030	0.0046	0.0102	0.0008	0.0006	0.0028	0.0060
Annelida : Polychaeta	*Microphthalmus aberrans*	0.0100	0.0012	0.0002	0.0006		0.0004		
	Scolelepis squamata		0.0184	0.0500	0.1236		0.0328		
Arthropoda : Amphipoda	*Amphiporeia virginiana*	0.0226	0.0336	0.0006	0.0016				
	Bathyporeia parkeri	0.0048	0.0010						
	Haustorius canadensis		0.2284	0.0204			0.0208		
Arthropoda : Decapoda	*Emerita talpoida*	1.8376		0.0580	0.0148	0.3992	2.7856		1.8376
	Ovalipes stephensoni	0.5916	2.8216						0.5916
Arthropoda : Mysidacea	*Neomysis americana*	0.0002		0.0140	0.0024	0.0024			
Mollusca : Bivalvia	*Donax variabilis*	0.0096	0.0196	0.0660	0.0318		0.0024		

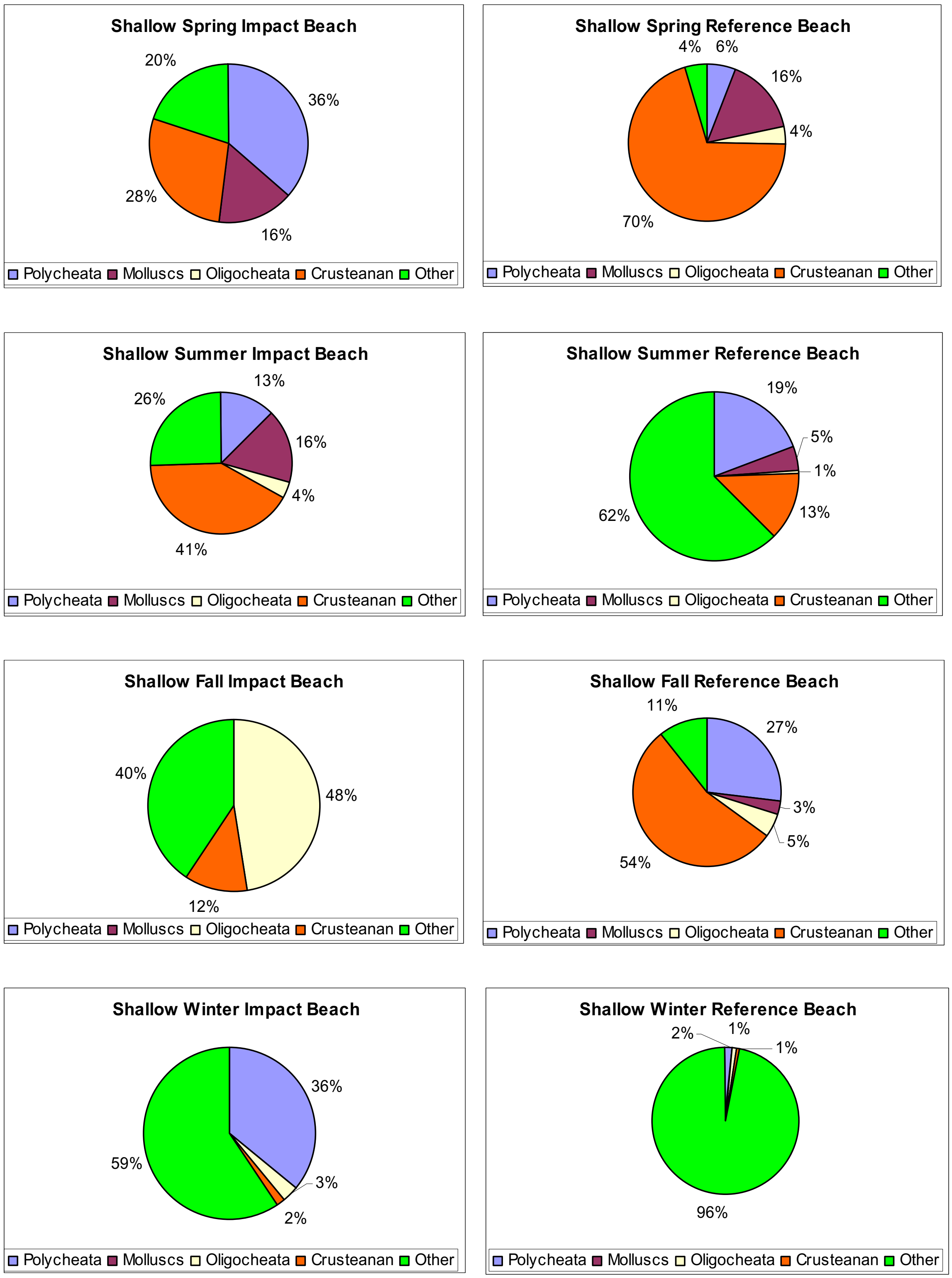

Figure 3-6. Community composition of benthic organisms collected in the shallow habitat of the impact and reference beaches in Dare County, NC.

In the shallow beach habitat, although differences in abundances of major taxonomic groups between the two beaches were apparent, overall total infauna abundance was similar between the two beaches in all seasons (Figure 3-7). Mean infauna abundance was highest in the spring and summer, fell to a low in fall, and increased somewhat during the winter sampling period (Figure 3-7). Although differences in mean infauna biomass was detected between the beaches, in general, biomass was lowest during the summer and winter sampling periods, as was the case in the swash habitat (Figure 3-8). Both measures of diversity were very similar between the reference and impact beaches in all seasons sampled (Figures 3-9 and 3-10). As in the swash habitat, the mean number of infauna taxa collected from each station in the shallow area was low, less than 4 taxa per station (Figure 3-9).

3.2.3 Borrow Area

A total of 168 distinct infauna and epifauna taxa were collected from both the borrow and reference site. Of the 168 total taxa collected, 39 taxa were unique to the borrow site only and 31 taxa were unique to the reference site only. Only one species, the polychaete worm, *Parougia caeca*, was collected frequently in the borrow site but was not collected in the reference site (mean of 457/m^2). All of the other taxa unique to either sampling site were only collected in low numbers in the other sampling site. In general, the top ten taxa collected overall were dominant in both sampling sites (Table 3-5). The dominant taxa collected from both sites were all worms, nine taxa of which were polychaetes (Table 3-5). The top ten dominant taxa by weight also consisted of six polychaete worm species but also included some large species of snails, clams, and sand dollars (Table 3-6).

The macrobenthic community was similar between the borrow and reference site. Community composition of the borrow and reference sites in all seasons, except the borrow site in winter, was dominated by polychaete worms (Figure 3-11). In the borrow site during the winter sampling site, a high number of nemertean worms were collected leading to higher proportion of miscellaneous taxa (Table 3-5).

Mean benthic infauna abundance was highest in summer, averaging over 10, 000 individuals/m^2 at both sampling sites and was generally lowest in the fall (Figure 3-12). The borrow site consistently had fewer organisms than the reference site in all sampling seasons (Figure 3-12). Mean total biomass was also highest in summer and low in fall and winter (Figure 3-13). Biomass was also lower in the borrow site than the reference site, however, the difference in biomass was not as great as with abundance (Figure 3-13). The mean number of taxa collected from each offshore sampling station followed the same pattern of high numbers of taxa collected in the summer (over 30 infauna taxa) to a low in the fall and winter (less than 25 in the reference site and less than 15 in the borrow, Figure 3-14). Again the borrow site had fewer mean number of infauna taxa collected in all seasons but the difference between the sampling sites was not as apparent in the Shannon Weiner Diversity Index (Figure 3-15).

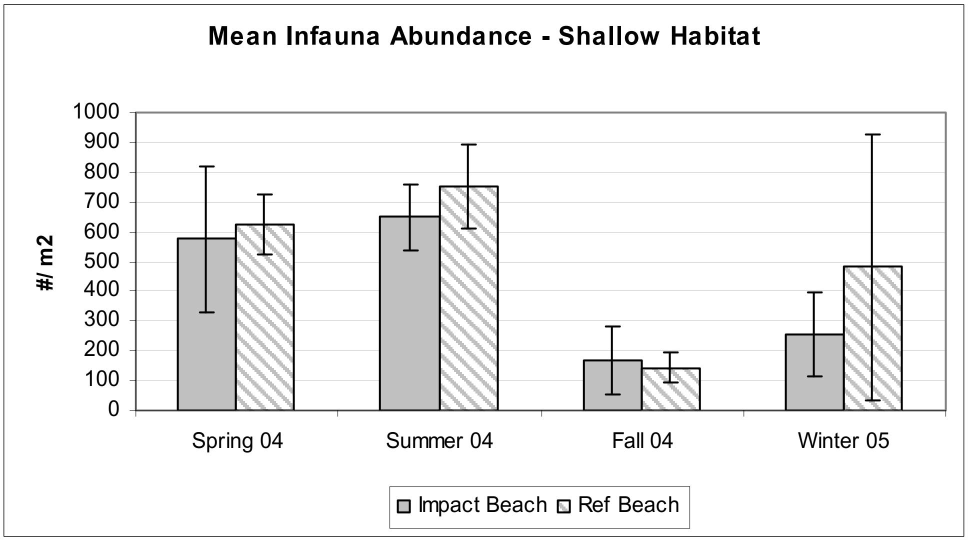

Figure 3-7. Mean total infauna abundance collected from the shallow habitat at the impact and reference beaches in Dare County, NC.

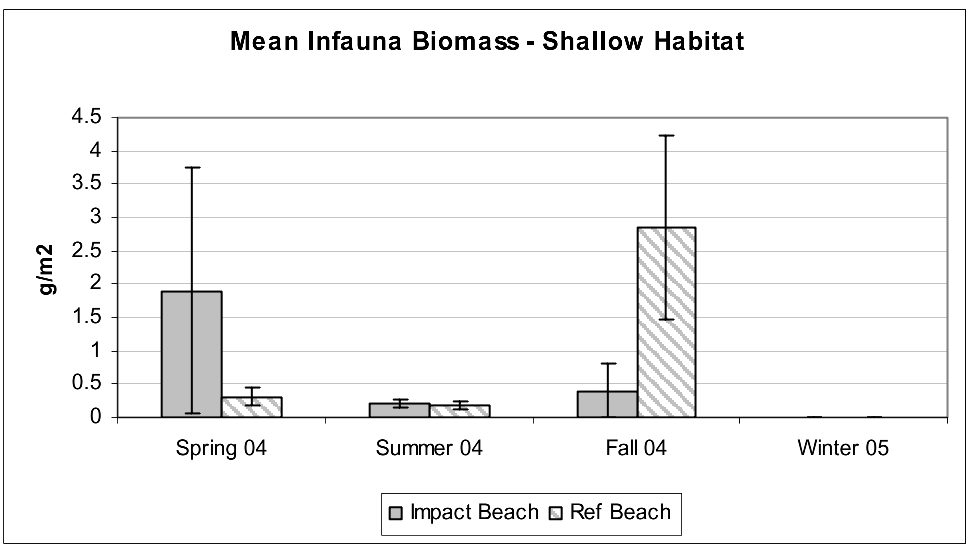

Figure 3-8. Mean total infauna biomass collected from the shallow habitat at the impact and reference beaches in Dare County, NC.

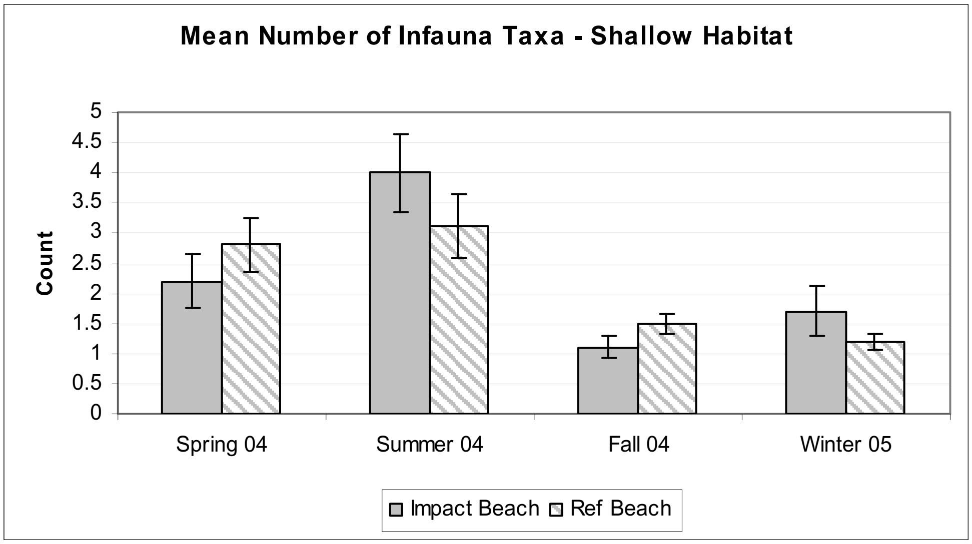

Figure 3-9. Mean number of infauna taxa collected from the shallow habitat at the impact and reference beaches in Dare County, NC.

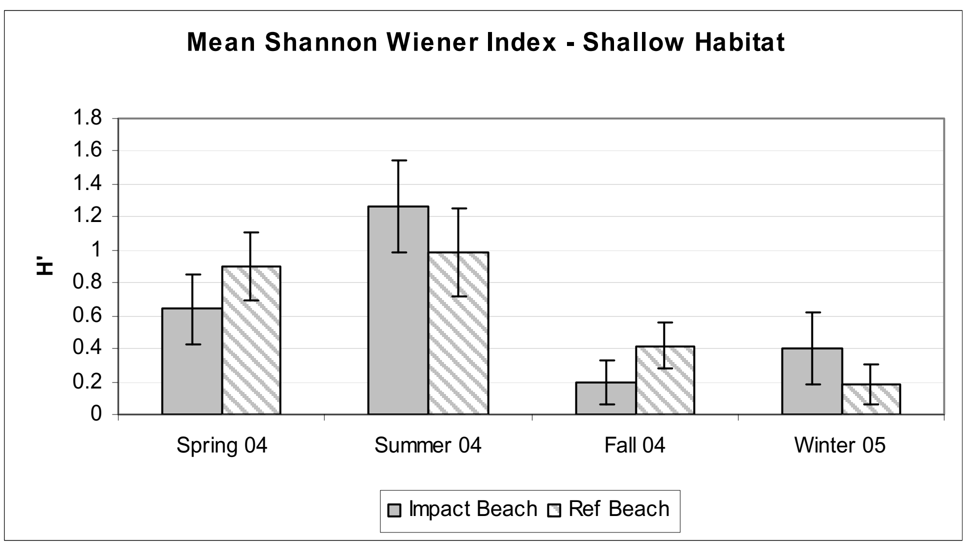

Figure 3-10. Mean Shannon Wiener Diversity Index measured from the shallow habitat at the impact and reference beaches in Dare County, NC.

Table 3-5. Mean abundance (#/m^2) of the top ten macrobenthic taxa collected in the borrow and reference borrow sites offshore of Dare County, NC.

Taxonomic Group	Taxonomic Name	Spring		Summer		Fall		Winter	
		Borrow	Ref.	Borrow	Ref.	Borrow	Ref.	Borrow	Ref.
Nemertina	Nemertina	100.00	4.55	247.73	56.82	77.27	22.73	918.18	18.18
Annelida : Polychaeta	*Amastigos caperatus*	202.27	2270.45	647.73	2552.26	120.45	2118.18	29.55	4074.99
	Apoprionospio pygmaea	604.54	886.36	277.27	1840.90	18.18	1747.72		772.72
	Aricidea catherinae	211.36	202.27	11.36	54.55	84.09	163.64		581.82
	Caulleriella sp. B (Blake)	118.18	381.82	22.73	400.00	31.82	125.00	2.27	286.36
	Mediomastus ambiseta	343.18	897.72	822.72	161.36	184.09	113.64		6.82
	Owenia fusiformis	579.54	79.55	3899.99	604.54	215.91	513.63	25.00	713.63
	Polygordius spp.	54.55	215.91	70.45	90.91	22.73	329.54	4.55	772.72
	Spiophanes bombyx	511.36	2120.45	2184.08	8979.52	145.45	1706.81	11.36	1899.99
	Tharyx sp. A Morris	579.54	79.55	3899.99	604.54	215.91	513.63	25.00	713.63

Table 3-6. Mean biomass (g/m^2) of the top ten macrobenthic taxa (based on biomass) collected in the borrow and reference borrow sites offshore of Dare County, NC.

Taxonomic Group	Taxonomic Name	Spring		Summer		Fall		Winter	
		Borrow	Ref.	Borrow	Ref.	Borrow	Ref.	Borrow	Ref.
Annelida : Polychaeta	*Amastigos caperatus*	0.0764	0.1382	0.0256	0.0655	0.0077	0.0710	0.0005	0.1182
	Apoprionospio pygmaea	0.0907	0.1377	0.0215	0.1339	0.0020	0.2068		0.0891
	Glycera dibranchiata	0.1961	0.2392	0.0315	0.0041		0.2936	0.0018	0.0559
	Nephtys picta	0.0833	0.1143	0.0618	0.1825	0.0389	0.2425	0.0132	0.2718
	Owenia fusiformis	0.0236	0.0777	0.0452	0.4220	0.0015	0.6477		0.5400
	Tharyx sp. A Morris	0.1040	0.4489	0.1382	0.7477	0.0232	0.2159	0.0018	0.2667
Mollusca : Gastropoda	*Nassarius trivittatus*		0.1857	0.2661	0.8376	0.0530	0.1601	0.0077	0.1218
	Polinices duplicatus			1.1525					
Mollusca : Bivalvia	*Ensis directus*	0.2127	0.0047	0.3518	0.5348	0.0005	0.0002		0.0001
Echinodermata : Echinoidea	*Mellita quinquiesperforata*		0.0077	1.5423	2.6027		0.0001		

Figure 3-11. Community composition of benthic organisms collected at the borrow and reference borrow sites offshore of Dare County, NC.

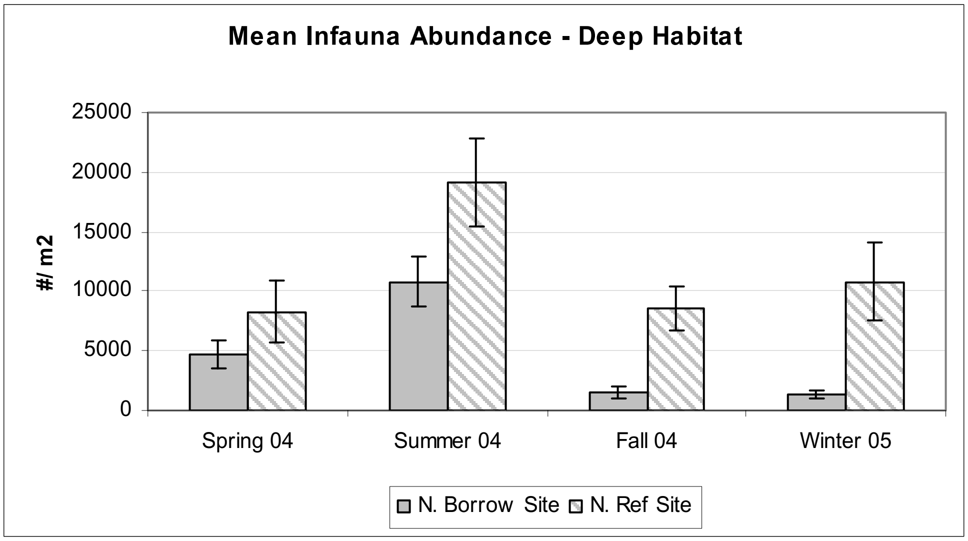

Figure 3-12. Mean total infauna abundance collected from the borrow and reference sites.

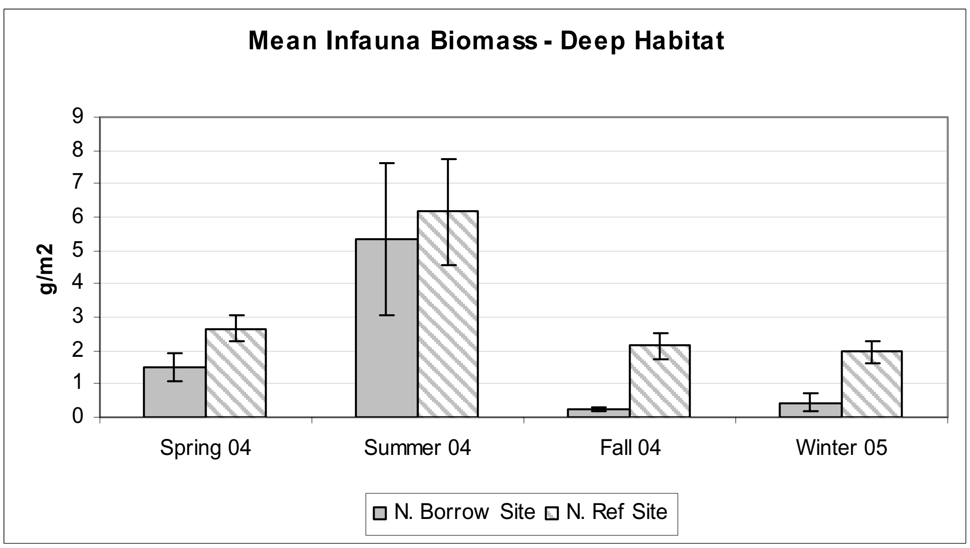

Figure 3-13. Mean total infauna biomass collected from the borrow and reference borrow sites offshore of Dare County, NC.

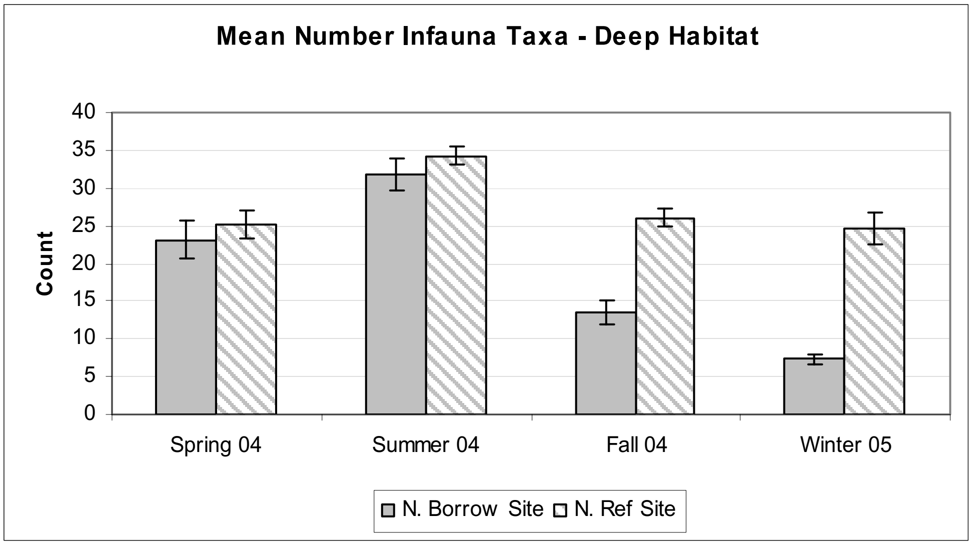

Figure 3-14. Mean total number of infauna taxa collected from the borrow and reference borrow sites offshore of Dare County, NC.

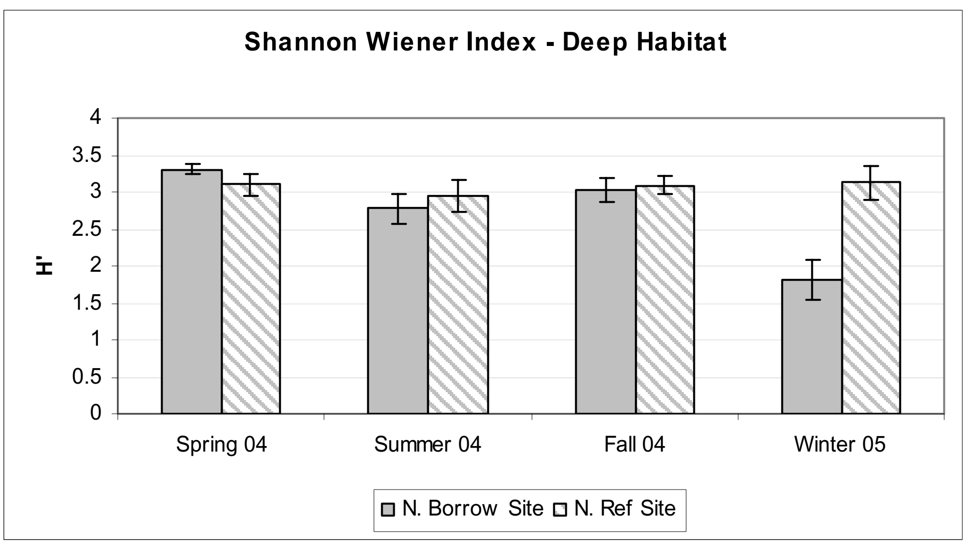

Figure 3-15. Mean Shannon Wiener Diversity Index measured from the northern borrow and reference borrow sites offshore of Dare County, NC.

