Final Report
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PRE-CONSTRUCTION ECOLOGICAL CONDITION FOR THE DARE COUNTY BEACH SHORELINE PROTECTION PROJECT, DARE COUNTY, NORTH CAROLINA

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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 recommended two years of pre-construction monitoring of biological resources. Because of changes to project priorities, three years of pre-construction monitoring were conducted from April 2004 to February 2007. This report presents the results of the three years 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 three years. In the summer of 2005 an additional offshore ocean site (S1) was added to the sampling regime due to concerns of questionable sand quality and quantity at the original borrow sites. In addition to the offshore sampling, 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 potentially two of the ocean sites. All other sites in this program were used as reference sites. Three years of pre-construction monitoring indicates significant temporal and spatial scale fluctuations in many of the biological resources 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. Fish diets from species collected in the surf and at the ocean sites indicated the importance of those habitats to several species. 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. These results are consistent with other studies reported within the region.

The pre-construction monitoring program to characterize temporal and spatial baseline conditions is now complete. Due to federal budget constraints, the beach replenishment project has not been funded and therefore monitoring has been stopped until funding is acquired. If and when construction funds are appropriated, the USACE intends to re-institute the program beginning with the during-construction monitoring study plan. At that point these data will be used to assess beach replenishment impacts and recovery as the program moves into construction and post-construction monitoring periods.

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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 (USACE 2000).

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 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 the extent to which 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 a 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 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 originally committed to a

5-year study that included two pre-construction, one during-construction, and two post-construction years. Due to federal budget constraints, no construction funds were appropriated; however funds were available for biological monitoring and because of this a total of three years of pre-construction monitoring has been conducted. In addition, a third borrow site was added to the program after year one. After three years of pre-construction monitoring, it was apparent that construction funds would not be available, hence monitoring was discontinued. If and when construction funds are appropriated, the USACE intends to re-institute the program beginning with the during-construction monitoring study plan.

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 and reference beach, inclusive of fisheries, benthic, and ghost crab surveys
- Biological monitoring of the N1/N2 and S1 borrow sites, 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 three years 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. The data collected during the monitoring program has been summarized and is presented in this report as three year seasonal averages.

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 three years (Fig. 2-1). Beginning in the summer of 2005, an additional offshore ocean site was added to the sampling regime due to concerns of questionable sand quality and quantity at the original borrow sites. 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 has been conducted for three years prior to beach nourishment, and if and when construction funds are appropriated, monitoring will continue during the nourishment process, and during two years post-nourishment. The monitoring program consists of sampling the densities of fish, benthos, ghost crabs, and birds at the beaches. Only fish and benthos densities are monitored at the ocean sites. In addition, a creel survey was 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.

2.2 BEACH SITES

The beach sites are located in Dare County, NC, and consist 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 (Fig. 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 (Fig. 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 (Fig. 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 piers represent an important resource to recreational