Water quality collected during benthic sampling does not show any differences between the borrow sites or the reference (Table 3-7). All measurements varied seasonally, but values were typical of oceanic conditions in all seasons. Temperature ranged from a low of 6.3 ^{o}C in the winter to a high of 18.8 ^{o}C in the summer and differences between the sites did not vary more that 0.1 ^{o}C during any season. Seasonal salinities fluctuated from over 40 ppt in the summer to lower than 30 ppt at both sites in the winter (Table 3-7). Dissolved oxygen (DO) values were good at both sites and remained constant from spring through fall sampling, with a rise of nearly 2 ppt at both sites in the winter. DO was slightly higher at the reference site during all seasonal sampling. PH values at the borrow site and reference borrow site were nearly neutral (PH 7) in spring, summer, and winter, and slightly basic in the fall sampling (Table 3-7).

Table 3-7. Summary of water quality values collected in the spring, summer, fall and winter on the bottom at the northern borrow and borrow reference sites offshore of Dare County, NC.

Season	Temperature (c)		Salinity (ppt)		DO (mg/l)		pH	
	Borrow	Reference	Borrow	Reference	Borrow	Reference	Borrow	Reference
Spring	9.3	9.3	34.0	35.0	7.5	7.6	7.6	7.6
Summer	18.8	18.8	40.6	41.4	7.2	7.8	7.5	7.6
Fall	14.8	14.7	30.8	30.4	7.8	8.6	8.2	8.2
Winter	6.3	6.4	28.9	29.5	10.0	11.6	7.6	7.6

3.3 FISH

3.3.1 Impact Beach and Reference Site

Seining was conducted at the beach sites to characterize seasonal densities and community differences of large fish and invertebrate species residing in the surf zone. Overall, a total of 4,863 individuals were collected from a combination of 37 seines at the impact beach site and 37 seines at the reference beach. In the collections there were a total of 42 species of fish including 7 species of sharks, skates, and rays (Table 3-8). In addition, there were 7 invertebrate species, represented by 6 decapod crustations and the horseshoe crab.

The seasonal catches at both beaches exhibited similar trends of total species relative abundance (CPUE), mean numbers of species, and community diversity (Figure 3-16). For both beaches, the mean CPUE varied greatly between seasons and was highest in the spring. Summer had the second highest mean total CPUE and winter had the lowest mean total CPUE. The mean number of species and mean diversity were both highest in the summer for both reference and impact beaches. Spring had the second highest number of species and diversity while winter had the lowest mean number of species and mean diversity (Figure 3-16). In general, differences in measured values between beaches were minimal in all seasons except the total abundance in the summer. This is primarily due to large catches of the schooling fish Atlantic menhaden at the impact beach (Table 3-8). The abundance of all other fish collected between the beaches during that season is comparable.

Table 3-8. Mean seasonal catch per unit effort (CPUE) of fish and mobile benthos collected in the haul seines at the impact and reference beaches in Dare County, NC.

Taxonomic Name	Common Name	Spring		Summer		Fall		Winter	
		Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.
Fish									
Alosa pseudoharengus	Alewife	0.19						0.75	
Alosa sapidissima	American shad	1.31	1.69	1.07					
Micropogonias undulatus	Atlantic croaker		1.31	1.34	0.54	0.19			0.38
Brevoortia tyrannus	Atlantic menhaden	54.41	0.75	123.29	4.56			0.19	
Selene setapinnis	Atlantic moonfish			0.8	0.27				
Menidia menidia	Atlantic silverside	0.38							
Chaetodipterus faber	Atlantic spadefish				0.54				
Dasyatis sabina	Atlantic stingray	0.94	1.69	0.27	0.8				
Opisthonema oglinum	Atlantic thread herring	12.38							
Larimus fasciatus	Black drum			6.16	1.61	5.25			
Pomatomus saltatrix	Bluefish	0.56	2.44	1.34	2.68				
Myliobatis freminvillei	Bullnose ray		0.38						
Peprilus triacanthus	Butterfish	0.38	0.75	1.07					
Raja eglanteria	Clearnose skate	1.13	3.75	0.27		1.13			
Rhinoptera bonasus	Cownose ray	54.6	1.13						
Caranx hippos	Crevalle jack			0.27					
Trachinotus carolinus	Florida pompano			12.33	12.87				
Dorosoma cepedianum	Gizzard shad	0.38	0.38	6.97	6.43	0.19		0.19	0.94
Menticirrhus littoralis	Gulf kingfish	0.38	0.19	2.14	2.41		0.19		
Peprilus alepidotus	Harvestfish	21.01	5.07	17.69	4.02				
Alosa mediocris	Hickory shad				1.07	1.88	1.31	2.25	0.56
Selene vomer	Lookdown			1.61	1.88				
Menticirrhus saxatilis	Northern kingfish	0.56	0.56						
Sphoeroides maculatus	Northern puffer	1.31	2.44		0.27	0.19			

Table 3-8. (Continued)

Taxonomic Name	Common Name	Spring		Summer		Fall		Winter	
		Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.
Orthopristis chrysoptera	Pigfish				0.27				
Sciaenops ocellatus	Red drum			0.54		0.94	0.38		
Archosargus probatocephalus	Sheepshead		0.56			0.19			
Bairdiella chrysoura	Silver perch		0.38						
Gymnura micrura	Smooth butterfly ray		0.56						
Mustelus canis	Smooth dogfish	0.94	3.94						
Menticirrhus americanus	Southern kingfish	0.94	0.94	3.75	4.56				
Dasyatis americana	Southern stingray	3.75	14.63						
Scomberomorus maculatus	Spanish mackerel			0.27					
Leiostomus xanthurus	Spot	130.02	208.82	57.09	39.4				
Cynoscion nebulosus	Spotted seatrout	0.56	0.56	0.8	1.88	0.38	0.19		
Morone saxatilis	Striped bass			2.14	0.27	0.38	1.5		1.31
Chilomycterus schoepfi	Striped burrfish	44.84	11.07						
Mugil cephalus	Striped mullet			2.14	0.8				
Paralichthys dentatus	Summer flounder	0.19		1.34	0.54	0.56			
Cynoscion regalis	Weakfish	4.13	9.57	1.07					
Mugil curema	White mullet				0.27				
Scophthalmus aquosus	Windowpane	0.19		3.22	1.88	0.38	0.75		
Invertebrates									
Cancer irroratus	Atlantic rock crab		0.56			0.38	0.19		
Callinectes sapidus	Blue crab	0.94	1.13	0.27		0.19	0.19		
Ovalipes stephensoni	Coarsehand lady crab					0.38			
Limulus polyphemus	Horseshoe crab		0.19						
Ovalipes ocellatus	Lady crab	0.19	0.94	2.41	5.09	27.96	4.69		
Libinia emarginata	Portly spider crab					0.19			
Arenaeus cribrarius	Speckled swimming crab				0.27				

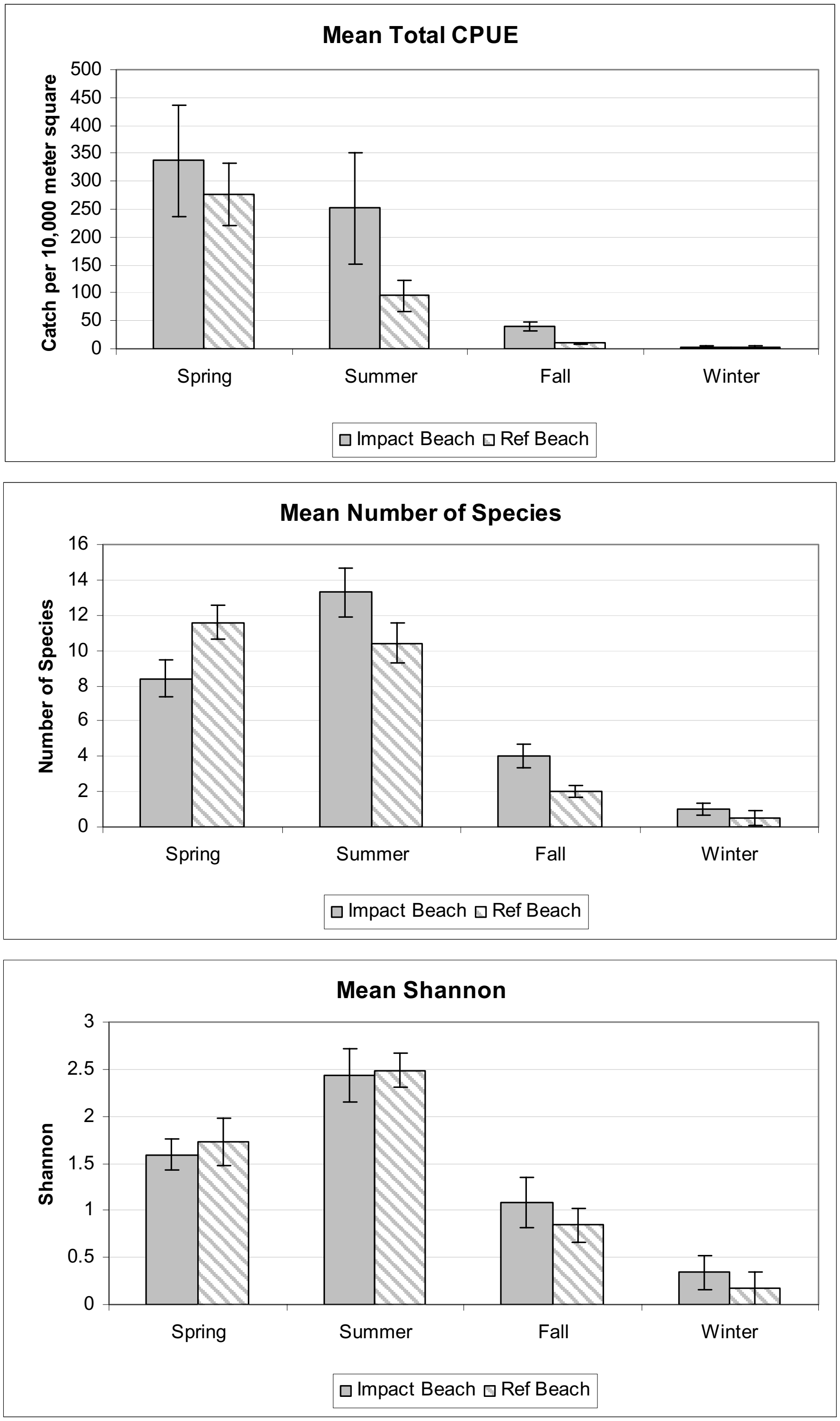

Figure 3-16. Seasonal mean total species CPUE, number of species, and species diversity collected in the haul seines at the impact and reference beaches in Dare County, NC.

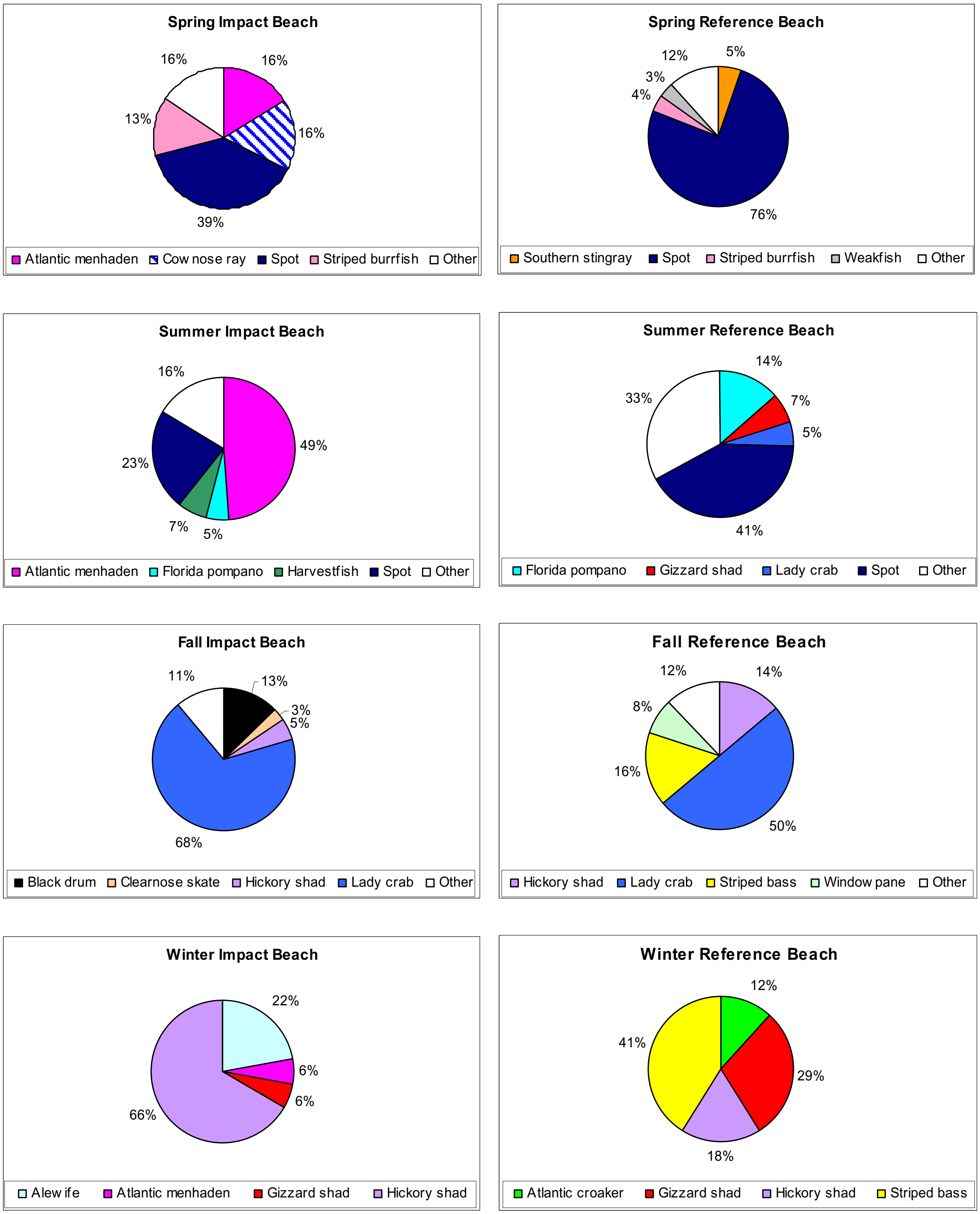

Figure 3-17. Community composition of fish and mobile benthos collected in the haul seines at the impact and reference beaches in Dare County, NC.

Several commercial, recreational, and ecologically important species were collected at both beaches during the first year. In particular, spot were abundant in the spring and summer surveys (Table 3-8), and comprised the majority of the catch in both seasons (Figure 3-17). Florida pompano, an important recreational fish, was present in equal numbers at both beaches in the summer (Table 3-8). The Atlantic menhaden, was collected at both beaches, but was most abundant in the spring and summer at the impact beach (Table 3-8 and Figure 3-17). In the winter, only four species of Alosids and the striped bass were collected in the surf zone. Between them, the hickory shad (66% of the total catch) was most abundant at the impact beach and striped bass accounted for 41% of the catch at the reference beach.

There were several invertebrate species collected in the seines throughout the first year of monitoring (Table 3-8). Although the seine is not necessarily suited to capture crabs and other invertebrates effectively, it is important to document invertebrates collected by the seine because of their forage value to fish. The most notable invertebrate collected in the seines was the Lady crab, which accounted for the majority of the total catches during the fall collections (Table 3-8 ; Figure 3-17).

3.3.2 Ocean Borrow and Reference Sites

Trawling was conducted at the borrow sites and borrow reference site to characterize seasonal densities of large fish and invertebrate species residing offshore. Overall, a total of 466 individuals were collected from a combination of 46 trawls at the borrow sites and 46 at the reference borrow site. In the collections there were a total of 32 species of fish including 7 species of sharks, skates, and rays (Table 3-9). In addition, there were 4 invertebrate species, represented by 3 decapod crustations and squid. Unlike the haul seines, seasonal trawling at the borrow and reference sites captured very few species in low abundance (Table 3-9). The spring had the highest collection of individuals at both sites with 342 organisms, which accounted for nearly 75% of the yearly collection.

The seasonal catches at the borrow sites and the borrow reference site followed similar trends of total species relative abundance (CPUE), mean numbers of species, and community diversity (Figure 3-18). The mean CPUE varied greatly between seasons and was highest in the spring for both sites. Catches were low in the summer and fall surveys and only one windowpane flounder was collected in the winter survey (Table 3-9). The reference borrow had the highest mean number of species in the fall and was slightly lower than the borrow site in the spring. The mean number of species for the borrow site was highest in the spring and second highest in the fall. Community diversity trends were similar to mean number of species at both sites, with the highest diversity in spring and lowest in the winter (Figure 3-18).

In the spring collections at the borrow site, weakfish and spotted hake had the highest CPUE and were responsible for 44% and 34%, of the total catch, respectively. Spotted hake had the highest CPUE at the reference site and accounted for over 50% of the total catch (Table 3-9 and Figure 3-19). Pinfish and Atlantic croaker were the most abundant species at the borrow site in the summer and the Atlantic croaker, pigfish, and spot were collected in nearly equal numbers

Table 3-9. Mean seasonal catch per unit effort (CPUE) of fish and mobile benthos collected in trawls at the borrow and reference borrow sites offshore of Dare County, NC.

Taxonomic Name	Common Name	Spring		Summer		Fall		Winter	
		Borrow	Ref.	Borrow	Ref.	Borrow	Ref.	Borrow	Ref.
Fish									
Micropogonias undulatus	Atlantic croaker	0.12	0.28	0.19	0.08	0.53	0.72		
Larimus fasciatus	Banded drum						0.2		
Anchoa mitchilli	Bay anchovy	3.14			0.07	0.34	1.49		
Centropristis striata	Black sea bass								
Pomatomus saltatrix	Bluefish					0.09	0.09		
Peprilus triacanthus	Butterfish	2.83	0.28	0.1		0.34	0.71		
Raja eglanteria	Clearnose skate	0.81	0.56			0.09			
Rhinoptera bonasus	Cownose ray	0.12							
Menticirrhus littoralis	Gulf kingfish	0.14							
Peprilus alepidotus	Harvestfish					0.09			
Sphoeroides maculatus	Northern puffer		0.16						
Orthopristis chrysoptera	Pigfish			0.1	0.08	0.08			
Lagodon rhomboides	Pinfish	0.14	0.16	0.29					
Dasyatis centroura	Roughtail stingray		0.15						
Bairdiella chrysoura	Silver perch					0.46			
Gymnura micrura	Smooth butterfly ray					0.09			
Mustelus canis	Smooth dogfish		0.66						
Menticirrhus americanus	Southern kingfish						0.11		
Dasyatis americana	Southern stingray	0.12	0.38						
Squalus acanthias	Spiny dogfish	0.14				0.17	0.33		
Leiostomus xanthurus	Spot	0.43			0.1				
Urophycis regia	Spotted hake	13.5	3.97				0.35		
Anchoa hepsetus	Striped anchovy	0.14							
Chilomycterus schoepfi	Striped burrfish			0.09			0.08		

Table 3-9 (Continued)

Taxonomic Name	Common Name	Spring		Summer		Fall		Winter	
		Borrow	Ref.	Borrow	Ref.	Borrow	Ref.	Borrow	Ref.
Prionotus evolans	Striped searobin					0.08			
Paralichthys dentatus	Summer flounder						0.09		
Cynoscion regalis	Weakfish	17.45	0.27			1.27	1.54		
Scophthalmus aquosus	Windowpane							0.17	
Invertebrates									
Penaeus aztecus	Brown shrimp			0.09					
Ovalipes ocellatus	Lady crab				0.08				
Crangon septemspinosa	Sand shrimp	0.13	0.13						
Cephalopoda	Squids	0.42	0.41				0.24		

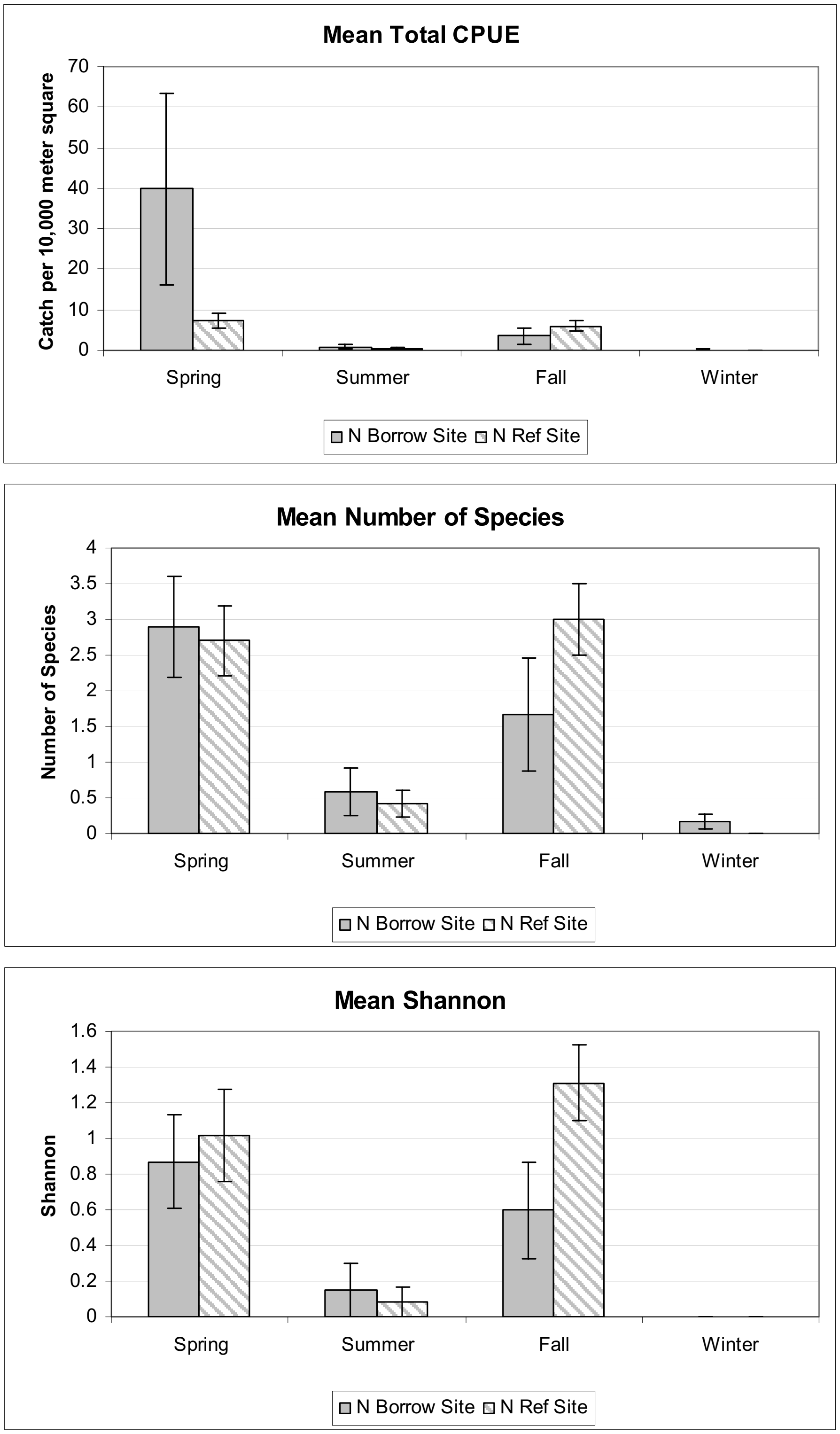

Figure 3-18. Seasonal mean total species CPUE, number of species, and species diversity of species collected in trawls at the borrow and reference borrow sites offshore of Dare County, NC.