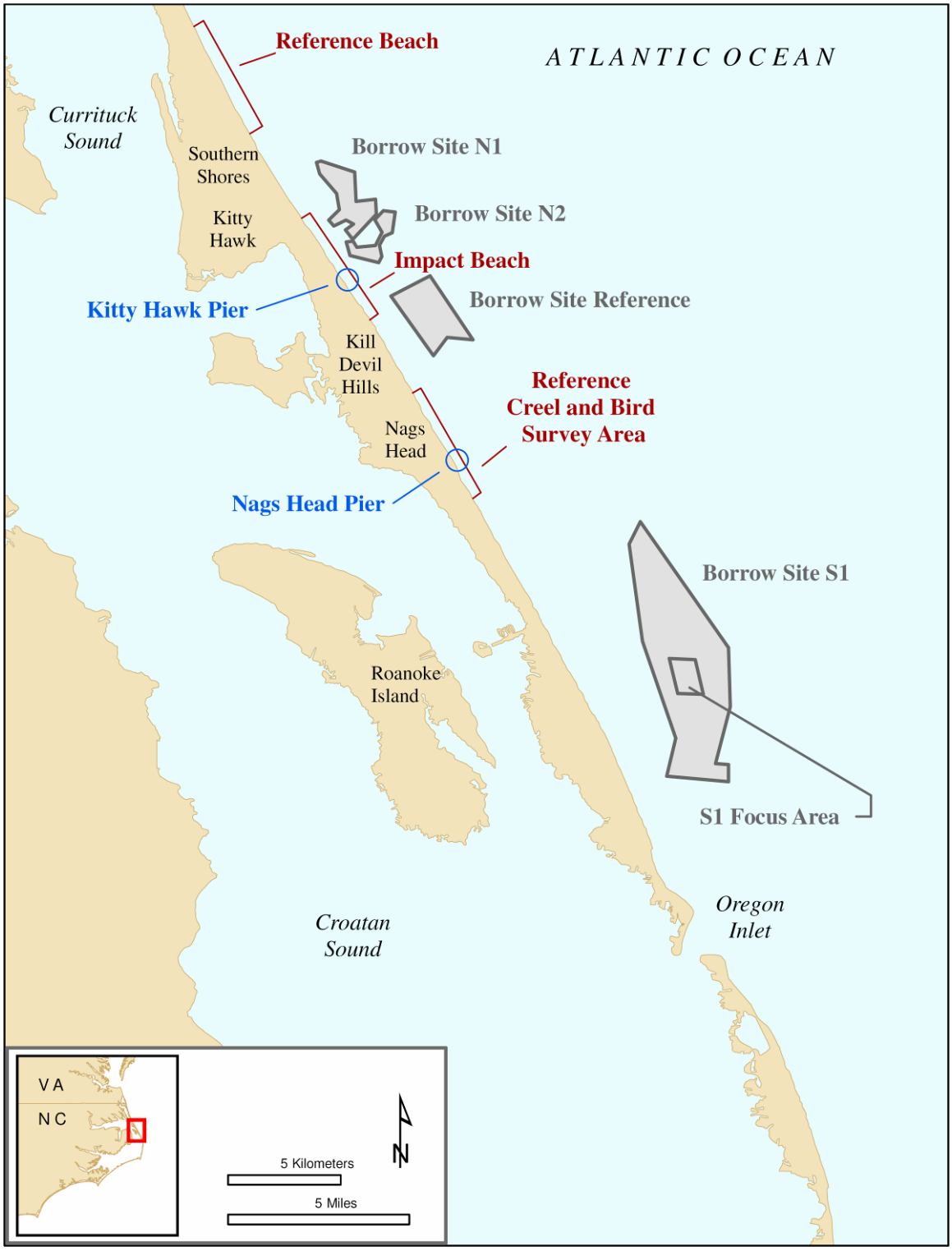


Figure 2-1. Map of several beaches and offshore sand borrow sites located in Dare County, NC that were sampled seasonally for three years as part of a biological monitoring project for the U.S. Army Corps of Engineers, Wilmington District

fisherman, we chose a separate reference beach for the creel survey that had an active fishing pier.

2.3 OCEAN BORROW SITES

The ocean sites consist of a combination of three potential sand borrow sites and a reference site used for comparison. Borrow sites N1 and N2 are located approximately 0.8 km offshore of the impact beach and the S1 borrow site is 23 km to the south of the impact beach (Fig. 2-1). Several past geological investigations have identified these sites as having good quality sand for beach nourishment and therefore sand from these sites has been proposed for use to nourish the Northern Project Beach as funds are available.

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 (Boss and Hoffman 2001), several potential reference areas to the south of the borrow sites were delineated prior to conducting the video survey (Fig. 2-2). After these areas were identified, Dial Cordy and Associates Inc., from Jacksonville Beach, FL 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 (Fig. 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 (Fig. 2-1).

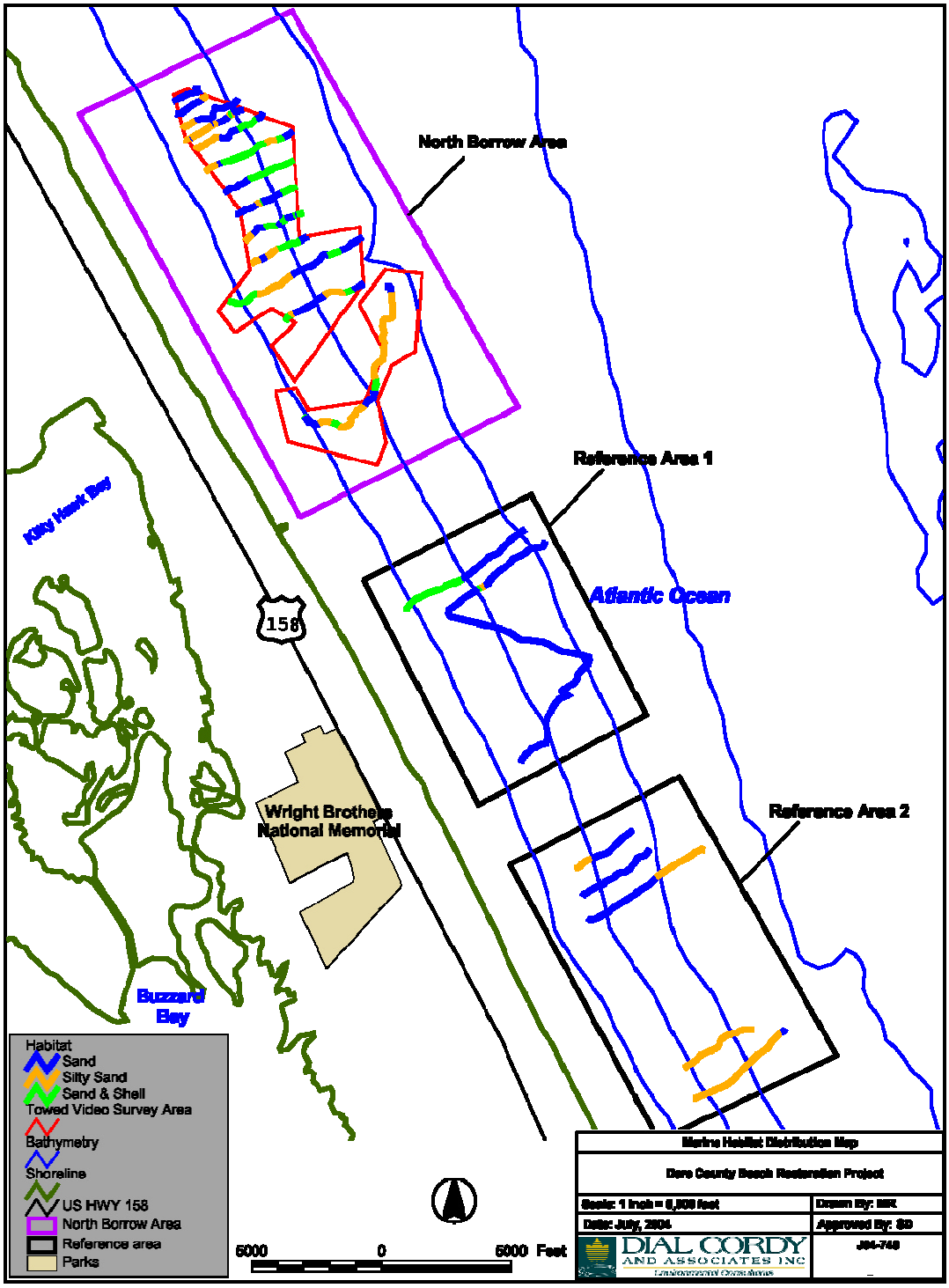


Figure 2-2. Map of two ocean borrow sites and two potential reference sites surveyed with an underwater video sled to identify a suitable reference borrow site for the biological monitoring project in Dare County, NC. Lines show actual video transects and substrate type.

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 (Fig. 2-3). Fixed sites at both beaches were chosen to coincide with physical habitat survey transects previously established by researchers from the Army Corps of Engineers Field Research Facility in Duck, NC. 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 (Tables 2-1 and 2-2).

Table 2-1. Impact beach benthic stations. Bolded physical station numbers were randomly 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			