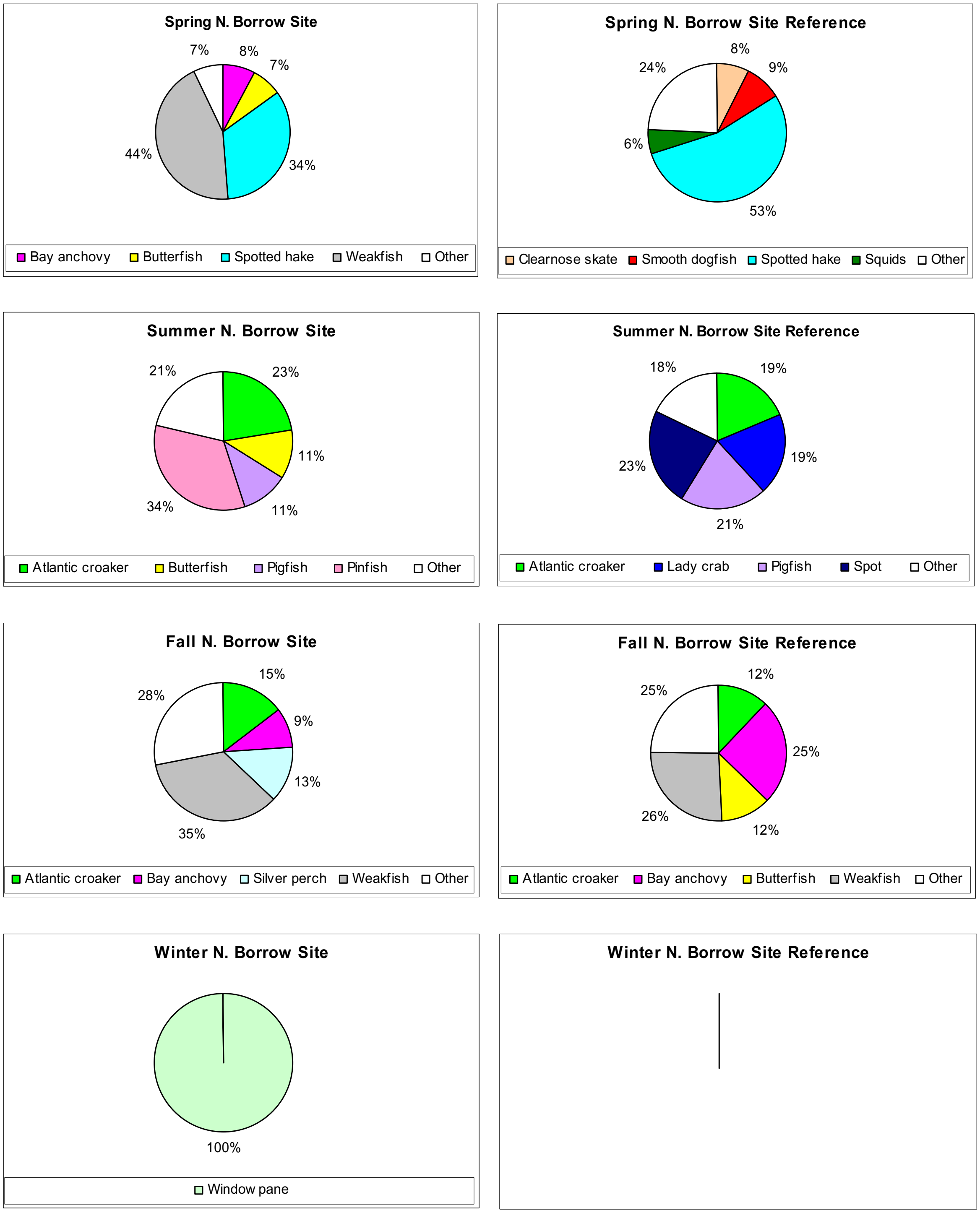

Figure 3-19. Community composition of fish and mobile benthos collected in trawls at the borrow and reference borrow sites offshore of Dare County, NC.

at the reference site (Table 3-9 and Figure 3-19). In the fall, weakfish, Atlantic croaker, and bay anchovy were collected in similar numbers at the borrow and reference sites comprising over 50% of the catches at both sites.

Very few invertebrate species were collected in the trawls throughout the first year of monitoring (Table 3-9). The squid was the most frequently occurring, collected at the borrow and reference sites in the spring and again at the reference in the fall survey. Two species shrimp were collected, the brown shrimp collected at the borrow site in the summer and the sand shrimp collected at both sites in the spring. The lady crab was collected at the reference site in the fall and accounted for 23% of the total catch in that season.

3.4 STOMACH CONTENTS

A total of 304 individual fish from several species were collected at the beaches and ocean borrow sites for stomach content analysis during the first year of sampling (Table 3-10 and Table 3-11). Nine species were collected in the seines and 6 were collected in the trawls. Seventy one percent of all stomachs collected contained prey items. Seven major prey groups were identified, including a group of unknown items, usually unidentifiable because of advanced digestion. For all the fishes studied, shrimp was the most frequently consumed prey item occurring in 22% of all stomachs containing prey items (Figure 3-20). Emerita, crabs, and bivalves were also commonly consumed occurring in 19, 11, and 7% of stomachs, respectively. Tables 3-10 and 3-11 present summaries of the abundance, occurrence and percent index of relative importance (%IRI) for all prey items found in fish stomachs at the beaches and borrow sites for all seasons but winter, when no target fish for stomach analysis were present in the collections. The food habits of all fish species collected with prey items in their stomachs are described below. Because of low sample sizes and inconsistent collections of target species in all seasons, only seasonal trends in food habits will be addressed for species with sufficient data.

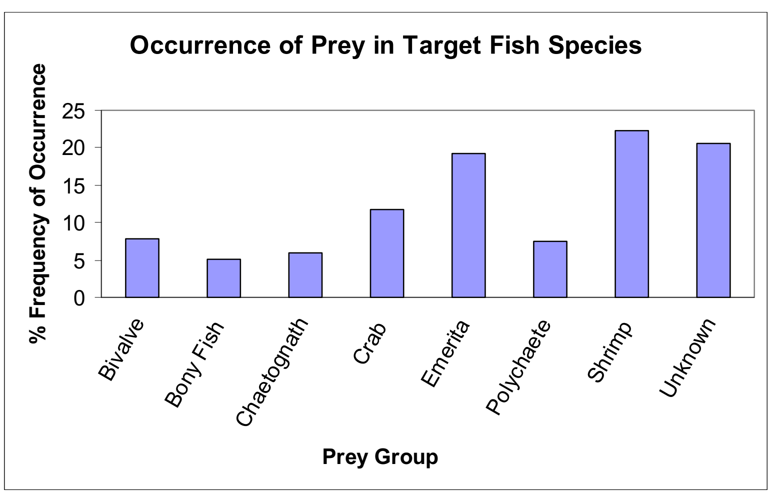

Figure 3-20. Frequency of occurrence (%) of prey groups in the stomachs of all target fish species collected in seines and trawls at the impact beach, reference beach, borrow site and borrow site reference in Dare County, NC.

Table 3-10. Summary of prey items found in stomachs of target fish species collected in trawls at the borrow and reference borrow sites offshore of Dare County, NC. *n* = number of stomachs dissected, %full = percentage of stomachs with prey item

Season	Site	Fish Species	*n*	% Full	Bivalve	Bony Fish	Chaetog-nath	Crab	Emerita	Poly-chaete	Shrimp	Unknown	Bivalve	Bony Fish	Chaetog-nath	Crab	Emerita	Poly-chaete	Shrimp	Unknown
Spring	Borrow	Altantic croaker	1	100	0.0	0.0	25.0	0.0	0.0	0.0	75.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	10.4	87.5
		Gulf kingfish	1	100	50.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0	75.0	0.0
		Spot	4	100	21.4	28.6	0.0	7.1	7.1	0.0	35.7	0.0	11.4	62.5	0.0	0.2	0.0	0.0	1.3	24.6
		Spotted hake	18	100	1.2	3.5	3.5	2.4	0.0	0.0	89.4	0.0	0.5	30.3	0.0	0.2	0.0	0.0	24.5	44.6
	Reference	Spotted hake	14	100	0.0	9.7	3.2	0.0	0.0	3.2	83.9	0.0	0.0	64.9	0.0	0.0	0.0	0.3	11.4	23.3
Summer	Borrow	Altantic croaker	2	100	0.0	0.0	11.1	22.2	0.0	66.7	0.0	0.0	0.0	0.0	2.9	8.8	0.0	11.8	0.0	76.5
	Reference	Altantic croaker	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Spot	1	100	1.0	0.0	0.0	0.0	0.0	98.5	0.5	0.0	4.5	0.0	0.0	0.0	0.0	95.3	0.2	0.0
Fall	Borrow	Altantic croaker	7	100	0.0	0.0	0.0	1.0	0.0	70.8	28.1	0.0	0.0	0.0	0.0	0.2	0.0	81.1	6.9	11.7
		Silver perch	4	100	0.0	0.0	0.0	0.0	0.0	3.1	96.9	0.0	0.0	0.0	0.0	0.0	0.0	30.5	68.4	1.1
	Reference	Altantic croaker	8	100	0.0	0.0	0.7	0.0	0.0	92.4	6.9	0.0	0.0	0.0	0.2	0.0	0.0	68.0	0.2	31.5
		Southern kingfish	1	100	0.0	14.3	0.0	0.0	0.0	57.1	28.6	0.0	0.0	15.4	0.0	0.0	0.0	16.7	10.3	57.7
		Spotted hake	4	50	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
					% F								% IRI							
Season	Site	Fish Species	*n*	% Full	Bivalve	Bony Fish	Chaetog-nath	Crab	Emerita	Poly-chaete	Shrimp	Unknown	Bivalve	Bony Fish	Chaetog-nath	Crab	Emerita	Poly-chaete	Shrimp	Unknown
Spring	Borrow	Altantic croaker	1	100	0.0	0.0	50.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	24.1	0.0	0.0	0.0	75.9	0.0
		Gulf kingfish	1	100	50.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	37.5	0.0	0.0	0.0	0.0	0.0	62.5	0.0
		Spot	4	100	20.0	20.0	0.0	20.0	20.0	0.0	20.0	0.0	18.7	51.9	0.0	4.2	4.1	0.0	21.1	0.0
		Spotted hake	18	100	20.0	20.0	20.0	20.0	0.0	0.0	20.0	0.0	1.1	21.7	2.3	1.6	0.0	0.0	73.3	0.0
	Reference	Spotted hake	14	100	0.0	25.0	25.0	0.0	0.0	25.0	25.0	0.0	0.0	42.2	1.8	0.0	0.0	2.0	53.9	0.0
Summer	Borrow	Altantic croaker	2	100	0.0	0.0	25.0	25.0	0.0	25.0	0.0	25.0	0.0	0.0	7.0	15.5	0.0	39.2	0.0	38.2
	Reference	Altantic croaker	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Spot	1	100	33.3	0.0	0.0	0.0	0.0	33.3	33.3	0.0	2.7	0.0	0.0	0.0	0.0	96.9	0.3	0.0
Fall	Borrow	Altantic croaker	7	100	0.0	0.0	0.0	25.0	0.0	25.0	25.0	25.0	0.0	0.0	0.0	0.6	0.0	76.0	17.5	5.9
		Silver perch	4	100	0.0	0.0	0.0	0.0	0.0	33.3	33.3	33.3	0.0	0.0	0.0	0.0	0.0	16.8	82.7	0.5
	Reference	Altantic croaker	8	100	0.0	0.0	25.0	0.0	0.0	25.0	25.0	25.0	0.0	0.0	0.5	0.0	0.0	80.2	3.6	15.8
		Southern kingfish	1	100	0.0	25.0	0.0	0.0	0.0	25.0	25.0	25.0	0.0	14.8	0.0	0.0	0.0	36.9	19.4	28.8
		Spotted hake	4	50	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0

Table 3-11. Summary of prey items found in stomachs of target fish species collected in seines at the impact and reference beaches in Dare County, NC. n = number of stomachs dissected, %full = percentage of stomachs with prey items, %N = percent numeric

					% N								% W							
Season	**Site**	**Fish Species**	***n***	**% Full**	**Bivalve**	**Bony Fish**	**Chaetog-nath**	**Crab**	**Emerita**	**Poly-chaete**	**Shrimp**	**Unknown**	**Bivalve**	**Bony Fish**	**Chaetog-nath**	**Crab**	**Emerita**	**Poly-chaete**	**Shrimp**	**Unknown**
Spring	Impact	Black drum	5	80	30.0	0.0	0.0	0.0	30.0	0.0	40.0	0.0	30.2	0.0	0.0	0.0	65.8	0.0	4.0	0.0
		Gulf kingfish	2	100	0.0	0.0	0.0	0.0	33.3	0.0	66.7	0.0	0.0	0.0	0.0	0.0	68.5	0.0	24.0	7.6
		Northern kingfish	3	67	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	85.5	0.0	0.0	14.5
		Southern kingfish	2	50	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.6	0.0	0.0	0.0	68.4
		Spot	27	63	3.3	0.0	70.0	0.0	6.7	6.7	13.3	0.0	0.3	0.0	0.1	0.0	6.0	0.0	0.3	93.3
	Reference	Altantic croaker	8	88	0.0	14.3	33.3	19.0	0.0	9.5	23.8	0.0	0.0	84.2	0.3	0.0	0.0	0.0	0.3	15.1
		Gulf kingfish	2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Northern kingfish	4	50	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	14.9	69.1	0.0	0.0	16.0
		Silver perch	2	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
		Southern kingfish	3	33	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
		Spot	17	65	2.4	0.8	24.4	1.6	0.0	0.0	70.9	0.0	0.9	2.5	0.3	25.0	0.0	0.0	19.0	52.3
Summer	Impact	Black drum	13	77	8.6	0.0	0.0	0.0	60.0	0.0	31.4	0.0	10.9	0.0	0.0	0.0	83.0	0.0	5.4	0.7
		Florida pompano	16	69	2.1	0.0	0.0	0.0	52.6	0.0	45.4	0.0	0.7	0.0	0.0	0.0	96.0	0.0	0.4	3.0
		Gulf kingfish	2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Southern kingfish	7	57	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.7	0.0	0.0	0.0	7.3
		Spot	25	64	0.1	0.0	0.0	0.4	3.0	0.0	96.5	0.0	0.7	0.0	0.0	0.0	62.4	0.0	19.7	17.2
	Reference	Altantic croaker	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Florida pompano	14	43	0.0	0.0	0.0	0.0	93.6	0.0	6.4	0.0	0.0	0.0	0.0	0.0	89.7	0.0	0.2	10.1
		Gulf kingfish	7	86	0.0	0.0	0.0	10.0	90.0	0.0	0.0	0.0	0.0	0.0	0.0	34.2	64.4	0.0	0.0	1.4
		Southern kingfish	11	73	0.0	15.4	0.0	30.8	0.0	15.4	38.5	0.0	0.0	32.7	0.0	55.5	0.0	3.2	0.1	8.5
		Spot	34	62	0.3	0.0	0.0	0.1	0.1	0.2	99.3	0.0	1.7	0.0	0.0	0.7	0.3	0.1	75.2	21.9
Fall	Impact	Altantic croaker	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Black drum	17	71	0.0	0.0	0.0	0.0	25.0	0.0	75.0	0.0	0.0	0.0	0.0	0.0	88.0	0.0	6.8	5.1
		Florida pompano	5	60	0.0	0.0	0.0	0.0	37.5	0.0	62.5	0.0	0.0	0.0	0.0	0.0	97.2	0.0	2.8	0.0
		Gulf kingfish	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Red drum	4	50	0.0	12.5	0.0	37.5	50.0	0.0	0.0	0.0	0.0	1.7	0.0	19.0	79.3	0.0	0.0	0.0
		Southern kingfish	2	100	0.0	0.0	0.0	0.0	80.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	88.0	0.0	0.1	11.9
	Reference	Gulf kingfish	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Red drum	2	50	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0

Table 3-11. (Continued)

					% F								% IRI							
Season	Site	Fish Species	*n*	% Full	Bivalve	Bony Fish	Chaetog-nath	Crab	Emerita	Poly-chaete	Shrimp	Unknown	Bivalve	Bony Fish	Chaetog-nath	Crab	Emerita spp.	Poly-chaete	Shrimp	Unknown
Spring	Impact	Black drum	5	80	33.3	0.0	0.0	0.0	33.3	0.0	33.3	0.0	30.1	0.0	0.0	0.0	47.9	0.0	22.0	0.0
		Gulf kingfish	2	100	0.0	0.0	0.0	0.0	33.3	0.0	33.3	33.3	0.0	0.0	0.0	0.0	50.9	0.0	45.3	3.8
		Northern kingfish	3	67	0.0	0.0	0.0	33.3	33.3	0.0	0.0	33.3	0.0	0.0	0.0	25.0	67.7	0.0	0.0	7.3
		Southern kingfish	2	50	0.0	0.0	0.0	50.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	65.8	0.0	0.0	0.0	34.2
		Spot	27	63	16.7	0.0	16.7	0.0	16.7	16.7	16.7	16.7	1.8	0.0	35.0	0.0	6.3	3.3	6.8	46.7
	Reference	Altantic croaker	8	88	0.0	16.7	16.7	16.7	0.0	16.7	16.7	16.7	0.0	49.3	16.8	9.5	0.0	4.8	12.1	7.5
		Gulf kingfish	2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Northern kingfish	4	50	0.0	0.0	0.0	33.3	33.3	0.0	0.0	33.3	0.0	0.0	0.0	32.4	59.6	0.0	0.0	8.0
		Silver perch	2	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
		Southern kingfish	3	33	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
		Spot	17	65	16.7	16.7	16.7	16.7	0.0	0.0	16.7	16.7	1.6	1.7	12.3	13.3	0.0	0.0	44.9	26.1
Summer	Impact	Black drum	13	77	25.0	0.0	0.0	0.0	25.0	0.0	25.0	25.0	9.7	0.0	0.0	0.0	71.5	0.0	18.4	0.4
		Florida pompano	16	69	25.0	0.0	0.0	0.0	25.0	0.0	25.0	25.0	1.4	0.0	0.0	0.0	74.3	0.0	22.9	1.5
		Gulf kingfish	2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Southern kingfish	7	57	0.0	0.0	0.0	50.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	96.4	0.0	0.0	0.0	3.6
		Spot	25	64	20.0	0.0	0.0	20.0	20.0	0.0	20.0	20.0	0.4	0.0	0.0	0.2	32.7	0.0	58.1	8.6
	Reference	Altantic croaker	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Florida pompano	14	43	0.0	0.0	0.0	0.0	33.3	0.0	33.3	33.3	0.0	0.0	0.0	0.0	91.7	0.0	3.3	5.0
		Gulf kingfish	7	86	0.0	0.0	0.0	33.3	33.3	0.0	0.0	33.3	0.0	0.0	0.0	22.1	77.2	0.0	0.0	0.7
		Southern kingfish	11	73	0.0	20.0	0.0	20.0	0.0	20.0	20.0	20.0	0.0	24.1	0.0	43.1	0.0	9.3	19.3	4.2
		Spot	34	62	14.3	0.0	14.3	14.3	14.3	14.3	14.3	14.3	1.0	0.0	0.0	0.4	0.2	0.1	87.3	10.9
Fall	Impact	Altantic croaker	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Black drum	17	71	0.0	0.0	0.0	0.0	33.3	0.0	33.3	33.3	0.0	0.0	0.0	0.0	56.5	0.0	40.9	2.6
		Florida pompano	5	60	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	67.4	0.0	32.6	0.0
		Gulf kingfish	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Red drum	4	50	0.0	33.3	0.0	33.3	33.3	0.0	0.0	0.0	0.0	7.1	0.0	28.2	64.7	0.0	0.0	0.0
		Southern kingfish	2	100	0.0	0.0	0.0	0.0	33.3	0.0	33.3	33.3	0.0	0.0	0.0	0.0	84.0	0.0	10.1	5.9
	Reference	Gulf kingfish	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Red drum	2	50	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0

3.4.1 Atlantic croaker

A total of 29 Atlantic croaker were collected; 10 at the beaches and 19 at the borrow sites (Table 3-10 and 3-11). Seventy percent of the stomachs collected at the beaches and 95% of the stomachs collected from the borrow sites contained prey. Atlantic croaker collected at the beaches consumed four of the six known prey items and five prey items were found in the stomachs of fish collected at the borrow sites. Unknown organisms also contributed to some of the stomach content items. For Atlantic croaker collected at the borrow sites, both polychaetes and shrimp dominated the diet in number (%N), weight (%W) and frequency of occurrence (%F) (Table 3-11). Atlantic croaker with stomach contents were only collected in the spring at the beaches and chaetognaths and shrimp were numerically (%N) dominant, but bony fish dominated by weight (84%) and was therefore more important (49 %IRI) to the diet than any other prey group (Table 3-10).

3.4.2 Black drum

A total of 35 black drum were collected at the beach sites and none were collected at the borrow sites (Table 3-10). Seventy-four percent of black drum stomachs contained prey. The diet of black drum was very consistent throughout the seasons with only three known prey groups; bivalves, Emerita and shrimp. Very few unknown organisms were found in the black drum stomachs. Overall, Emerita dominated the diet by weight (%W) and had the highest %IRI values for all three seasons. Shrimp were numerically dominant in spring (40%N) and fall (75%N), but contributed little to the weight of prey items. Bivalves were found in black drum stomachs in the spring and summer with the highest numbers, weight, and %IRI values in the spring collection (Table 3-10).

3.4.3 Florida pompano

A total of 35 Florida pompano were collected at the beach sites and none were collected at the borrow sites (Table 3-10). Fifty-seven percent of Florida pompano stomachs contained prey. Florida pompano were only collected in the summer and fall. Similar to Black drum, the Florida pompano diet did not very between seasons containing three known prey groups; bivalves, Emerita and shrimp. Very few unknown organisms were found (Table 3-10). Overall, Emerita dominated the diet by weight (%W) and had the highest %IRI values in both seasons. Numerically (%N), more shrimp were found in fall than were Emerita, but shrimp did not contribute much to the overall weight (3%W). Bivalves contributed little to the diet of Florida pompano and were found in the stomachs only in the summer season (Table 3-10).

3.4.4 Gulf kingfish

A total of 16 gulf kingfish were collected; 15 at the beaches and one at the borrow sites (Table 3-10 and 3-11). Fifty-three percent of the stomachs collected at the beaches and the stomach from the borrow sites contained prey. Gulf kingfish were present in all seasonal collections on the beach, but prey items were only present in the spring and summer. Gulf kingfish were only found in the spring at the borrow sites. Similar to black drum and Florida pompano, much of the gulf kingfish diet consisted of Emerita and shrimp. Crabs were also found in beach fish stomachs. Bivalves and shrimp were contained in the borrow site fish (Table 3-11). Unknown organisms contributed very little to stomach content items. For beach fish, Emerita were the numerically (%N) dominant prey in the summer and shrimp were in the spring. Emerita also comprised most of the biomass and had the highest % IRI for both seasons as well. Crabs replaced shrimp in the diet of beach fish during the summer (Table 3-10).

3.4.5 Northern kingfish

A total of 7 northern kingfish were collected in the spring at the beach sites and none were collected at the borrow sites (Table 3-10). Fifty-seven percent of northern kingfish stomachs contained Emerita and crabs. In addition, some of the northern kingfish diet consisted of unknown organisms. The numbers (%N) of crabs and Emerita found in northern kingfish stomachs were similar. Emerita dominated the diet by weight (%W) and had the highest %IRI value (Table 3-10).

3.4.6 Red drum

A total of six red drum were collected in the fall at the beach sites and none were collected at the borrow sites (Table 3-10). Fifty percent of red drum stomachs contained Emerita, crabs and bony fish. Emerita dominated the diet by number (%N), weight (%W) and had the highest %IRI value (Table 3-10).

3.4.7 Silver perch

A total of six silver perch were collected; two at the beaches and four at the borrow sites (Table 3-10 and 3-11). All silver perch stomachs contained prey items. The two silver perch collected in the spring at the borrow sites contained 100% unknown organisms. Shrimp and polychaetes were the dominant prey in the four silver perch collected at the beaches in the fall (Table 3-10).