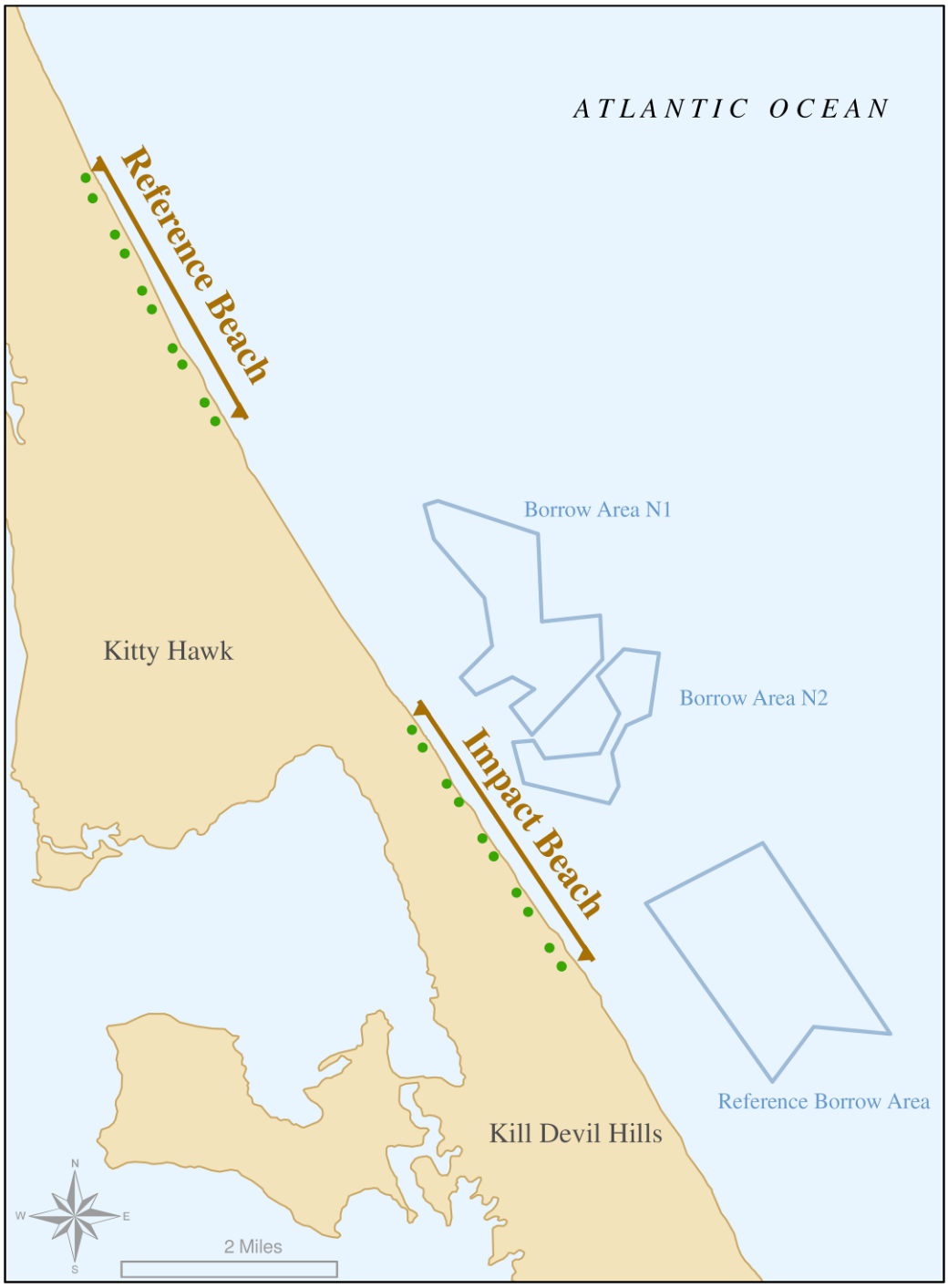


Figure 2-3. Map showing sample sites at two beaches located in Dare County, NC that were sampled for benthic organisms seasonally for three years as part of a biological monitoring project for the U.S. Army Corps of Engineers, Wilmington District

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			

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

In the laboratory, the samples were re-sieved and processed to identify all organisms present in the sample. 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 (Fig. 2-1). Using a random point generator in a GIS, 10 randomly chosen sites were generated and sampled in each season within the borrow (seven sites in N1 and three in N2) and reference sites (Fig. 2-4). In the summer of 2005 a new borrow site (S1) was