3.4.8 Southern kingfish

A total of 21 southern kingfish were collected; 20 at the beaches and one at the borrow sites (Table 3-10 and 3-11). Seventy percent of the stomachs collected at the beaches and the stomach from the borrow sites contained prey. Southern kingfish with prey were collected in all three seasons at the beaches and only in the fall at the borrow sites. Polychaetes, shrimp, and bony fish were contained in the stomachs of borrow site fish (Table 3-11). No unknown organisms were found in the borrow site fish, but unknown organisms contributed to the stomach content items of the beach fish. All prey items but bivalves were present in the stomachs of southern kingfish collected on the beach (Table 3-10). The spring and fall collections indicated a limited diet of Emerita and crabs in the spring and shrimp and Emerita in the fall. Summer diets were much more diverse with four known prey items in the stomachs. Crabs and Emerita were the most dominant and most frequently (%F) occurring prey items with the highest %IRI overall (Table 3-10). Shrimp were found in two seasons (summer and fall), but in limited numbers. Bony fish were only second to Emerita in weight (%W) and %IRI in the summer, but were not present in any other season.

3.4.9 Spot

A total of 108 spot were collected; 103 at the beaches and five at the borrow sites (Table 3-10 and 3-11). Sixty-three percent of the stomachs collected at the beaches and all the stomachs from the borrow sites contained prey. Spot with prey items were collected in the spring and summer at both the beaches and the borrow sites. Spot stomachs collected at the borrow sites contained all prey items except chaetognaths (Table 3-11). Unknown organisms also contributed to a portion of the stomach content items in fish from the beaches and the borrow sites. For beach fish, diets were similar in both the spring and summer collections (Table 3-10). Shrimp and chaetognaths were numerically (%N) dominant and exhibited the highest %IRI for spot in the spring. However, crabs and shrimp contributed higher biomass (%W) to the diet in the spring. Shrimp also dominated the summer diets by number (%N), weight (%W) and exhibited the highest %IRI. Emerita were found in both seasons, but had higher weight (%W) and %IRI in the summer (Table 3-10).

3.4.10 Spotted hake

A total of 36 spotted hake were collected at the borrow sites and none at the beaches (Table 3-11). Ninety-four percent of spotted hake stomachs contained prey. Spotted hake were only collected in the spring and fall. Unknown organisms contributed to a good portion of the stomach content items. All prey items but Emerita were present in the stomachs of spotted hake in the spring and only shrimp were present in the fall. Shrimp dominated by number (%N) in the spring and summer and also contributed the highest %IRI. However, bony fish contributed the highest weights (%W) for all prey in the spring but had lower overall %IRI (Table 3-11).

3.5 GHOST CRAB SURVEY

Ghost crabs, as inferred from ghost crab hole counts, were present in every season but the winter (Figure 3-21). Ghost crab abundance was highly variable between seasons and between beaches. The highest densities of ghost crabs were recorded in the spring on the impact beach, with over three times more ghost crabs per square meter than the reference beach in that season. The reference beach had the second highest seasonal abundance in the summer, and ghost crab abundance at that beach was greater than the impact beach in the summer and fall seasons (Figure 3-21). Ghost crab abundance on the impact beach decreased from high to low as the seasons progressed from spring to winter. However, on the control beach ghost crab abundance increased after spring and then decreased in the fall and winter (Figure 3-21).

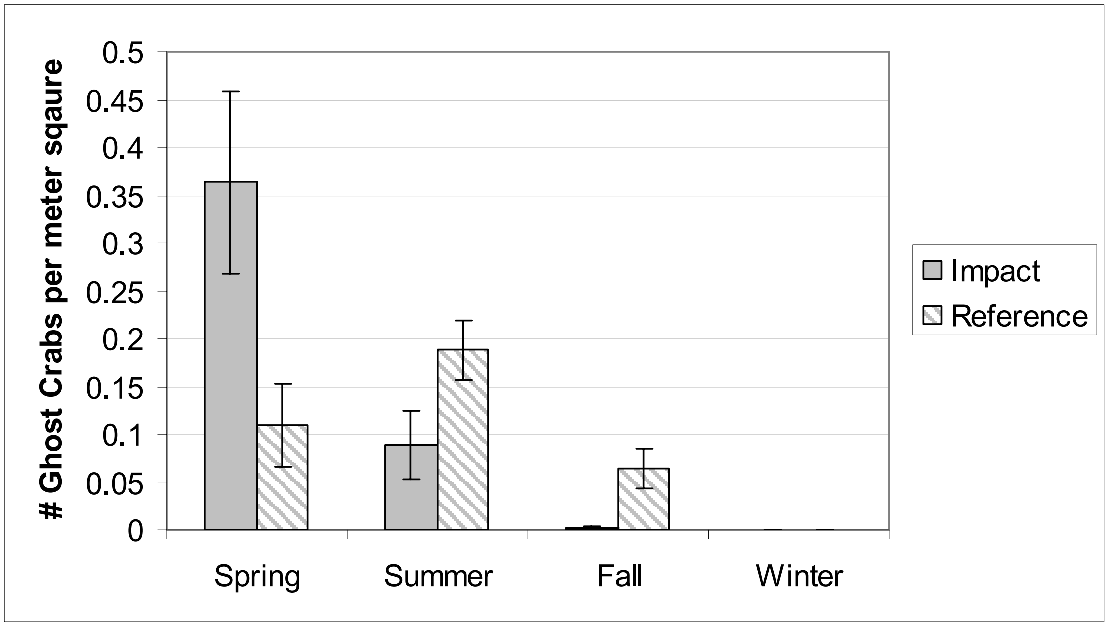

Figure 3-21. Mean abundance of ghost crabs (inferred from ghost crab hole counts) from the wrack line to the toe of the dune on the impact and reference beaches in Dare County, NC.

3.6 BIRD SURVEY

Nearly 11,000 birds were counted during 45 survey days (mean 7.8 surveys per season/beach) conducted at the impact and reference beaches. A cumulative total of 36 species were documented consisting of 9 species of shorebird, 18 waterbirds, and 9 other species (Table 3-12). Six birds were unique to the impact beach and only one, the common goldeneye was unique to the reference beach. However, in general species composition was similar between the beaches in all seasons (Figure 3-23).

There were no obvious differences in total species abundance between the beaches during any season (Figure 3-22). Total species abundance was highest in the spring averaging between 25.4 and 27.8 birds/per 500 m at the impact and reference beaches, respectively (Table 3-13). Fall and summer abundance was lower, averaging between 12 and 20 birds/500 m. In the winter, total species abundance was the lowest with approximately 8 birds/500 m at the beaches. Shorebird and waterbird abundance followed similar patterns of high abundance in spring and fall, and lower abundance in the summer and winter months (Figure 3-25 and 3-28). Differences in abundance between the beaches within bird groups were minor, but overall, shorebird abundance was much lower than waterbird abundance in all seasons.

Total mean species richness followed the same pattern as total abundance (Figure 3-22). Total species richness was highest in the spring averaging between 14.7 and 11 species/500 m. Species richness was lowest in the winter with between 6.4 and 5.8 species/500 m at the impact and reference beaches, respectively (Table 3-13). Only minor differences in total species richness between the beaches were seen throughout the year (Figure 3-22). Total species diversity was also similar to species richness with the highest diversity in summer and lowest in the winter (Figure 3-22). Shorebird and waterbird species richness and diversity followed the same seasonal trend and were similar at both beaches with shorebird values highest in spring and waterbird values nearly equal in all seasons (Figures 3-25 and 3-28).

Species composition was similar between the impact and reference beaches within each of the four seasons. However, there were large changes in species composition between seasons at both beaches during the first year of sampling (Figure 3-23). In the spring, summer and fall, the brown pelican and laughing gull were the most abundant species accounting for the majority of the birds at both the beaches in those seasons (Figure 3-23). Those two species were also the most frequently documented waterbird species in all seasons but winter when the ring-billed gull was more abundant (Figure 3-29). The semipalmated sandpiper was the most prevalent species of shorebird accounting for the majority of the species composition in all seasons at both beaches (Figure 3-26). Ruddy turnstones were the second most abundant shorebird species in the spring and summer and the western sandpiper was second in the fall. Two species other than shorebird or waterbird species that were prevalent on the beaches were the boat-tailed grackle and the pigeon (Figure 3-23).

Overall, more birds used the beach habitat and none were documented on the dunes (Figure 3-24a). Habitat use at both beaches were similar with most birds found using the beach in the summer, fall, and winter months, and slightly more in the surf/intertidal zone in the spring. Shorebirds used the beach exclusively at the reference beach and more in the summer and fall at impact beach (Figure 3-27a). In all seasons except the spring, waterbirds used the beach more than the surf/intertidal zone at both beaches (Figure 3-30a). Bird activity was similar between beaches with more birds flying on average than resting or feeding (Figure 3-24b). However, overall shorebirds were found to feed more than rest or fly, and waterbirds were resting or flying more than feeding (Figure 3-27b and 3-30b).

Table 3-12. Seasonal mean abundance (birds/500 meters) of individual shorebirds, waterbirds, and other birds counted on the impact and reference beaches in Dare County, NC.

Taxonomic Name	Common Name	Spring		Summer		Fall		Winter	
		Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.
Shorebird									
Pluvialis squatarola	Black Bellied Plover	0.1	0.03		0.02				
Calidris minutilla	Least Sandpiper			0.02	0.02				
Arenaria interpres	Ruddy Turnstone	1.27	2.8	0.41	0.54	0.11	0.19		
Calidris alba	Sanderling	1.3	2	0.01	0.14				
Calidris pusilla	Semipalmated Sandpiper	2.57	2.73	0.59	1.5	1.71	2.03		0.06
Calidris mauri	Western Sandpiper	1.07	1.73	0.09	0.4	0.8	0.69		
Numenius phaeopus	Whimbrel	0.4	0.07						
Calidris fuscicollis	White-rumped Sandpiper	0.07		0.05	0.13		0.09		
Catoptrophorus semipalmatus	Willet			0.11	0.34	0.13	0.17		
Waterbird									
Melanitta nigra	Black Scoter					0.98			
Pelecanus occidentalis	Brown Pelican	6.83	6.27	3.89	4.12	2.16	2.95	1.64	1.34
Sterna caspia	Caspian Tern	0.2	0.03	0	0.01	0.03	0.06		
Gavia immer	Common Loon			0	0.06		0.01		
Sterna hirundo	Common Tern	0.8		0.38	0.57				
Phalacrocorax spp.	Cormorant spp.	1.87		0.01					
Phalacrocorax auritus	Double Crested Cormorant					0.07			
Sterna forsteri	Forster's Tern	0.53				0.5	0.25		
Larus marinus	Great Black Backed Gull	0.5	0.2	0.05	0.01	1.57	1.2	0.62	0.64
Phalacrocorax carbo	Great Cormorant					0.01			
Larus spp.	Gull spp.					2.5			
Larus argentatus	Herring Gull	2.6	2.2	0.43	0.3	0.28	0.11	0.16	0.36
Larus atricilla	Laughing Gull	4.77	6.7	3.15	6.04	5.05	4.17		
Sterna antillarum	Least Tern			0.02	0.02				
Larus fuscus	Lesser Black Back Gull					0.08	0.02	0.06	0.02

Table 3-12. (Continued)

Taxonomic Name	Common Name	Spring		Summer		Fall		Winter	
		Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.
Morus bassanus	Northern Gannet					0.07	0.4	0.48	0.62
Pandion haliaetus	Osprey	0.1	0.3	0.16	0.15	0.01			
Larus delawarensis	Ring-billed Gull	1.13	0.13	0.5	0.37	1.76	1.92	3.54	4.24
Other Birds									
Corvus brachyrhynchos	American Crow			0.01					
Riparia riparia	Bank Swallow			0.19	0.26		0.02		
Quiscalus major	Boat-tailed Grackle	1.03	0.2	1.7	0.51	0.4	0.32	0.58	0.46
Quiscalus quiscula	Common Grackle					0.03			
Sturnus vulgaris	European Starling			0.3	0.14				
Quiscalus spp.	Grackle spp.	0.13			0.02				
Passer domesticus	House Sparrow			0.05					
Zenaida macroura	Mourning Dove			0.06	0.01				
Columba livia	Pigeon	0.57		0.53	0.3	1.02	0.6	0.96	0.52

Table 3-13. Seasonal mean abundance (bird/500 meters) of all bird, shorebird and waterbird groups counted on the impact and reference beaches in Dare County, NC.

Species	Metric	Spring		Summer		Fall		Winter	
		Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.
Total	Abundance	27.83	25.40	12.71	15.98	19.27	15.20	8.04	8.26
	Richness	14.67	11.00	9.60	9.90	9.80	9.10	6.40	5.80
	Diversity	3.07	2.61	2.28	2.24	2.55	2.52	1.93	1.80
Shorebird	Abundance	6.77	9.37	1.28	3.09	2.75	3.17		0.06
	Richness	5.33	4.67	1.00	2.00	2.00	2.30		0.20
	Diversity	1.91	1.95	0.33	0.56	0.61	0.77		
Waterbird	Abundance	19.33	15.83	8.59	11.65	15.07	11.09	6.50	7.22
	Richness	7.00	5.33	5.40	5.50	6.00	5.40	4.40	4.40
	Diversity	2.10	1.49	1.50	1.48	1.90	1.83	1.33	1.35

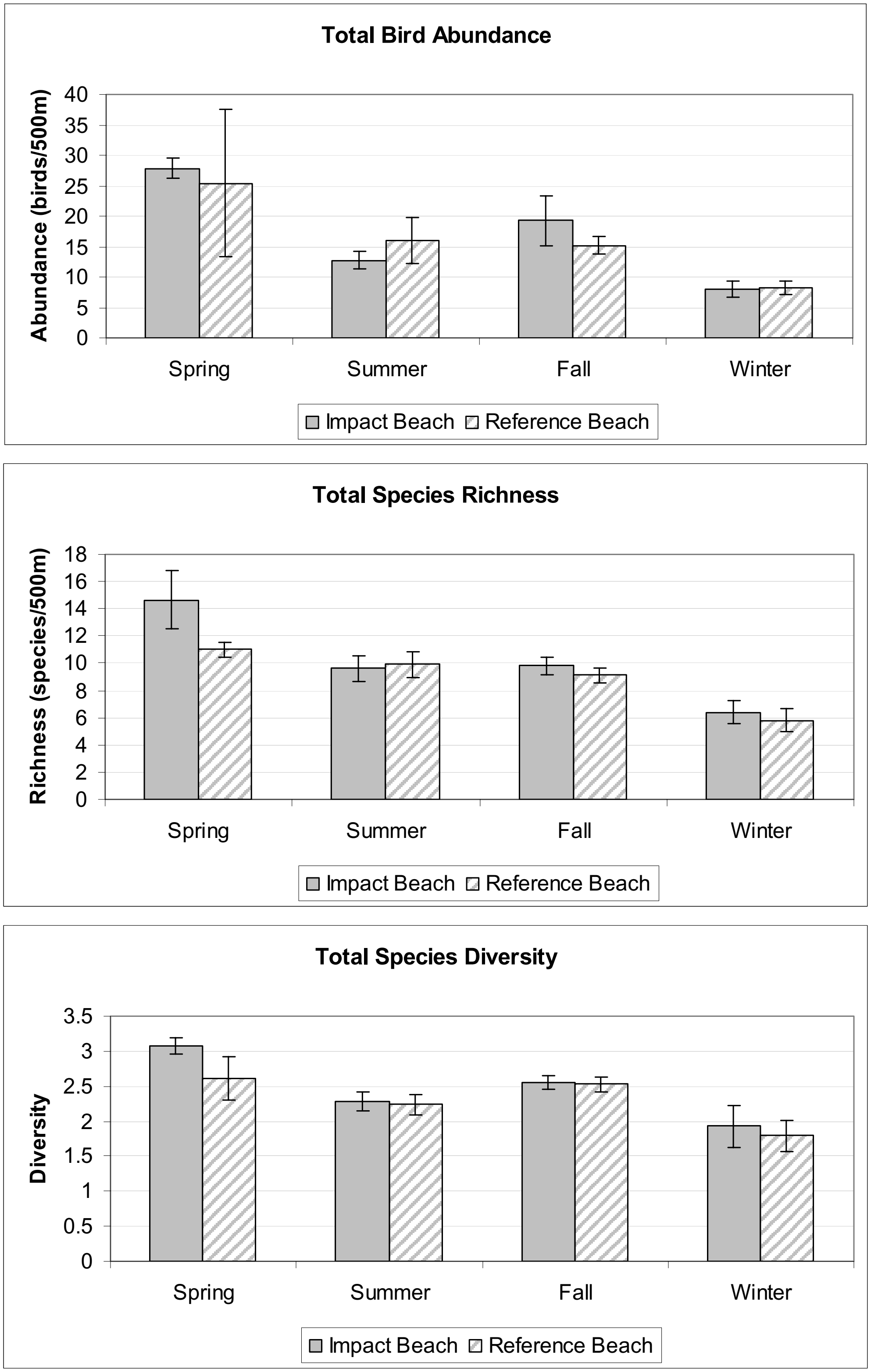

Figure 3-22. Seasonal mean total bird abundance, number of species, and species diversity occurring on the impact and reference beaches in Dare County, NC.

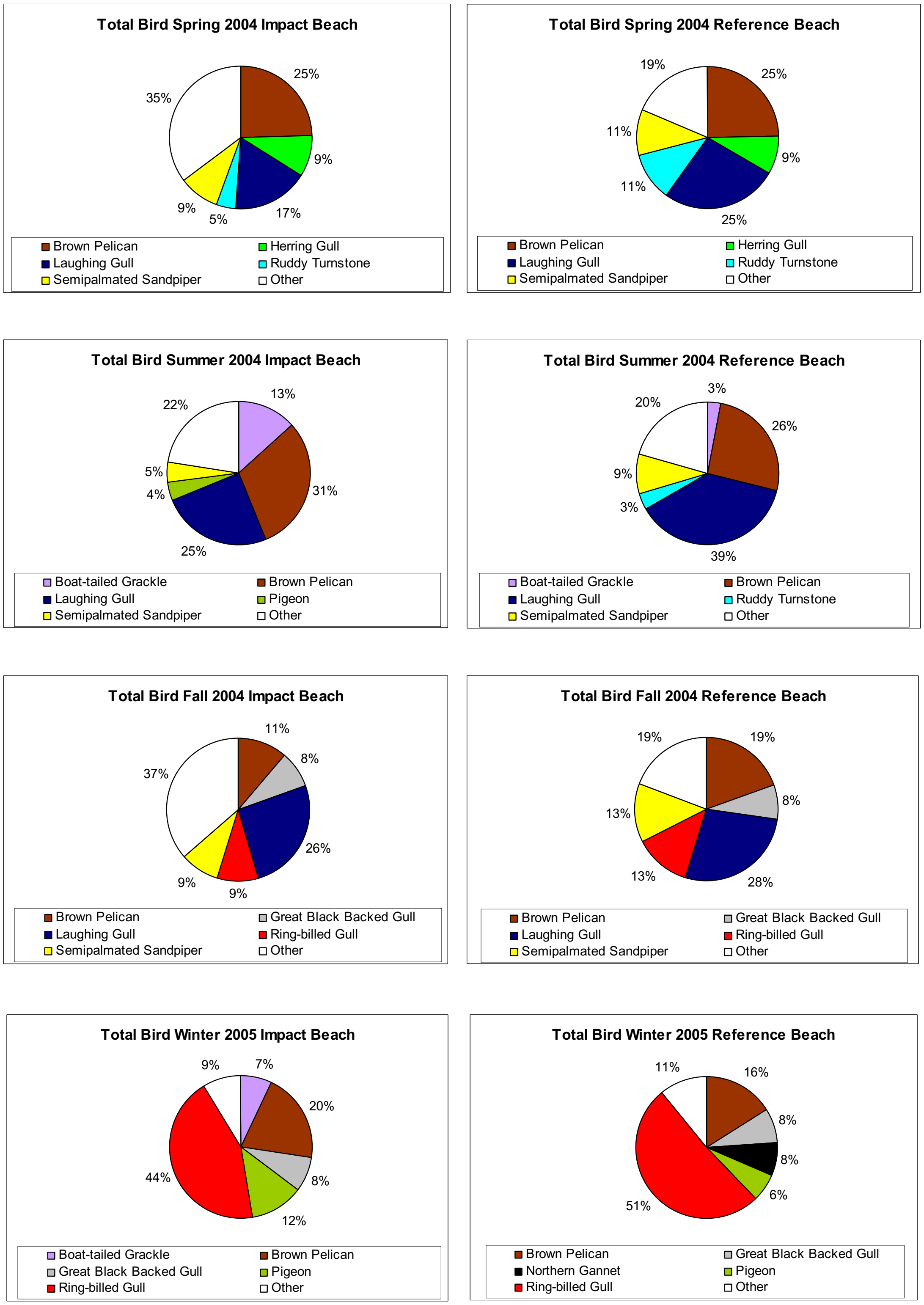

Figure 3-23. Seasonal total species composition occurring on the impact and reference beaches in Dare County, NC.

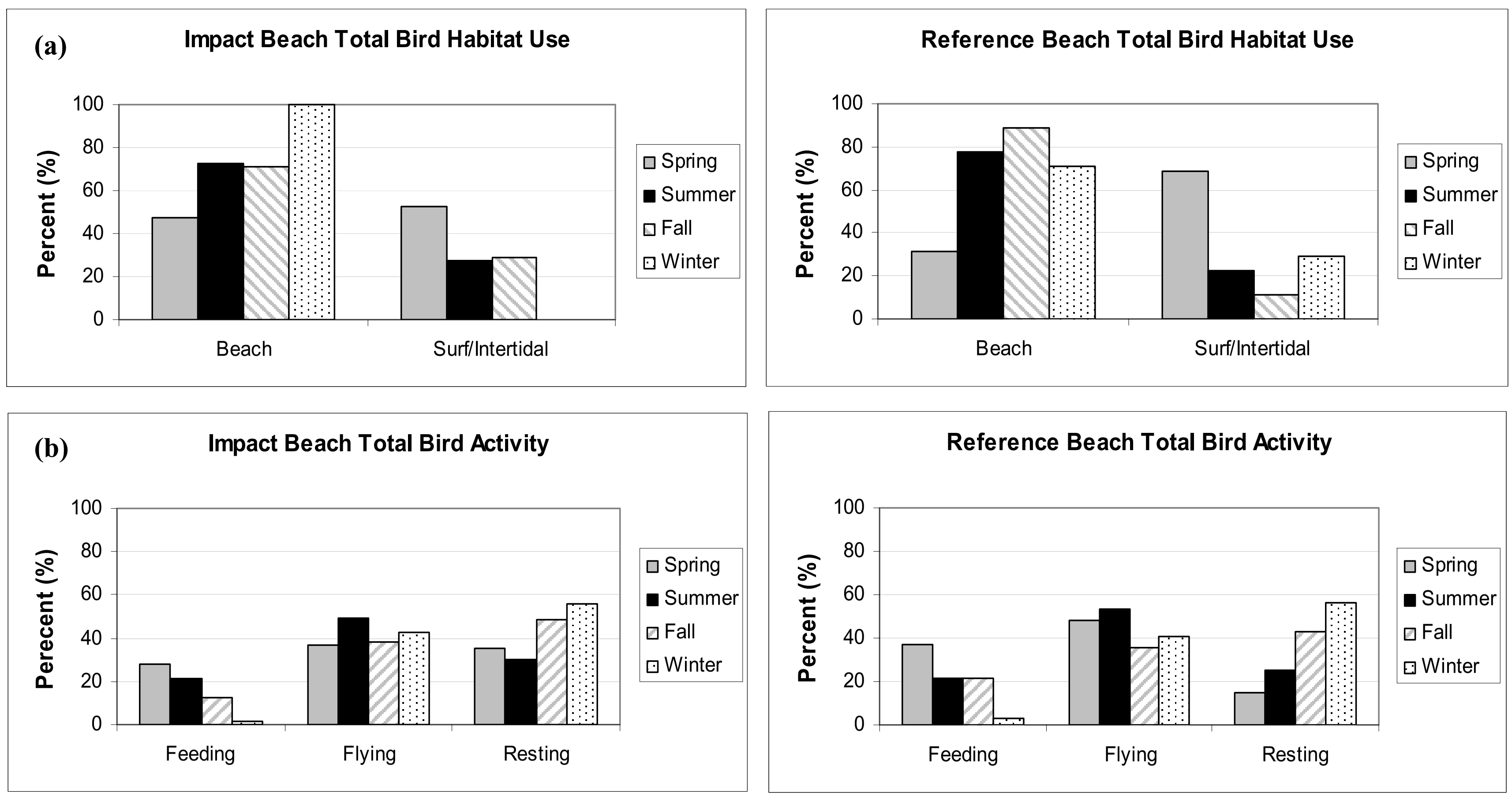

Figure 3-24. (a) Seasonal habitat use by all birds counted on the impact and reference beaches in Dare County, NC. (b) Seasonal activity of all birds counted on the impact and reference beaches in Dare County, NC.

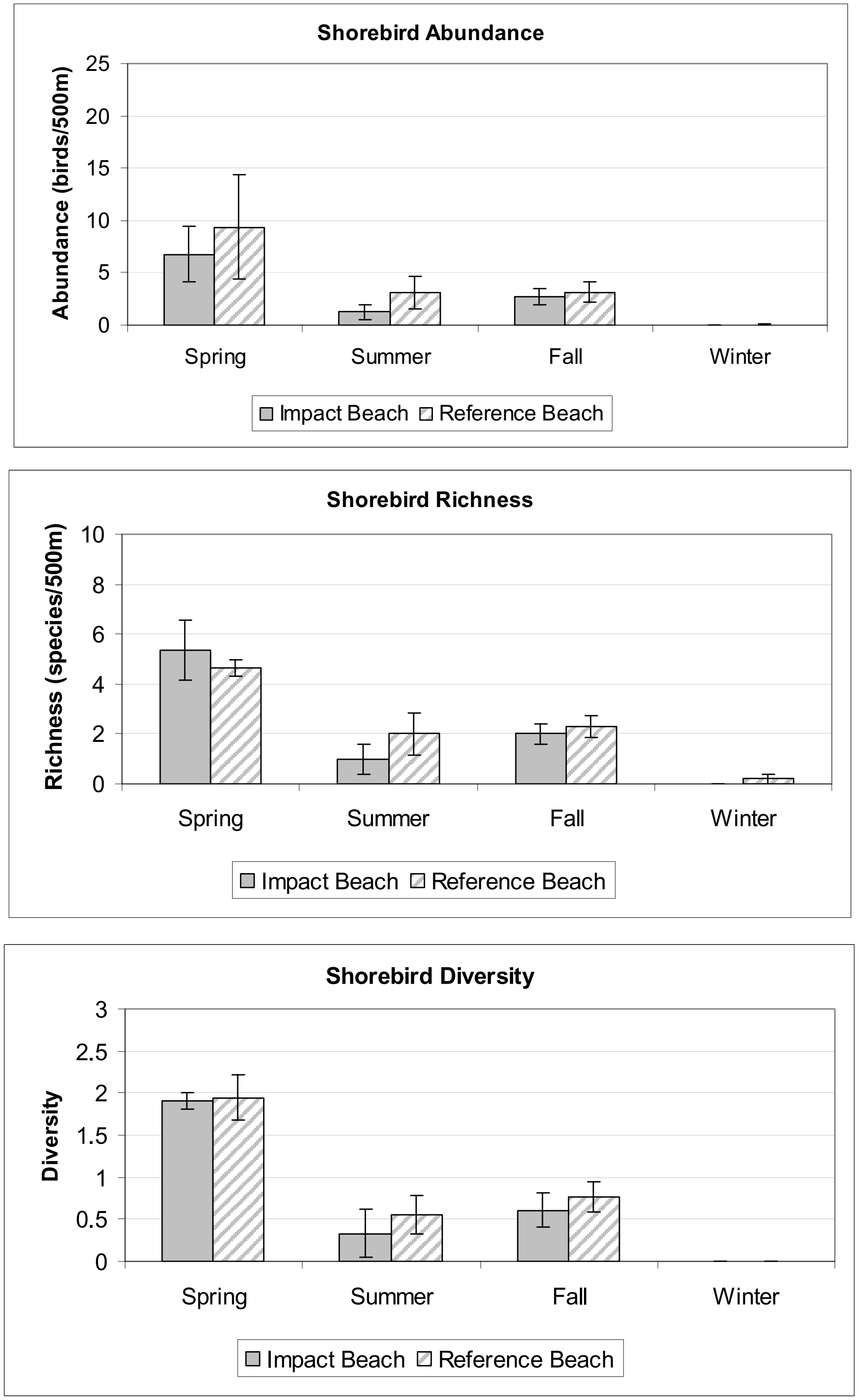

Figure 3-25. Seasonal mean shorebird abundance, number of species, and species diversity occurring on the impact and reference beaches in Dare County, NC.

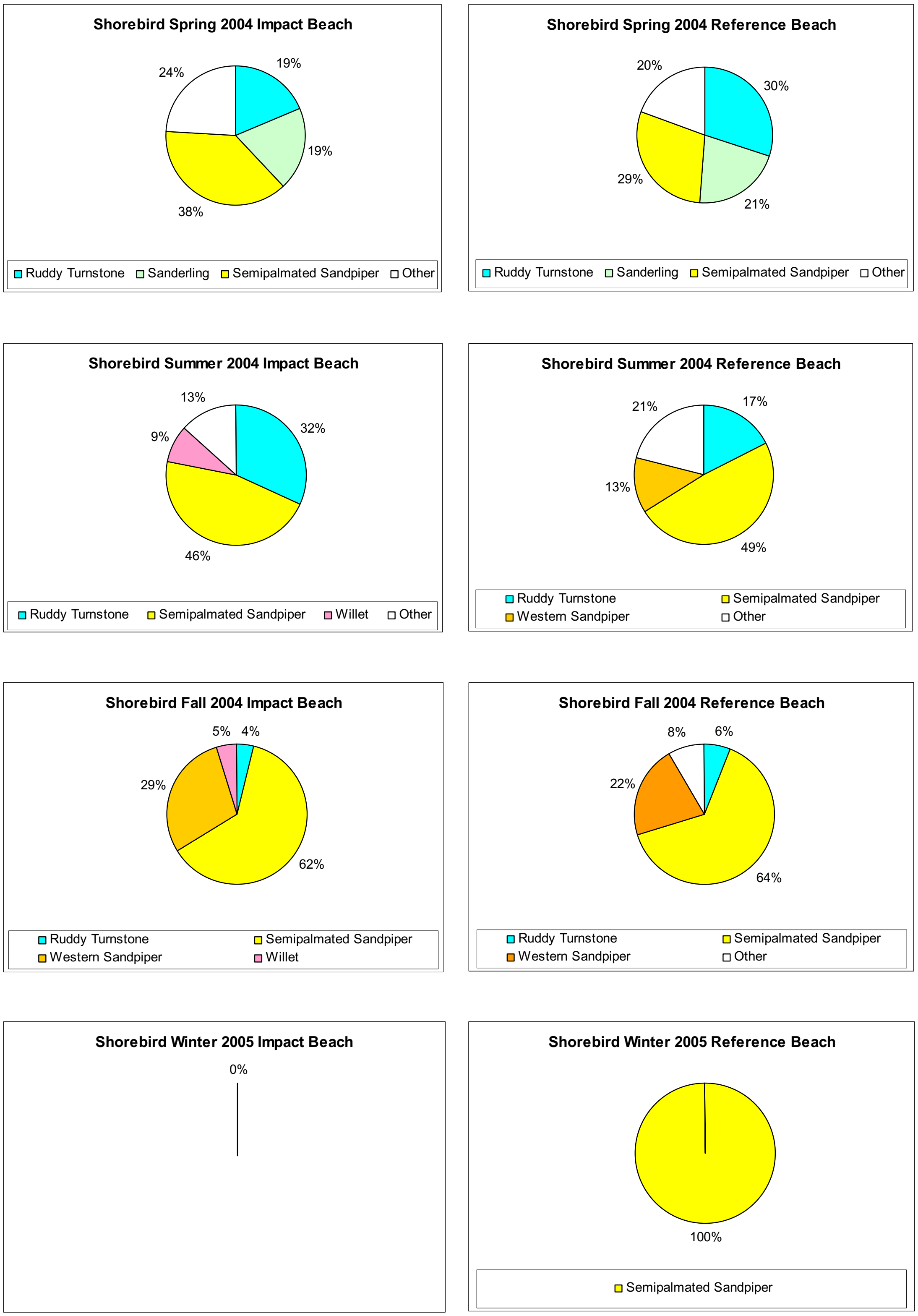

Figure 3-26. Seasonal shorebird species composition occurring on the impact and reference beaches in Dare County, NC.

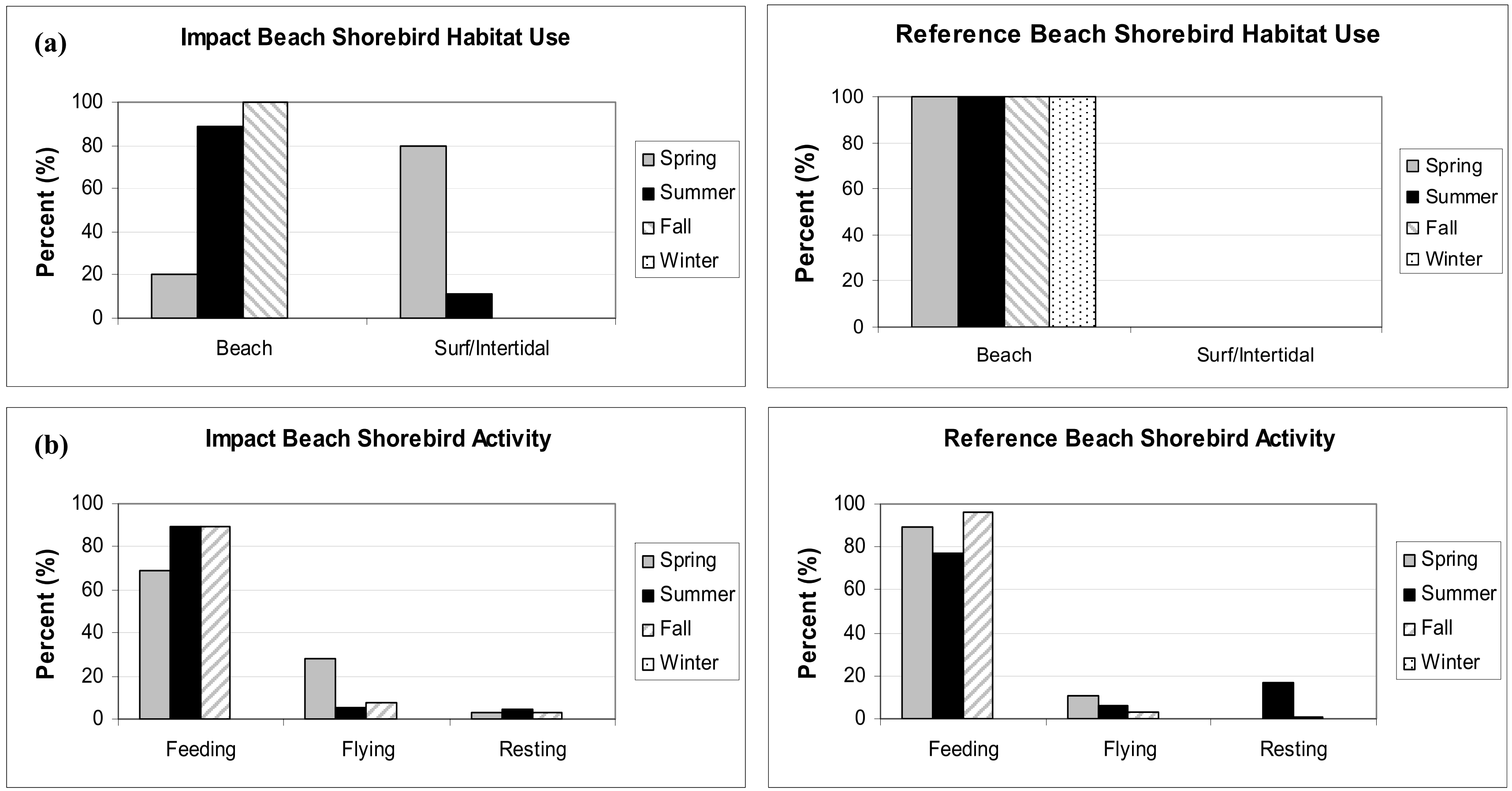

Figure 3-27. (a) Seasonal habitat use by shorebirds on the impact and reference beaches in Dare County, NC. (b) Seasonal activity of shorebirds on the impact and reference beaches in Dare County, NC.

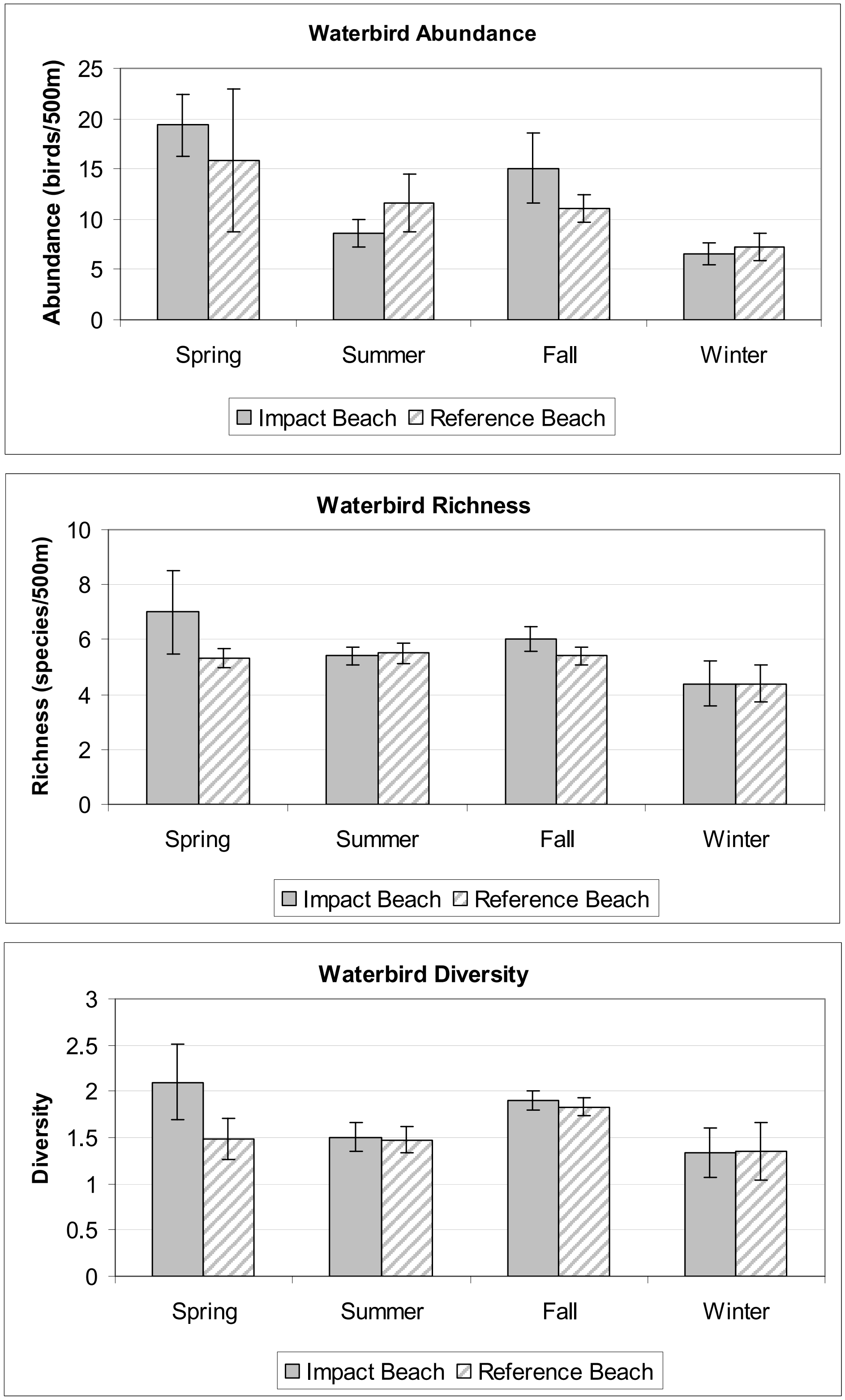

Figure 3-28. Seasonal mean waterbird abundance, number of species, and species diversity occurring on the impact and reference beaches in Dare County, NC.

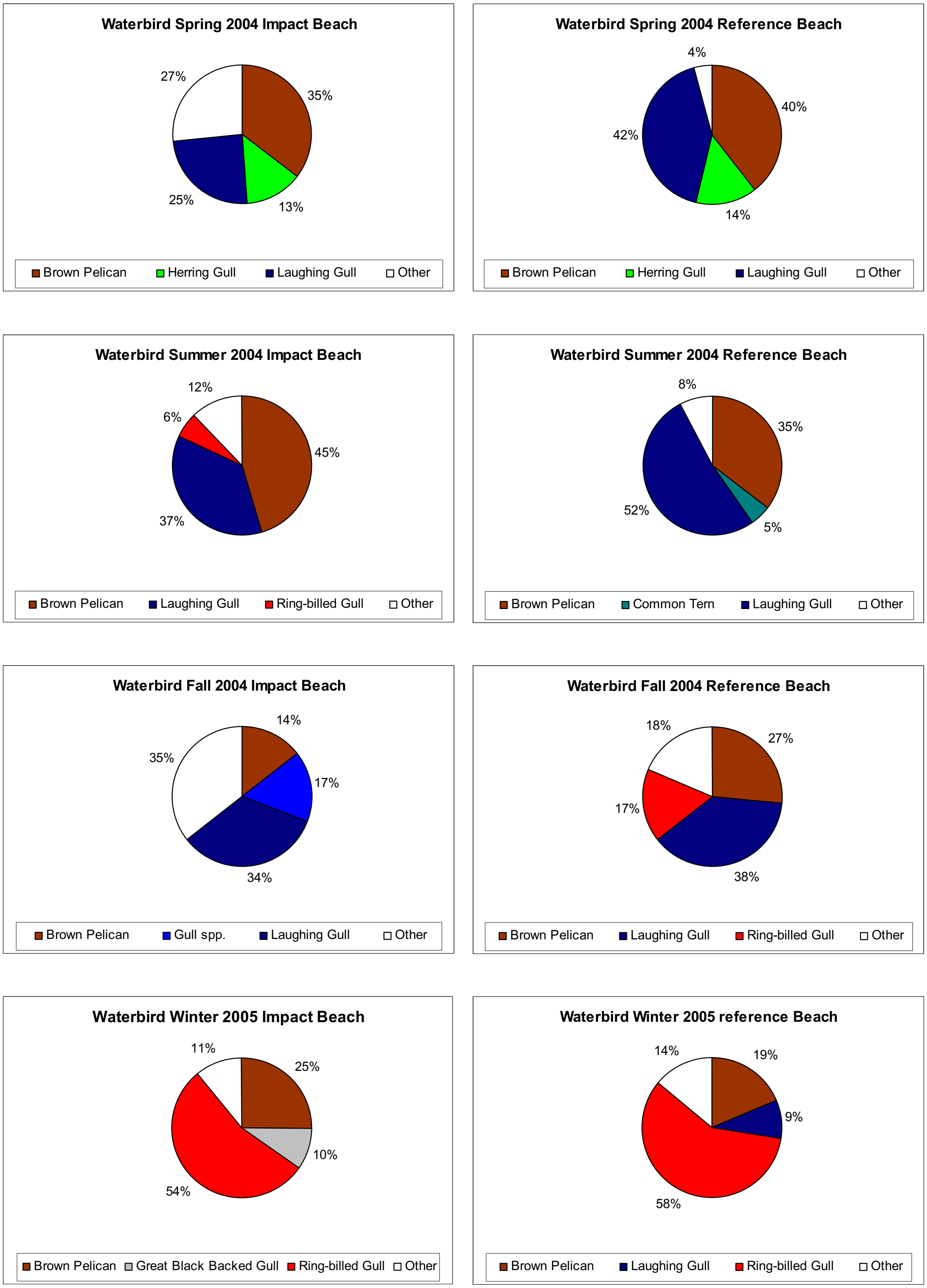

Figure 3-29. Seasonal waterbird composition occurring on the impact and reference beaches in Dare County, NC.

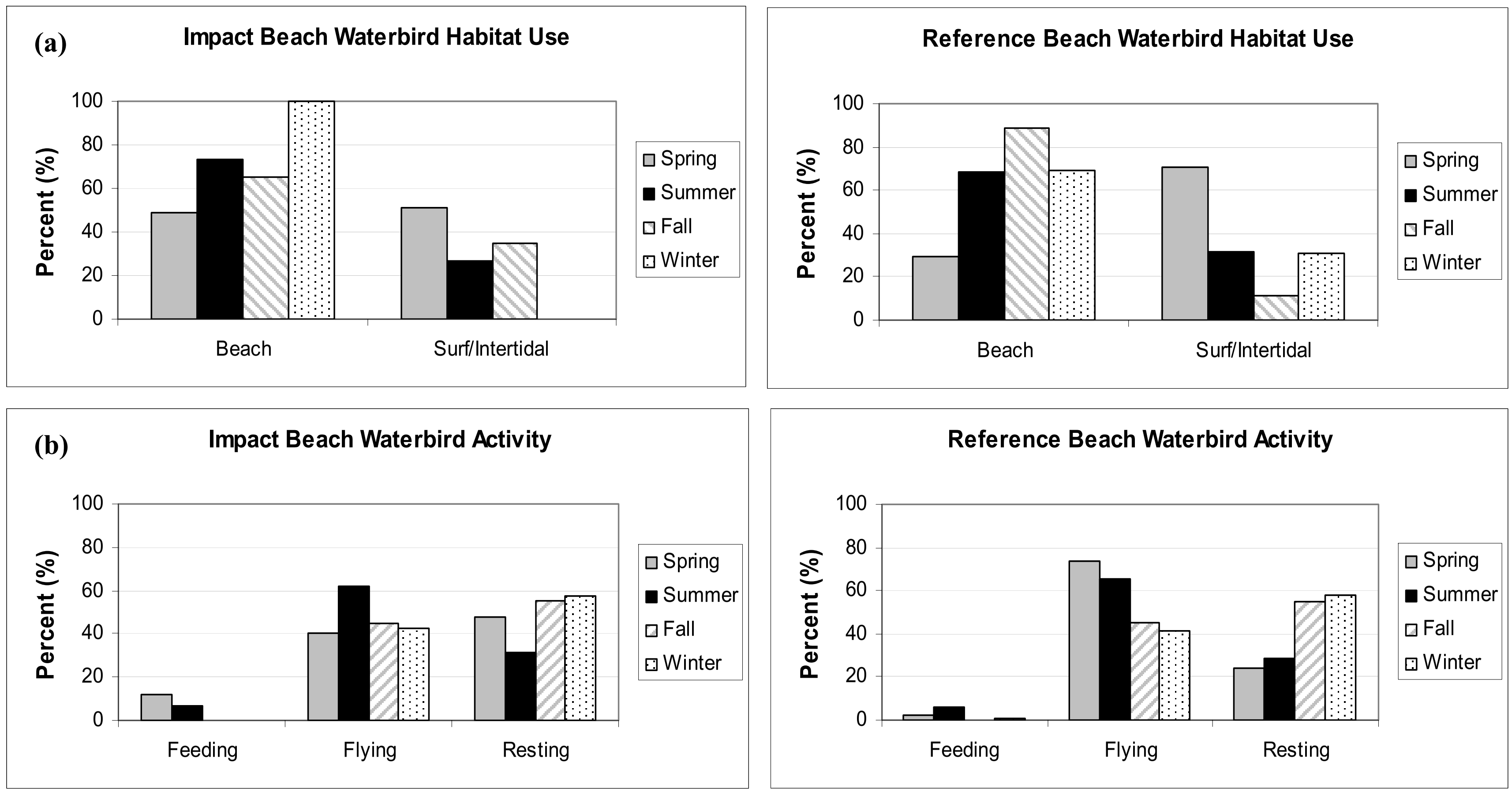

Figure 3-30. (a) Seasonal habitat use by waterbirds on the impact and reference beaches in Dare County, NC. (b) Seasonal activity of waterbirds on the impact and reference beaches in Dare County, NC.

3.7 CREEL SURVEY

A total of 696 anglers were approached for interviews during 72 survey days from spring 2004 to winter 2005. Among them, 555 anglers were successfully interviewed and 141 declined to be interviewed. Fishing effort was generally greatest in the summer and fall with the majority of angler interviews occurring in those two seasons (Figure 3-31). Catch and total fishing effort were much greater on the piers than on the beaches with over 75% (n=425) of all interviews conducted at the piers (Figure 3-32 and 3-33). The impact beach supported greater fishing effort and catch rates than the reference beach. However, the differences were not statistically significant. The impact beach pier likewise supported greater total catch and fishing effort during summer and fall, but not significantly so (Figure 3-33).

Over 85% of all anglers interviewed at the beaches and piers were males (Figure 3-34). Slightly more female anglers were documented on the piers that at the beaches and no female anglers were interviewed in the spring season on the beaches. The majority of the anglers interviewed at both the beaches and piers were adults between 18 and 50 years old (Figure 3-35). Thirty-seven percent of the anglers interviewed were over 50 (seniors) and only 3 youths younger than 18 years old were interviewed during the creel survey.