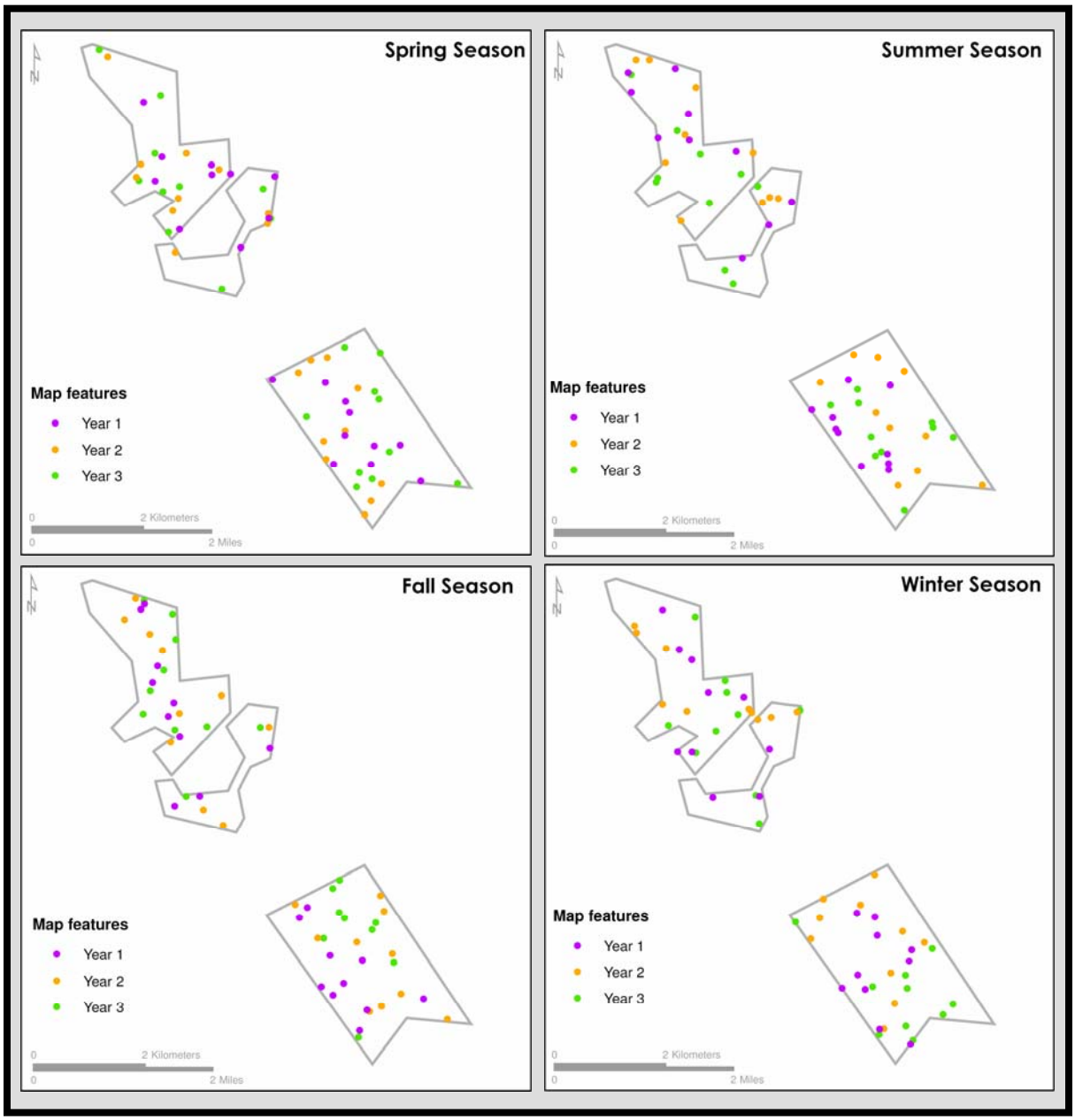


Figure 2-4. Maps showing the locations of three years of seasonal benthic samples collected at an ocean borrow site (N1 and N2) and a reference borrow site located offshore of Kitty Hawk, NC

added to the sampling programs and an additional 10 benthic samples were collected at this site during each seasonal sampling event (Fig. 2-5). At each sample site, the exact latitude and longitude were documented, and bottom water quality readings (dissolved oxygen, pH, temperature, and salinity) were also taken. Benthic samples were sieved through a 0.5 mm screen in the field and all organisms present on the screen were preserved and transported back to Versar, Inc., for processing. Benthic samples were 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 of 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 EC 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	Sieve Number	Sieve Size	Wentworth Size Category
4	4.75-mm	Pebble	140	106-µm	Fine Sand
10	2.00-mm	Granule	200	75-µm	Undefined
20	850-µm	Very Coarse Sand	230	63-µm	Very Fine Sand
40	425-µm	Coarse Sand		< 63-µm	Silt-Clay
60	250-µm	Medium Sand			

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 were conducted during each season at both the impact and reference beaches.