Interviewed anglers were from twenty-four states with the majority residing from North Carolina (37%), Virginia (29%), and Pennsylvania (14%) (Figure 3-36). In general, there were higher numbers of non-resident anglers interviewed at the piers, but overall, most of the anglers interviewed from season to season resided from North Carolina. North Carolina anglers resided from 24 different counties, some as far away as Graham (4%), but the majority of anglers were from Dare (50%), Pasquotank (9%), and Wake (4%) counties (Figure 3-37). Virginia anglers resided from 49 counties with the majority from Richmond (27%), Chesapeake (7%) and Chesterfield (7%) counties (Figure 3-38).

Anglers caught nearly 3,000 individual fish, skates and rays from 16 families during the first year of the survey (Table 3-14). Over half of the catch (58%) was released because of size, undesirable species or for conservation. The most commonly captured species were spot, bluefish, spotted seatrout, kingfish spp., and flounder spp. (Figure 3-33). Along with angler effort, angler catches were generally greatest in the summer and fall and most of the catch consisting of spot, bluefish, and spotted seatrout. Kingfish differed from this pattern and were captured in the greatest numbers on the piers and beaches during the spring. Flounder spp. were caught mostly in the summer. Compared to all fish species caught by anglers, spot were the most frequently documented and the highest of numbers of spot were recorded on the piers (Figure 5-33).

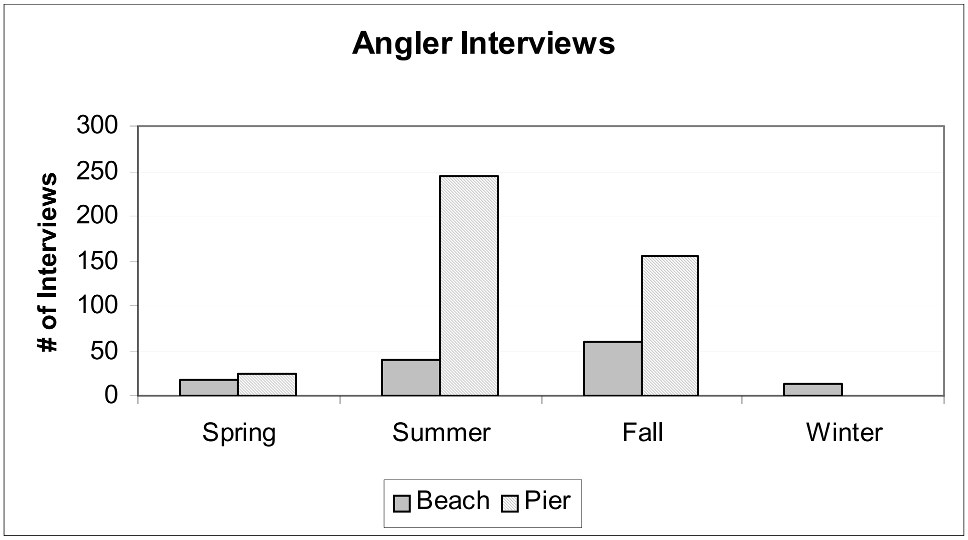

Figure 3-31. Seasonal number of angler interviews conducted on the beaches and piers at the impact and reference creel beaches in Dare County, NC.

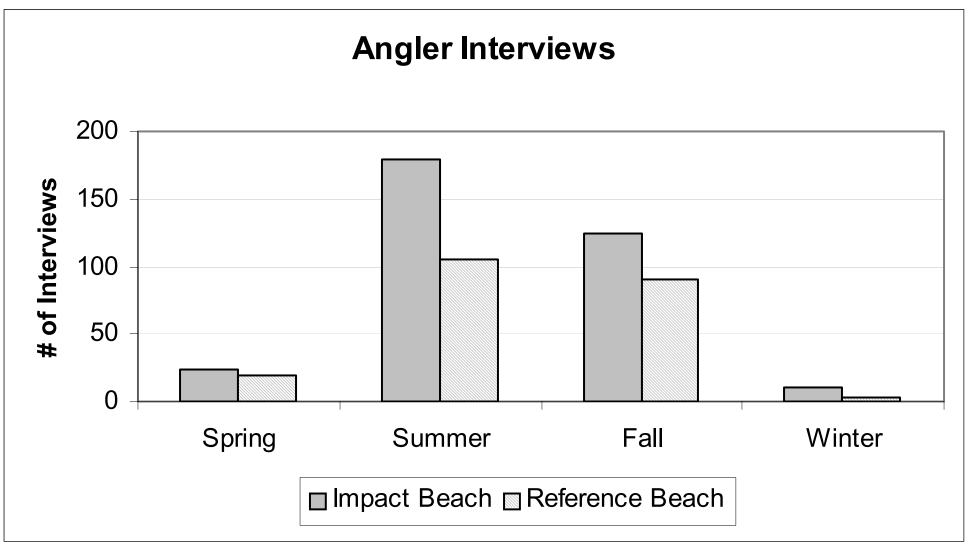

Figure 3-32. Seasonal number of angler interviews conducted at the at impact and reference creel beaches in Dare County, NC.

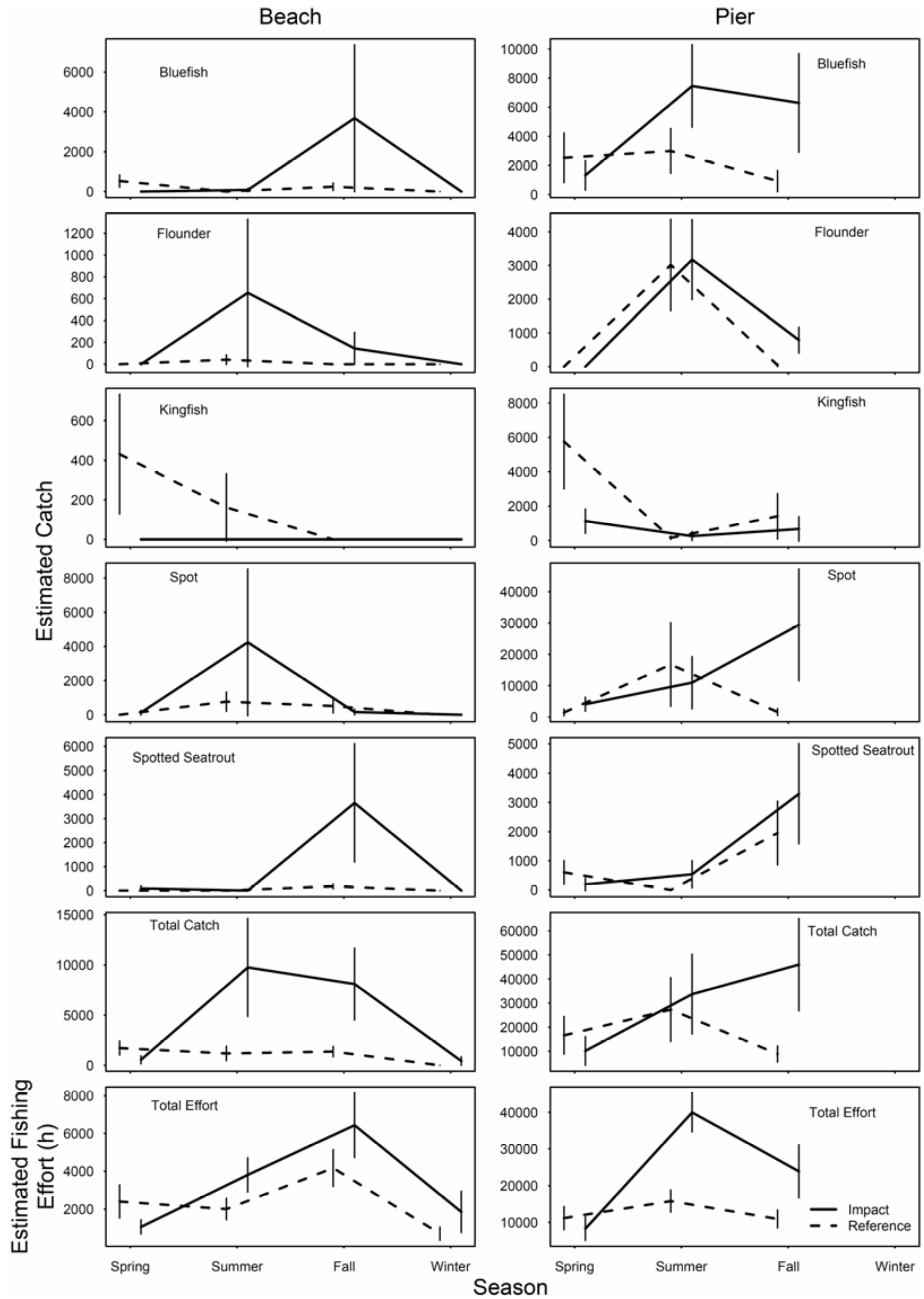

Figure 3-33. Catch of bluefish, flounder, kingfish, spot, and spotted seatrout, total catch, and total fishing effort at the impact and reference beaches and piers during the first complete year of angler interviews in Dare County, NC. Vertical bars indicate 1 SE. Piers were closed during winter. Note that y-axis scales differ among graphs.

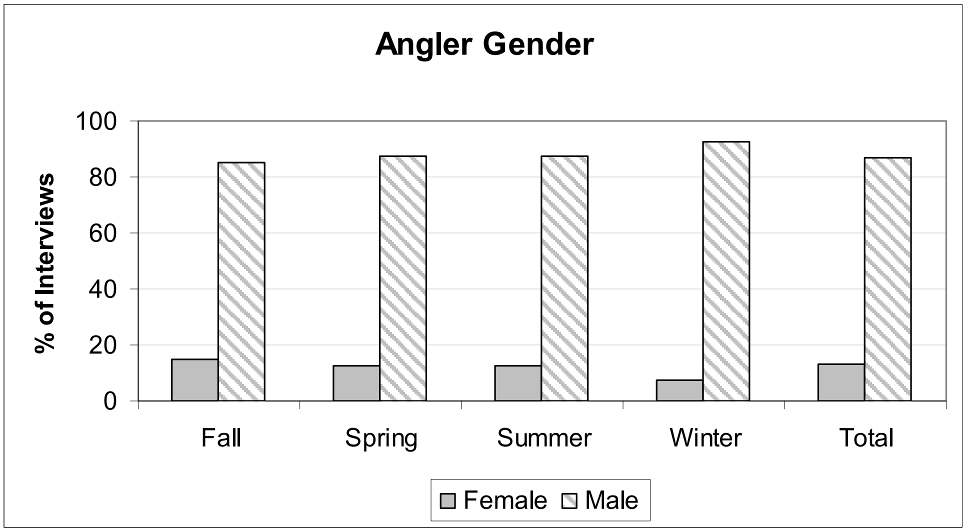

Figure 3-34 Percent of male and female anglers interviewed during the first year of angler interviews at the impact and reference beaches and piers in Dare County, NC.

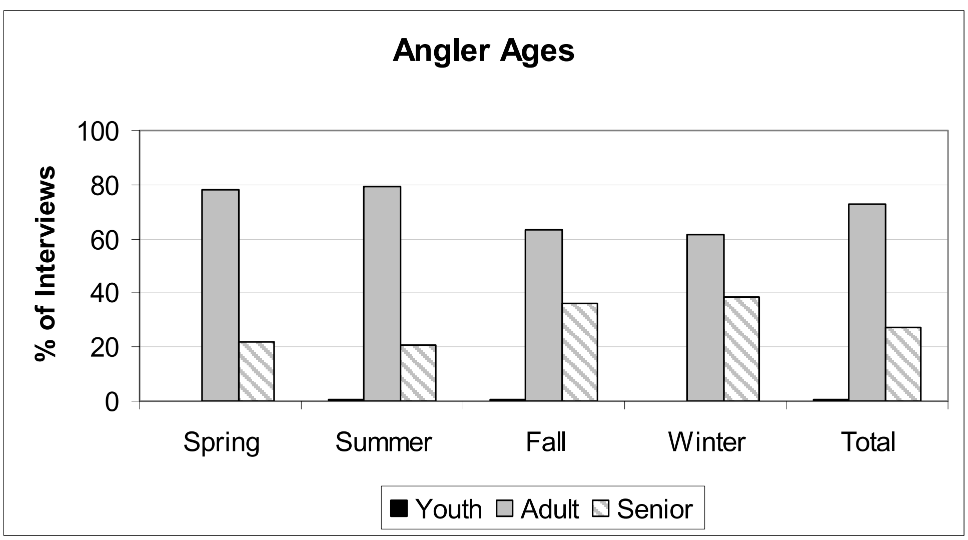

Figure 3-35. Ages of anglers interviewed during the first year of angler interviews at the impact and reference beaches and piers in Dare County, NC.

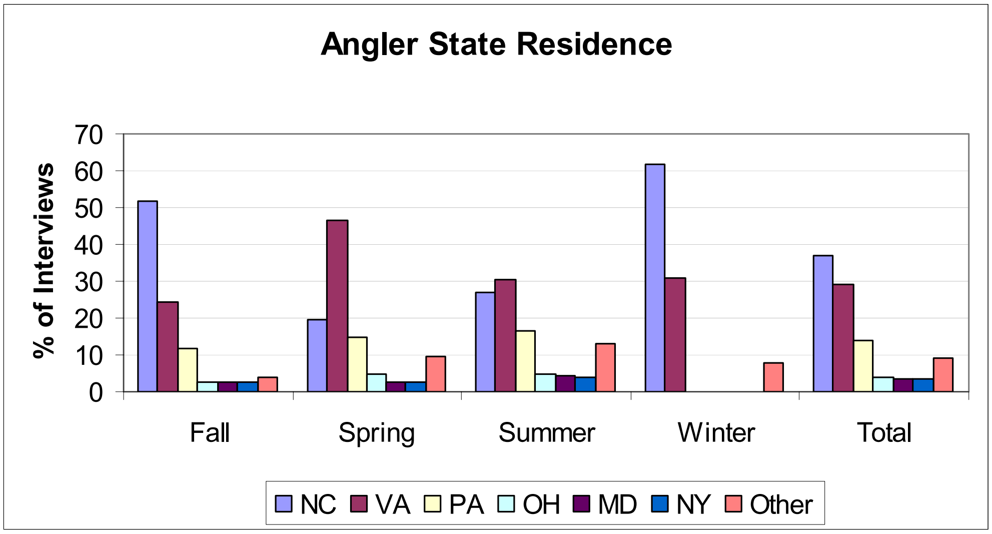

Figure 3-36. State residence of anglers interviewed during the first year of angler interviews at the impact and reference beaches and piers in Dare County, NC.

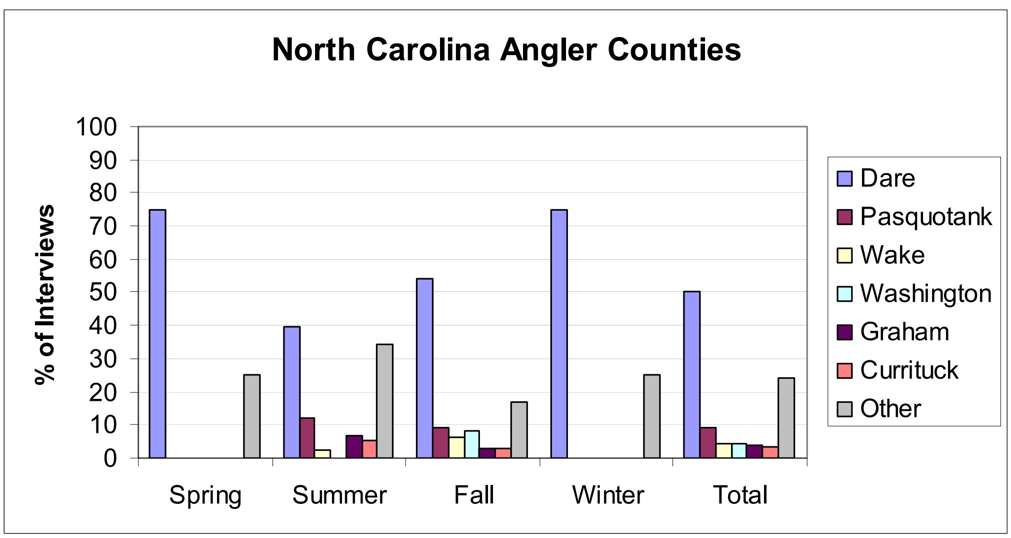

Figure 3-37. County of residence of North Carolina anglers interviewed during the first year of angler interviews at the impact and reference beaches and piers in Dare County, NC.

Table 3-14. Summary of fish species and family groups documented in the angler catches at the impact and reference beaches and piers in Dare County, NC.

Family	Taxonomic Name	Common Name
Sciaenidae	*Micropogonias undulatus*	Atlantic Croaker
Clupeidae	*Brevoortia tyrannus*	Atlantic Menhaden
Sciaenidae	*Pogonias cromis*	Black drum
Pomatomidae	*Pomatomus saltatrix*	Bluefish
Rachycentridae	*Rachycentron canadum*	Cobia
Squalidae		Dogfish Spp.
Sciaenidae		Drum Spp.
Pleuronectiidae		Flounder Spp.
Serranidae		Grouper Spp.
Scombridae	*Scomberomorus cavalla*	King Mackerel
Sciaenidae	*Menticirrhus*	Kingfish Spp.
Tetraodontidae	*Sphoeroides maculatus*	Northern Puffer
Haemulidae	*Orthopristis chrysoptera*	Pigfish
Sparidae	*Lagodon rhomboides*	Pinfish
Sciaenidae	*Sciaenops*	Pompano Spp.
Tetraodontidae	*Tetraodon*	Pufferfish Spp.
Rajidae		Rajidae Spp.
Sciaenidae	*Sciaenops ocellatus*	Red Drum
Sciaenidae	*Cynoscion*	Sea Trout Spp.
Triglidae	*Prionotus*	Searobin Spp.
Clupeidae	*Alosa*	Shad Spp.
Sparidae	*Archosargus probatocephalus*	Sheepshead
Lutjanidae		Snapper Spp.
Scombridae	*Scomberomorus maculatus*	Spanish Mackerel
Squalidae	*Squalus acanthias*	Spiny Dogfish
Sciaenidae	*Leiostomus xanthurus*	Spot
Sciaenidae	*Cynoscion nebulosus*	Spotted Seatrout
Moronidae	*Morone saxatilis*	Striped Bass
Balistidae		Triggerfish Spp.
Sciaenidae	*Cynoscion regalis*	Weakfish

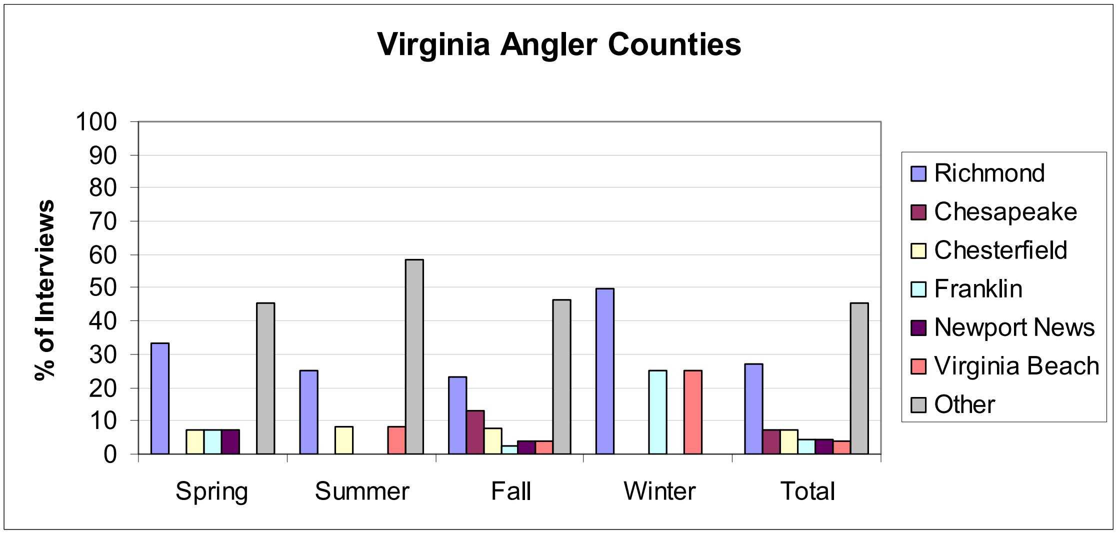

Figure 3-38. County of residence of Virginia anglers interviewed during the first year of angler interviews at the impact and reference beaches and piers in Dare County, NC.

3.8 UNDERWATER VIDEO SURVEY

Features documented in the video footage show differences in the physical habitat and only slight differences in the biological counts between the borrow sites and the reference borrow site. The substrate at both sites consisted of fine-medium sand with significant patches of shell in the substrate of the borrow sites and very little shell at the reference site (Figure 3-39 and 3-40). Bottom shape at the reference site was small-asymmetrical bedforms and the borrow site was more heterogeneous with portions of large and small-asymmetrical bedforms generally corresponding to areas of shell throughout the site (Figure 3-41). Although there were differences between each sites, a summary of all features indicate that the majority of physical features documented at both sites were small-smooth bedforms with fine-medium sand and less than 10% shell cover (Table 3-15).

Average counts of biogenic and biological features recorded on the video images at the borrow site and reference area were very similar suggesting nearly identical biological activity occurs within both areas (Figure 3-42). Biogenic features (burrows, mounds and biological traces) were documented in nearly equal numbers at both sites (Figure 3-42) and were distributed evenly throughout both sites (Figure 3-43). Burrows were the most dominant biogenic feature (Figure 3-42). Worm tubes and hermit crabs were also found in equal numbers at both sites and were the most dominant biological feature documented from video (Figure 3-42 and 3-44). Other biology documented in the video were starfish, squid, sand dollar and sea anemone (Figure 3-42).

Six fish species and one skate were also documented in equal numbers between the sites (Figure 3-45). Fish were rare and patchy throughout both sites (Figure 3-45). Spotted hake, clearnose skate and smallmouth and summer flounder were the most frequently encountered species at both sites, with sea robins and sheepshead occurring in limited numbers.

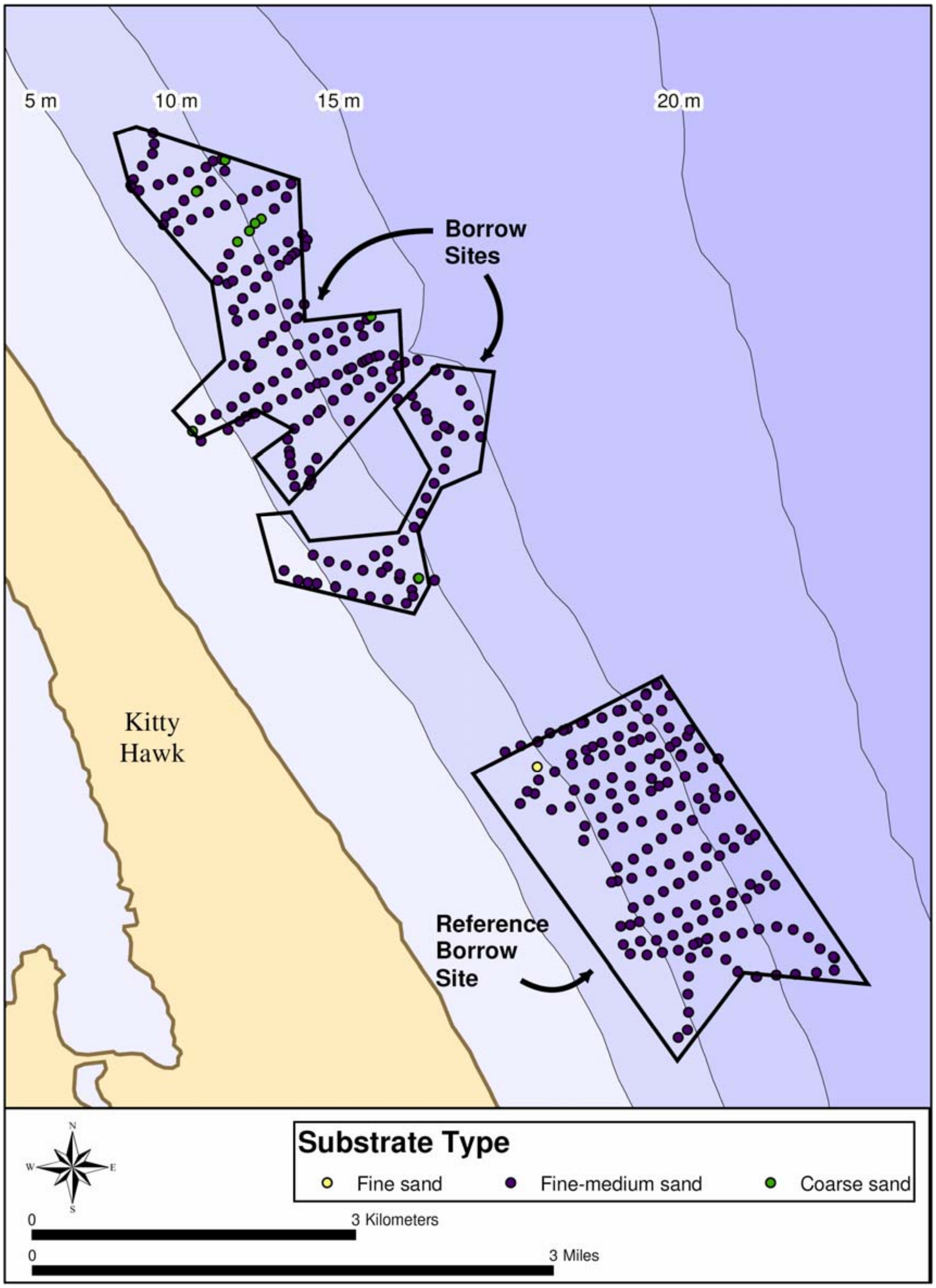

Figure 3-39. Distribution of substrate types observed in video images from an underwater video survey conducted within the borrow site and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

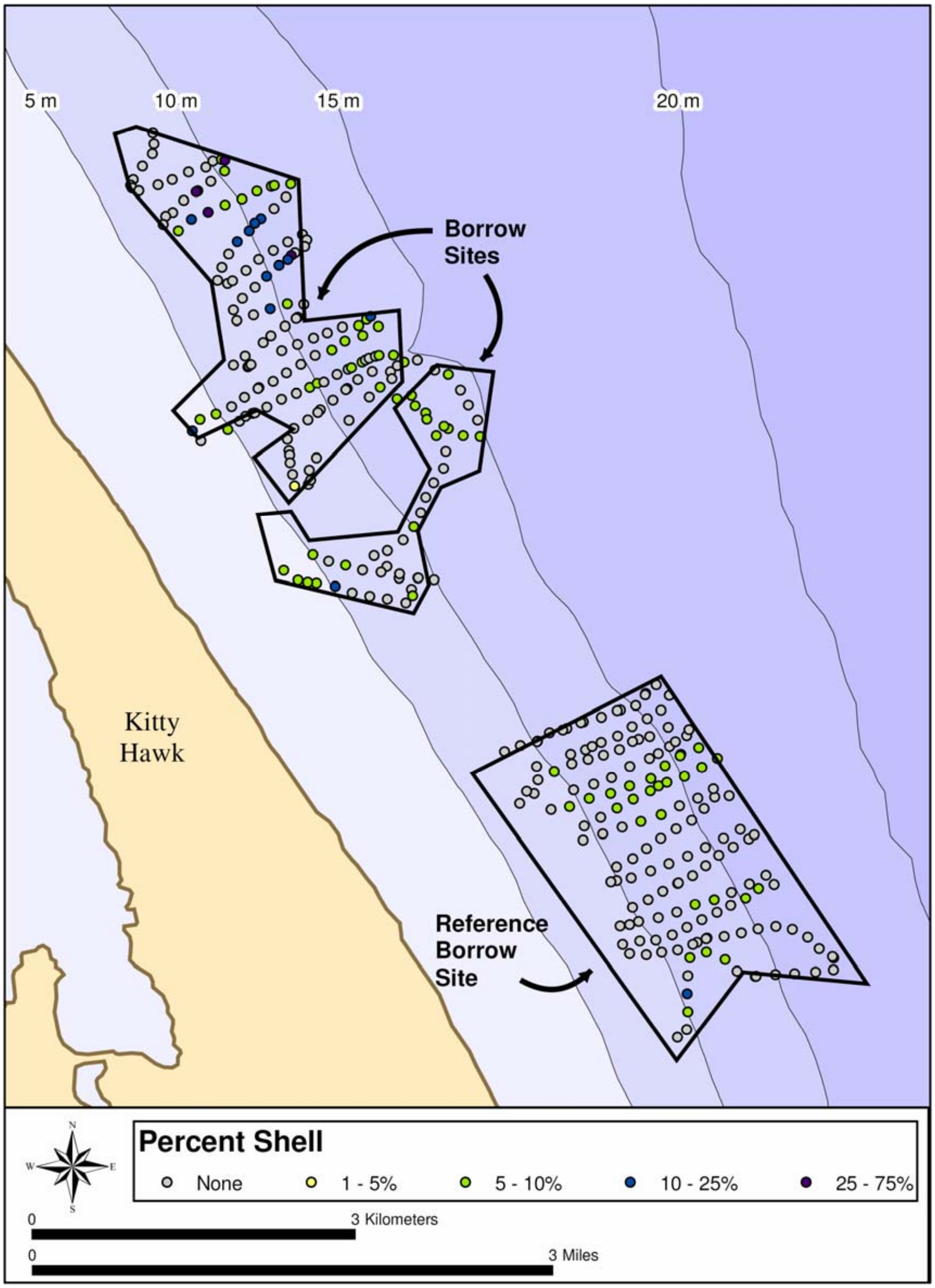

Figure 3-40. Distribution and coverage of shell observed in video images from an underwater video survey conducted within the borrow site and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

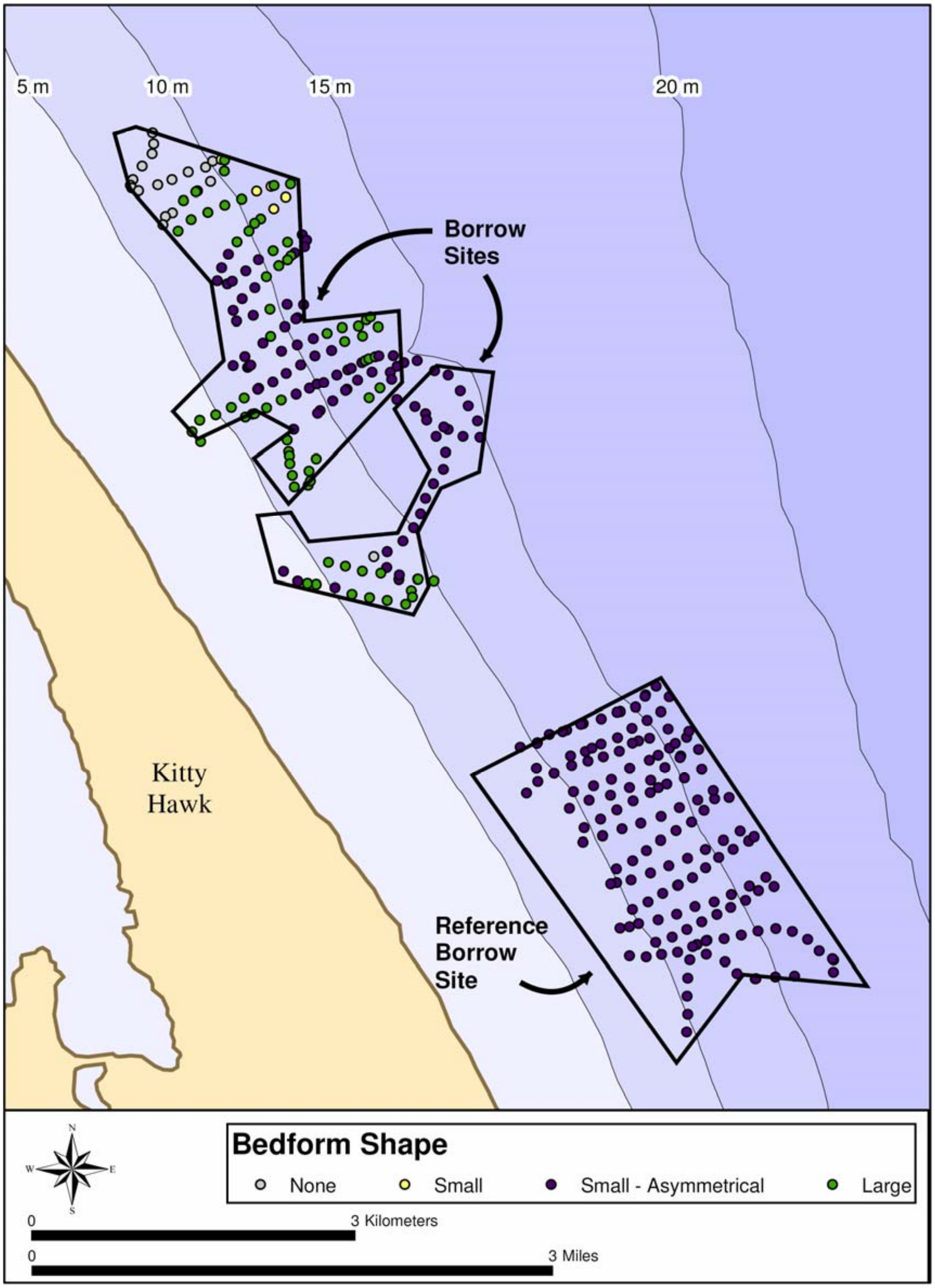

Figure 3-41. Distribution and shape of bedforms observed in video images from an underwater video survey conducted within the borrow site and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

Table 3-15. Frequency of final habitat classifications observed between the Dare county borrow areas and the adjacent reference site observed during the December 2004 benthic video sled survey conducted by VIMS. Final habitat classifications are derived by summarizing all variables presented in Table 4-1.

Bed form Size	Bed form Shape	Grain-size	Shell Cover	Biogenic	Borrow		Reference	
					Total Frequency	%	Total Frequency	%
Large	Smooth	Fine-Medium sand	<10% Shell	Not Biogenic	47	25.54	0	0.00
Large	Smooth	Fine-Medium sand	<10% Shell	Biogenic	6	3.26	0	0.00
Large	Smooth	Fine-Medium sand	>10% Shell	Not Biogenic	9	4.89	0	0.00
Large	Smooth	Fine-Medium sand	>10% Shell	Biogenic	1	0.54	0	0.00
Large	Smooth	Coarse sand-Granules	<10% Shell	Not Biogenic	1	0.54	0	0.00
Large	Smooth	Coarse sand-Granules	>10% Shell	Not Biogenic	8	4.35	0	0.00
Large	Smooth	Coarse sand-Granules	>10% Shell	Biogenic	1	0.54	0	0.00
Small	Smooth	Fine-Medium sand	<10% Shell	Not Biogenic	88	47.83	143	95.33
Small	Smooth	Fine-Medium sand	<10% Shell	Biogenic	4	2.17	6	4.00
Small	Smooth	Fine-Medium sand	>10% Shell	Not Biogenic	1	0.54	1	0.67
None	None	Fine-Medium sand	<10% Shell	Not Biogenic	18	9.78	0	0.00
Totals					**184**	**100**	**150**	**100**

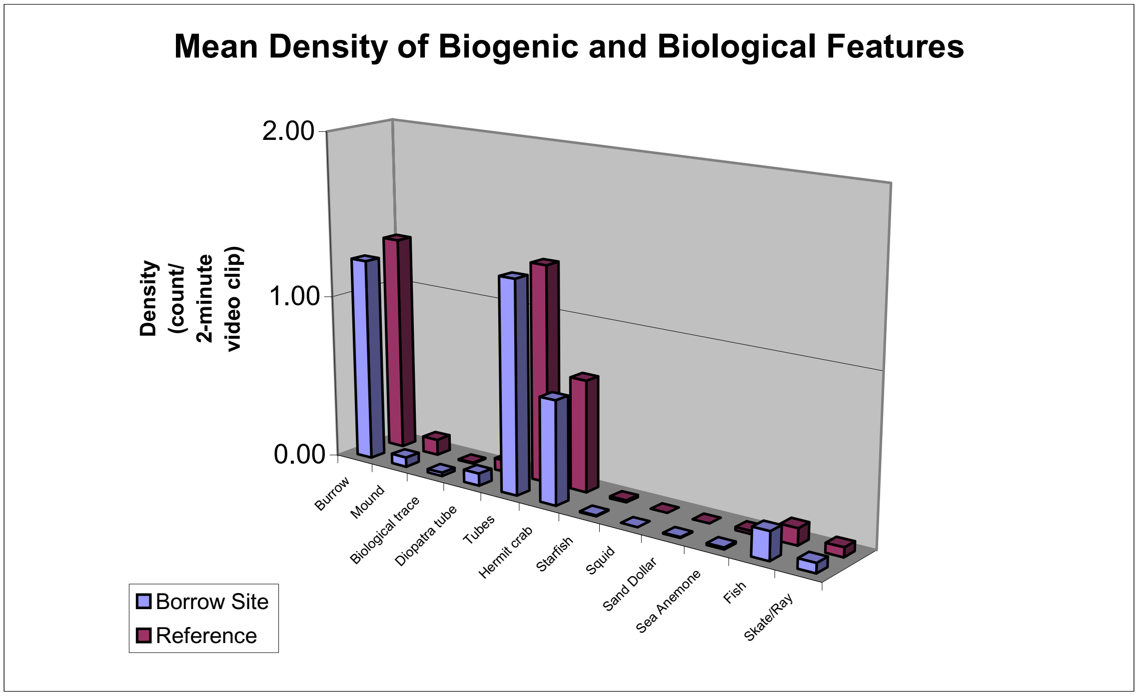

Figure 3-42. Mean count of biological features observed in video sled images taken within the Dare County borrow site and a nearby reference site in December 2004.

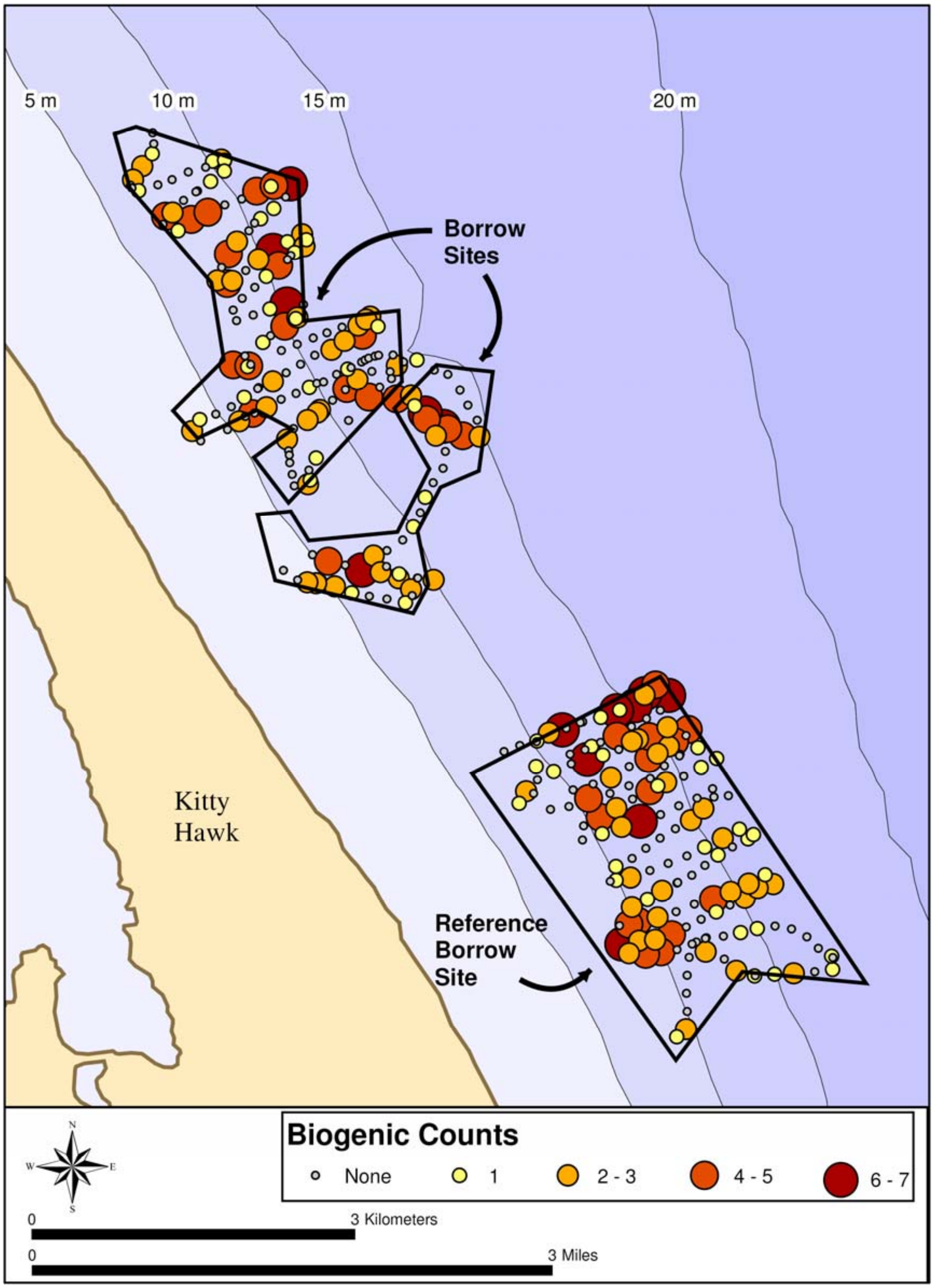

Figure 3-43. Distribution and quantity of all biogenic structure observed in video images from an underwater video survey conducted within the borrow site and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

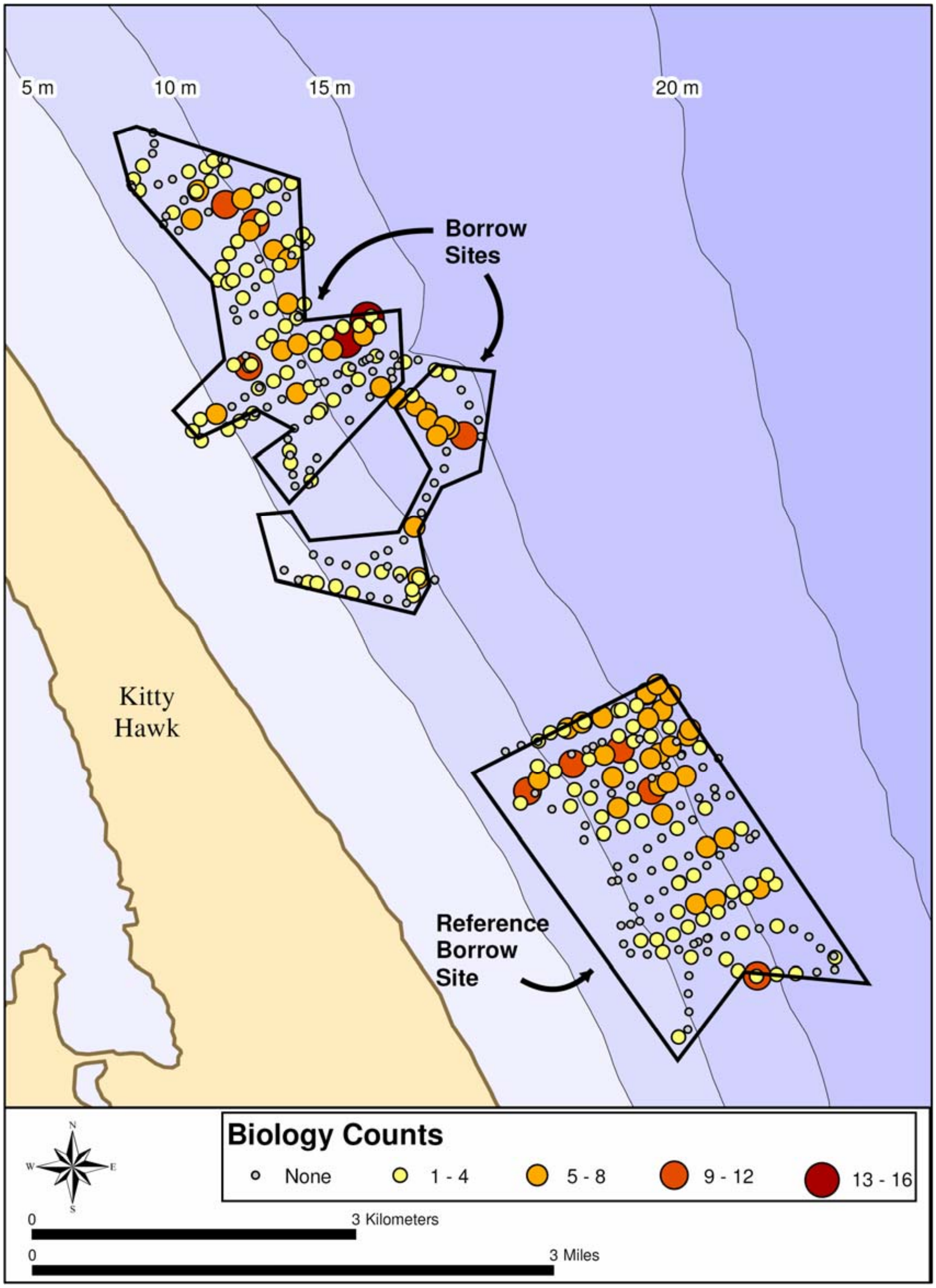

Figure 3-44. Distribution and quantity of surface biology observed in video images from an underwater video survey conducted within the borrow site and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

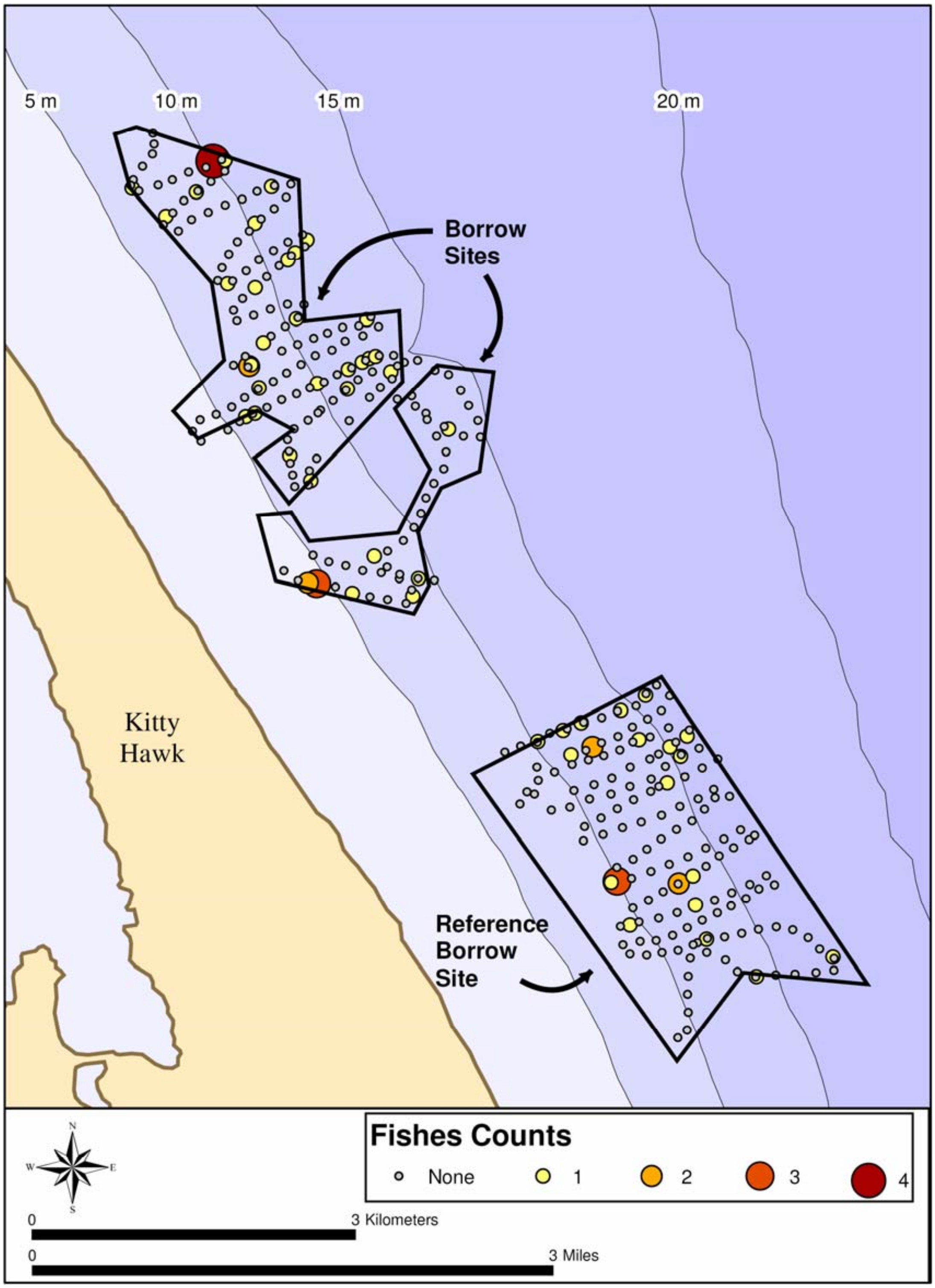

Figure 3-45. Distribution and quantity of fishes observed in video images from an underwater video survey conducted within the borrow site and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

4.0 DISCUSSION

The first year of pre-construction monitoring indicates significant temporal and spatial scale fluctuations in many of the biological recourses monitored. In some seasonal collections major differences in species abundances were documented between the reference and study sites. This was most apparent in the borrow site benthic data (Figure 3-12), fish data (Figure 3-16 and 3-18), and ghost crab data (Figure 3-21). There were also differences in creel survey data between the beaches (Figure 3-33). Although the differences between the sites were sometimes major, no obvious trends could be found and those differences are most likely attributed to small-scale seasonal variations rather than inherent site-specific variation.

Benthic communities at the beach sites were typical of those found at beaches along the Middle and Southern Atlantic Bight regions (Hackney et al. 1996, USACE 2001). Characteristic of high-energy beaches, the swash and shallow benthic communities exhibited low species diversity and were dominated by relatively few species. The swash zone community was dominated by two groups of worms; nemartina and oligochaeta, and the mole crab, *Emerita talpoida* (Table 3-1). Farther offshore in the shallow habitat, fewer species at lower abundances were documented, with *Donax variabilis*, nemartina worms, and the amphipod, *Amphiporeia virginiana*, being the most dominant. Similar communities were documented by Diaz and DeAlteris (1982), in their inventory of the benthic communities at the Duck Research Pier. Two of the most dominant species in that survey; *Emerita talpoida* and *Donax variabilis*, also dominated the communities in our survey. Versar (2002), also found these two species dominated the surf zone benthic communities at beaches in Brunswick County, NC.

Because of their abundance and ease of capture within the surf zone, *Emerita talpoida* and *Donax variabilis* have been identified by some investigators as important biological indicators of anthropogenic impacts to beach benthic communities (Hackney et al. 1996, Versar 2002). Both *Emerita talpoida* and *Donax variabilis* dominated the communities in this survey and are common to the surf zone of the east coast (Diaz and DeAlteris 1982, Hackney et al. 1996, USACE 2001, Versar 2002). Therefore these two species are likely to be important indicators of potential deleterious impacts to the benthic community at the Dare County beaches when the nourishment process begins.

Borrow site benthic communities were much more diverse and abundant than the inshore benthic communities (Section 3.2.3, Table 3-5). During the first year, 168 taxa were documented at the borrow and reference borrow sites. These results are similar to those documented by Byrnes et al. (2003). In that survey, a total of 178 taxa were collected in spring and summer sampling at four potential sand borrow sites located offshore of Dare County in Federal waters. The seasonal densities of species and species numbers were also similar to the Byrnes et al. (2003), survey with lower densities and species numbers in the spring and higher densities and more species in the summer (Figures 3-12 and 3-14).

The fish community documented from seines in the surf zone was similar to that reported along the Middle and Southern Atlantic Bight regions (Hackney et al. 1996). Compared to the ocean sites, more species were found in higher abundance in the surf zone, indicating that the surf zone may be an important habitat to fish throughout the year. Many of the species collected in the surf are recreational and commercially important species (Table 3-8). Among them, spot was the most dominant species. In addition, several important forage species were also collected. Comparisons between similar studies may not be relevant because our study employed a much larger net than most other studies found in the literature. However, some species documented in other studies were common to the collections of this study (USACE 2001, Versar 2002).

Fish collections at the borrow sites indicate depauperate conditions. Aside from the spring survey, very few fish or invertebrate species were collected during the first year of surveys at the borrow site and borrow reference site (Figure 3-18). This could be attributed to the fact that we are using a large mesh trawl and that few large fish inhabit the offshore borrow area. However, these results are similar to those of Byrnes et al. (2003), who also documented depauperate conditions at four sand resource sites offshore of Dare County while using a 7.6 m, small mesh mongoose trawl. More than likely, the lack of fish in the trawls is due the natural variability in species distributions both spatially and seasonally (Colvocoresses and Musick 1984, Gabriel 1992). Cape Hatteras is the farthest extent of many southern and northern species ranges, and therefore species diversity and distributions are extremely variable. Additionally, during seasonal sampling no commercial or recreational fishing vessels were witnessed at either the borrow site or its reference site, indicating these sites are not very productive fishing areas (Ward Slacum, personal observation)

Stomach contents analyzed from fish collected at the beaches and borrow sites indicate a strong link to benthic resources located at those sites (Table 3-11 and 3-12). For example, most of the surf zone species relied upon Emerita as a significant part of their diets in all three seasons. Emerita were also the most dominant benthic organism collected in the surf zone. Stomachs analyzed from the borrow site and its reference indicate that the most dominant benthic organisms from those sites, polychaetes, were also an important food source for fish at those sites. These data suggests if impacts associated with the beach nourishment negatively affect Emerita or polychaetes, impacts could also affect fish utilizing these species as food sources.

Bird species documented at the beaches during the first year were representative of species commonly found on the Outer Banks (Fussell 1994). In a recent study of shore and waterbird distribution, CZR (2003) documented over 60 species on the beaches of Brunswick County, NC. This is more than three times the total number of shore (N=9) and waterbird (N=18) species documented in this study (Table 3-12). However, findings from that study are based on two years of data collection and many of the species documented in that study were incidentals occurring only occasionally. Most of the more common and abundant species from Brunswick County were also common and abundant at the Dare County Beaches.

The creel survey documented extensive fishing activity at the beaches and piers of the impact and recreational creel survey beaches (Figure 3-31 and 3-32). The majority of fishing occurred in the summer and fall, but fishing occurred the entire time piers were open, and throughout the year on the beaches. Although most of the anglers interviewed in the survey resided from North Carolina, many also resided from other states indicating that this area is an important resource for out of state residents. Most of the fish species documented in the angler catches were also species collected in the seines (Table 3-33 and 3-8). Many of these species were also found to be common in the Marine Recreational Fisheries Statistics Survey (MRFSS) conducted in North Carolina and nationally throughout the year (NOAA 2005). Data from that survey indicates that over 20 % of all marine recreational fishing occurring on the Atlantic Coast occurs in the state of North Carolina (NOAA 2005).

5.0 REFERENCES

Boss, S.K. and C.W. Hoffman. 2001. Geologic Framework Derived from High-Resolution Seismic Reflection, Side-Scan Sonar, and Vibracore Data Offshore Oregon Inlet to Duck, Dare County, North Carolina. Prepared for the U.S. Minerals Management Service International Activities and Marine Minerals Division (INTERMAR) Under Cooperative Agreement 14-12-0001-30348. 47 pp.

Buchanan, J.B. 1984. Sediment analysis. *In*: N.A. Holme and A.D. McIntyre, Eds. *Methods for Study of Marine Benthos*. IBP Handbook No. 16 2nd Edition. Blackwell Scientific Publications. Oxford, England. Pages 41-65.

Byrnes, M.R., R.M. Hammer, B.A. Vittor, S.W. Kelley, D.B. Snyder, J.M. Côté, J.S. Ramsey, T.D. Thibaut, N.W. Phillips, J.D. Wood, and J.D. Germano, 2003. Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environmental Implications of Sand Removal for Coastal and Beach Restoration. U.S. Department of the Interior, Minerals Management Service, Leasing Division, Sand and Gravel Unit, Herndon, VA. OCS Report MMS 2000-056, Volume I: Main Text 256 pp. + Volume II: Appendices 69 pp.

Colvocoresses, J.A. and J.A. Musick, 1984. Species associations and community composition of the Middle Atlantic Bight continental shelf demersal fishes. Fishery Bulletin, 82(4): 295-314.

Cortes, E. 1997. A critical review of methods of studying fish feeding based on analysis of stomach contents: Application to elasmobranch fishes. Can. J. Fish. Aquat. Sci. 54: 726–738.

CZR. 2003. Waterbird and Shorebird Use of Beaches in Brunswick County North Carolina. Final report Prepared by CZR, Wilmington, NC for U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC.

Diaz, R.J. and J.T. DeAlteris. 1982. Long-term changes in beach fauna at Duck, North Carolina. U.S. Army Corps of Engineers Coastal Engineering Research Center Miscellaneous Report 82-12. November 1982, 48 pp.

Efron, B. 1982. *The jackknife, the bootstrap, and other resampling plans*. Society for Industrial and Applied Mathematics. Philadelphia, Pennsylvania, U.S.A.

Fussell, J.O. 1994. *A Birder's Guide to Coastal North Carolina*. The University of North Carolina Press, Chapel Hill, NC. 540 pp.

Gabriel, W., 1992. Persistence of demersal fish assemblages between Cape Hatteras and Nova Scotia, Northwest Atlantic. Journal Northwest Atlantic Fisheries Science, 14: 29-46.

Hackney, C.T., M.H. Posey, S.W. Ross, and A.R. Norris. 1996. A review and synthesis of data on surf zone fishes and invertebrates in the South Atlantic Bight and the potential impacts from beach nourishment. Prepared by the University of North Carolina at Wilmington and the North Carolina National Estuarine Research Reserve for the U.S. Army Corps of Engineers, Wilmington, NC.

Hyslop, E. J. Stomach content analysis: a review of methods and their applications. *J. Fish Biol.,* Southampton, v. 17, no.4, p.411-429, 1980.

National Oceanic and Atmospheric Administration (NOAA). 2005. Fisheries of the United States 2004. National Marine Fisheries Service Office of Science and Technology Fisheries, Statistics Division, Silver Springs, MD. 109 pp.

Pinkas, L.M., S. Oliphant & I.L.K. Iverson. 1971. Food habits of albacore, bluefin tuna and bonito in Californian waters. Calif. Fish Game. 152: 1–105.

Pollock, K.H., Jones, C.M., & Brown, T.L. (1994). Angler surveys and their application to fisheries management. American Fisheries Society Special Publication 25. Bethesda, MD. 371pp.

United States Army Corp of Engineers (USACE). 2000. Final Feasibility Report And Environmental Impact Statement On Hurricane Protection And Beach Erosion Control For Dare County Beaches. USACE Wilmington, NC District. 99 pp.

USACE. 2001. The New York District's Biological Monitoring Program for the Atlantic Coast of New Jersey, Asbury Park to Manasquan Section Beach Erosion Control Project, Final Report. Prepared by U.S. Army Corps of Engineers, Waterways Experiment Station Vicksburg, MS 39180.

Versar, Inc. 1999. Versar Benthic Laboratory Standard Operating Procedures and Quality Control Procedures. Columbia, Maryland.

Versar. 2002. Effects of dredged material beach disposal on surf zone and nearshore fish and benthic resources on Bald Head Island, Caswell Beach, Oak Island, and Holden Beach, North Carolina: Interim study findings. Prepared by Versar, Inc., Columbia MD for U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC. 2 volumes.

APPENDIX

GRAIN SIZE DATA

sed Table trip 1

sample	s_00_063	s_00_075	s_00_106	s_00_250	s_00_425	s_00_850	s_02_000	s_04_750	'% siltclay	% gravel	% sand
104700-1-SHALLOW-1	0.12	0.13	0.36	28.27	44.42	54.84	79.41	97.77	0.12	20.59	79.29
104700-1-SWASH-1	0.25	0.25	0.27	13.52	31.96	63.11	90.54	99.40	0.25	9.46	90.29
104700-2-SHALLOW-1	0.21	0.23	0.28	31.44	60.60	72.26	85.35	96.55	0.21	14.65	85.14
104700-2-SWASH-1	0.18	0.18	0.20	10.46	26.60	44.60	86.63	99.15	0.18	13.37	86.46
104700-3-01-401-1	0.80	0.84	1.15	15.81	71.71	98.54	99.86	100.00	0.80	0.14	99.06
104700-3-02-401-1	1.14	1.57	5.45	63.14	96.77	99.54	99.93	100.00	1.14	0.07	98.79
104700-3-03-401-1	1.39	1.66	2.75	27.57	83.58	99.10	99.82	100.00	1.39	0.18	98.43
104700-3-04-401-1	1.31	1.56	2.88	20.71	54.70	95.12	99.77	100.00	1.31	0.23	98.46
104700-3-05-401-1	0.80	0.85	1.11	4.68	14.86	30.58	58.43	84.22	0.80	41.57	57.63
104700-3-06-401-1	0.76	0.83	1.10	2.91	11.30	39.19	77.76	98.43	0.76	22.24	77.00
104700-3-07-401-1	16.05	16.41	18.90	74.94	98.25	99.59	99.98	100.00	16.05	0.02	83.93
104700-3-08-401-1	1.26	2.06	9.74	92.42	96.34	99.07	100.00	100.00	1.26	0.00	98.74
104700-3-09-401-1	1.01	1.02	1.14	5.25	54.83	91.60	98.86	100.00	1.01	1.14	97.85
104700-3-10-401-1	2.01	3.00	10.42	94.71	98.03	99.02	99.50	100.00	2.01	0.50	97.49
104700-4-01-401-1	5.00	7.79	27.20	97.99	99.25	99.72	100.00	100.00	5.00	0.00	95.00
104700-4-02-401-1	3.15	4.94	21.01	98.33	99.51	99.84	99.95	100.00	3.15	0.05	96.80
104700-4-03-401-1	1.96	3.09	15.34	96.17	99.21	99.61	99.87	100.00	1.96	0.13	97.91
104700-4-04-401-1	1.69	2.25	7.86	95.44	98.87	99.34	99.69	100.00	1.69	0.31	97.99
104700-4-05-401-1	1.09	1.36	4.43	74.93	98.88	99.95	100.00	100.00	1.09	0.00	98.91
104700-4-06-401-1	1.65	1.95	6.41	79.69	97.04	99.26	99.77	100.00	1.65	0.23	98.13
104700-4-07-401-1	1.96	2.79	9.13	90.31	98.18	99.76	99.99	100.00	1.96	0.01	98.03
104700-4-08-401-1	1.54	2.09	13.59	88.68	98.29	99.55	99.78	100.00	1.54	0.22	98.24
104700-4-09-401-1	2.42	3.82	13.98	94.55	98.28	99.35	99.77	100.00	2.42	0.23	97.35
104700-4-10-401-1	1.73	2.46	8.95	84.37	96.23	98.60	99.73	99.73	1.73	0.27	98.01

Sed table trip 2

sample	s_00_063	s_00_075	s_00_106	s_00_250	s_00_425	s_00_850	s_02_000	s_04_750	'% siltclay	% gravel	% sand
104700-03-01-402-01	1.08	1.20	1.55	12.14	52.65	91.42	98.73	99.87	1.08	1.27	97.65
104700-03-02-402-01	1.12	1.18	1.27	1.75	21.05	64.14	92.89	98.76	1.12	7.11	91.78
104700-03-03-402-01	1.09	1.24	1.72	7.41	28.93	67.31	89.43	97.88	1.09	10.57	88.34
104700-03-04-402-01	2.35	3.20	5.16	9.88	19.97	34.70	58.44	86.09	2.35	41.56	56.09
104700-03-05-402-01	1.29	1.50	2.19	16.75	63.88	96.73	99.52	100.00	1.29	0.48	98.23
104700-03-06-402-01	1.23	1.93	6.63	93.17	96.89	99.15	99.72	100.00	1.23	0.28	98.48
104700-03-07-402-01	11.55	24.31	68.29	98.23	99.60	99.98	100.00	100.00	11.55	0.00	88.45
104700-03-08-402-01	1.36	2.35	10.47	82.18	94.47	98.32	99.66	100.00	1.36	0.34	98.30
104700-03-09-402-01	5.27	9.33	29.36	94.53	98.63	99.21	99.83	100.00	5.27	0.17	94.56
104700-03-10-402-01	7.11	11.98	53.35	96.35	99.53	99.89	100.00	100.00	7.11	0.00	92.89
104700-04-01-402-01	2.03	2.99	9.81	90.48	97.55	99.41	99.83	100.00	2.03	0.17	97.80
104700-04-02-402-01	0.77	0.82	1.44	68.73	98.77	99.84	99.88	100.00	0.77	0.12	99.11
104700-04-03-402-01	1.75	2.87	11.62	96.81	99.26	99.60	99.75	100.00	1.75	0.25	98.01
104700-04-04-402-01	1.22	1.80	8.02	83.89	97.74	99.52	99.79	100.00	1.22	0.21	98.57
104700-04-05-402-01	1.06	1.65	7.55	81.74	97.58	99.25	99.69	100.00	1.06	0.31	98.63
104700-04-06-402-01	1.06	1.70	9.66	84.47	97.99	99.61	99.90	100.00	1.06	0.10	98.84
104700-04-07-402-01	1.52	2.24	11.67	94.60	98.70	99.65	100.00	100.00	1.52	0.00	98.48
104700-04-08-402-01	2.57	3.96	13.45	93.66	98.30	99.38	100.00	100.00	2.57	0.00	97.43
104700-04-09-402-01	2.69	4.38	17.14	94.90	98.47	99.36	100.00	100.00	2.69	0.00	97.31
104700-04-10-402-01	2.16	3.29	12.34	94.66	98.92	99.54	100.00	100.00	2.16	0.00	97.84

Sed Table Trip3

sample	s_00_063	s_00_075	s_00_106	s_00_250	s_00_425	s_00_850	s_02_000	s_04_750	'% siltclay	% gravel	% sand
104700-03-01-403-01	0.32	0.34	0.44	6.51	39.29	95.20	99.77	100.00	0.32	0.23	99.45
104700-03-02-403-01	0.38	0.44	0.69	7.19	34.29	75.90	93.02	99.82	0.38	6.98	92.63
104700-03-03-403-01	0.57	0.60	0.77	2.04	8.26	27.45	65.28	89.86	0.57	34.72	64.71
104700-03-04-403-01	0.83	1.12	2.66	26.72	52.49	83.98	96.60	99.66	0.83	3.40	95.78
104700-03-05-403-01	0.57	0.59	0.73	13.31	66.46	92.10	98.18	100.00	0.57	1.82	97.61
104700-03-06-403-01	0.80	0.83	1.14	22.42	77.80	95.04	99.32	100.00	0.80	0.68	98.53
104700-03-07-403-01	0.44	0.46	0.68	16.96	67.74	97.52	99.98	100.00	0.44	0.02	99.54
104700-03-08-403-01	1.83	2.78	9.01	87.27	92.40	97.89	100.00	100.00	1.83	0.00	98.17
104700-03-09-403-01	1.18	1.91	9.39	96.14	99.40	99.90	99.97	100.00	1.18	0.03	98.79
104700-03-10-403-01	0.77	1.23	8.36	90.02	96.93	99.50	100.00	100.00	0.77	0.00	99.23
104700-04-01-403-01	1.52	2.56	11.59	91.25	99.12	100.00	100.00	100.00	1.52	0.00	98.48
104700-04-02-403-01	1.24	2.09	8.82	94.25	99.21	100.00	100.00	100.00	1.24	0.00	98.76
104700-04-03-403-01	1.30	2.23	9.68	91.20	98.36	100.00	100.00	100.00	1.30	0.00	98.70
104700-04-04-403-01	1.93	3.47	11.82	94.40	98.79	100.00	100.00	100.00	1.93	0.00	98.07
104700-04-05-403-01	1.16	1.90	7.83	89.10	98.13	100.00	100.00	100.00	1.16	0.00	98.84
104700-04-06-403-01	1.59	2.57	10.82	87.91	98.05	100.00	100.00	100.00	1.59	0.00	98.41
104700-04-07-403-01	1.94	2.89	13.83	92.17	98.66	100.00	100.00	100.00	1.94	0.00	98.06
104700-04-08-403-01	1.86	3.26	13.11	95.75	98.95	100.00	100.00	100.00	1.86	0.00	98.14
104700-04-09-403-01	1.37	2.43	9.63	96.04	99.46	100.00	100.00	100.00	1.37	0.00	98.63
104700-04-10-403-01	3.86	5.19	13.35	97.49	98.93	100.00	100.00	100.00	3.86	0.00	96.14
Shallow Control-403	0.23	0.24	0.29	21.14	31.97	36.07	56.23	87.09	0.23	43.77	56.00
Shallow Impact-403	0.31	0.32	0.32	0.55	1.55	8.23	32.08	80.20	0.31	67.92	31.77
Swash Control-403	0.34	0.35	0.39	16.34	34.84	61.85	93.92	100.00	0.34	6.08	93.58
Swash Impact-403	0.32	0.32	0.33	1.85	7.54	38.12	87.57	98.95	0.32	12.43	87.25

Sed Table Trip 4

sample	s_00_063	s_00_075	s_00_106	s_00_250	s_00_425	s_00_850	s_02_000	s_04_750	'% siltclay	% gravel	% sand
104700-03-01-404-01	0.63	0.65	0.75	5.63	29.65	76.13	92.66	99.36	0.63	7.34	92.03
104700-03-02-404-01	1.96	2.97	8.42	88.35	98.07	99.56	100.00	100.00	1.96	0.00	98.04
104700-03-03-404-01	0.82	0.92	1.86	53.66	94.83	99.79	100.00	100.00	0.82	0.00	99.18
104700-03-04-404-01	1.02	1.13	1.82	32.93	69.57	91.23	99.70	100.00	1.02	0.30	98.68
104700-03-05-404-01	0.51	0.52	0.60	9.18	53.56	95.83	99.69	100.00	0.51	0.31	99.18
104700-03-06-404-01	0.60	0.72	1.57	39.60	52.77	85.86	99.81	100.00	0.60	0.19	99.21
104700-03-07-404-01	0.49	0.51	0.60	3.92	30.16	82.70	97.08	99.59	0.49	2.92	96.59
104700-03-08-404-01	0.63	0.67	0.99	8.52	27.64	65.72	91.76	99.01	0.63	8.24	91.13
104700-03-09-404-01	0.47	0.48	0.50	1.85	16.28	64.66	90.21	99.78	0.47	9.79	89.73
104700-03-10-404-01	0.56	0.57	0.68	9.11	49.67	83.65	99.26	100.00	0.56	0.74	98.70
104700-04-01-404-01	1.68	2.12	4.26	85.52	96.98	99.18	100.00	100.00	1.68	0.00	98.32
104700-04-02-404-01	1.51	3.05	11.33	89.48	97.30	99.37	99.99	100.00	1.51	0.01	98.48
104700-04-03-404-01	3.09	6.27	21.72	93.50	98.40	99.76	100.00	100.00	3.09	0.00	96.91
104700-04-04-404-01	2.71	4.57	19.77	94.95	98.30	99.73	100.00	100.00	2.71	0.00	97.29
104700-04-05-404-01	1.97	4.17	19.12	95.25	98.88	100.00	100.00	100.00	1.97	0.00	98.03
104700-04-06-404-01	1.77	3.06	15.07	90.51	98.29	99.46	99.94	100.00	1.77	0.06	98.17
104700-04-07-404-01	2.05	4.24	17.33	91.40	98.48	99.61	100.00	100.00	2.05	0.00	97.95
104700-04-08-404-01	1.28	2.19	14.14	91.99	98.28	99.59	100.00	100.00	1.28	0.00	98.72
104700-04-09-404-01	4.33	6.17	20.92	94.85	98.42	99.50	100.00	100.00	4.33	0.00	95.67
104700-04-10-404-01	2.85	5.84	23.81	98.19	99.36	99.77	100.00	100.00	2.85	0.00	97.15
Control-Shallow-04	0.20	0.21	0.21	0.22	0.27	1.38	33.47	78.11	0.20	66.53	33.26
Control-Swash-04	0.35	0.35	0.37	2.66	9.87	51.44	96.79	100.00	0.35	3.21	96.44
Impact-Shallow-04	0.36	0.36	0.37	1.86	6.76	20.28	48.40	86.50	0.36	51.60	48.05
Impact-Swash-04	0.53	0.56	0.66	10.04	40.88	90.71	99.77	100.00	0.53	0.23	99.24