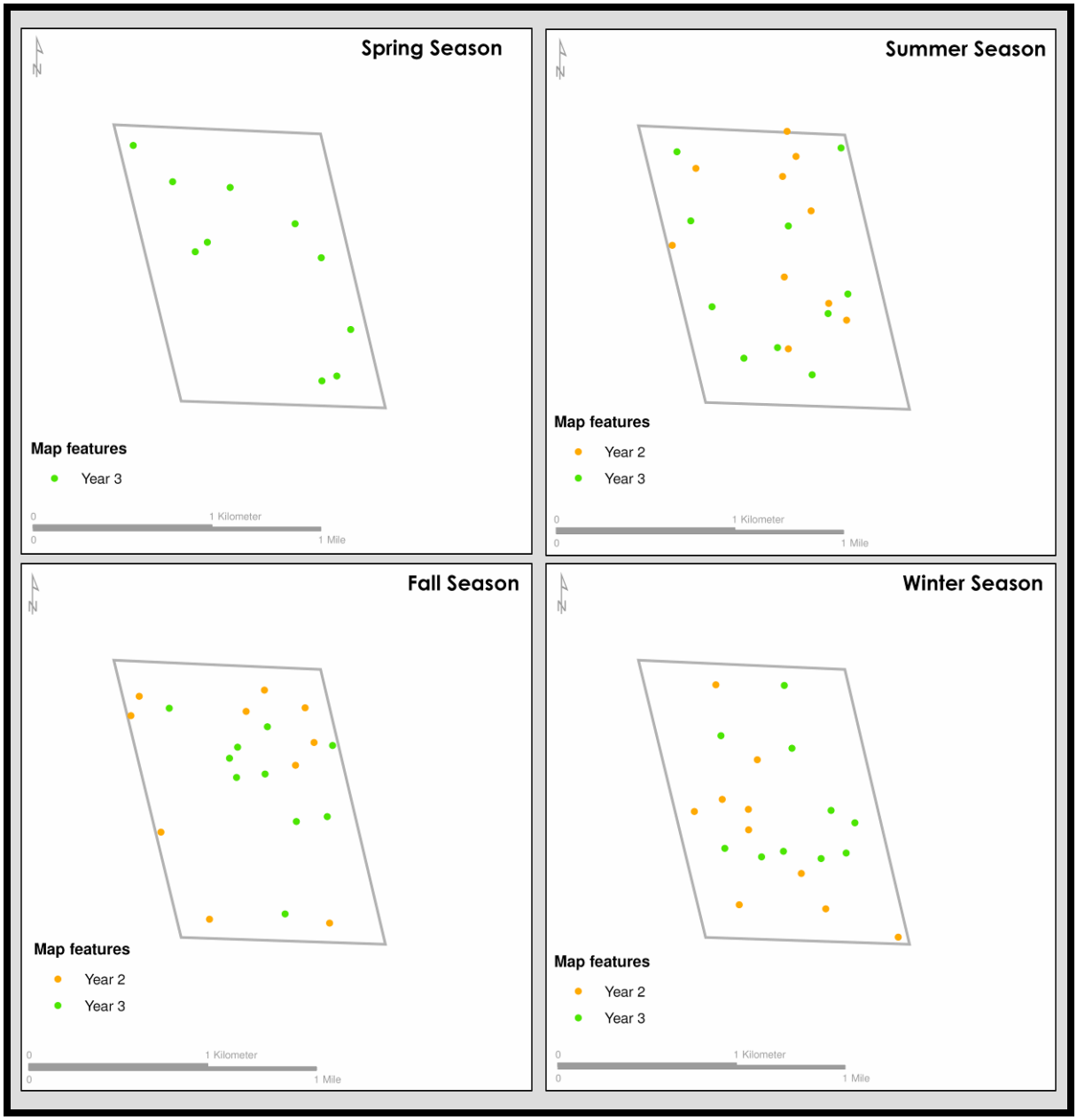


Figure 2-5. Maps showing the locations of one and three quarters years of seasonal benthic samples collected at the S1 ocean borrow site located offshore of Nags Head, NC

However, because of weather conditions only seven seines were conducted at each beach in the summer 2004 season. Attempts were 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 (Fig. 2-6), because of localized beach replenishment efforts and significant storm and erosion damage which restricted vehicle traffic.

Seines were 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 was then brought to shore farther down the beach, generally in a North to South direction, and then retrieved by hand. All organisms brought to the beach in the net were identified to species level, enumerated, and a sub-set of up to 25 specimens were 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, 12 at the S1 borrow site, and 12 at the reference borrow site (Figs. 2-7 and 2-8). However, during the first event, only ten trawls were conducted between the two borrow sites and ten trawls in the reference site (Fig. 2-7). Each trawl was generally towed for 10-minutes and the starting and ending latitude and longitude coordinates were 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.

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.

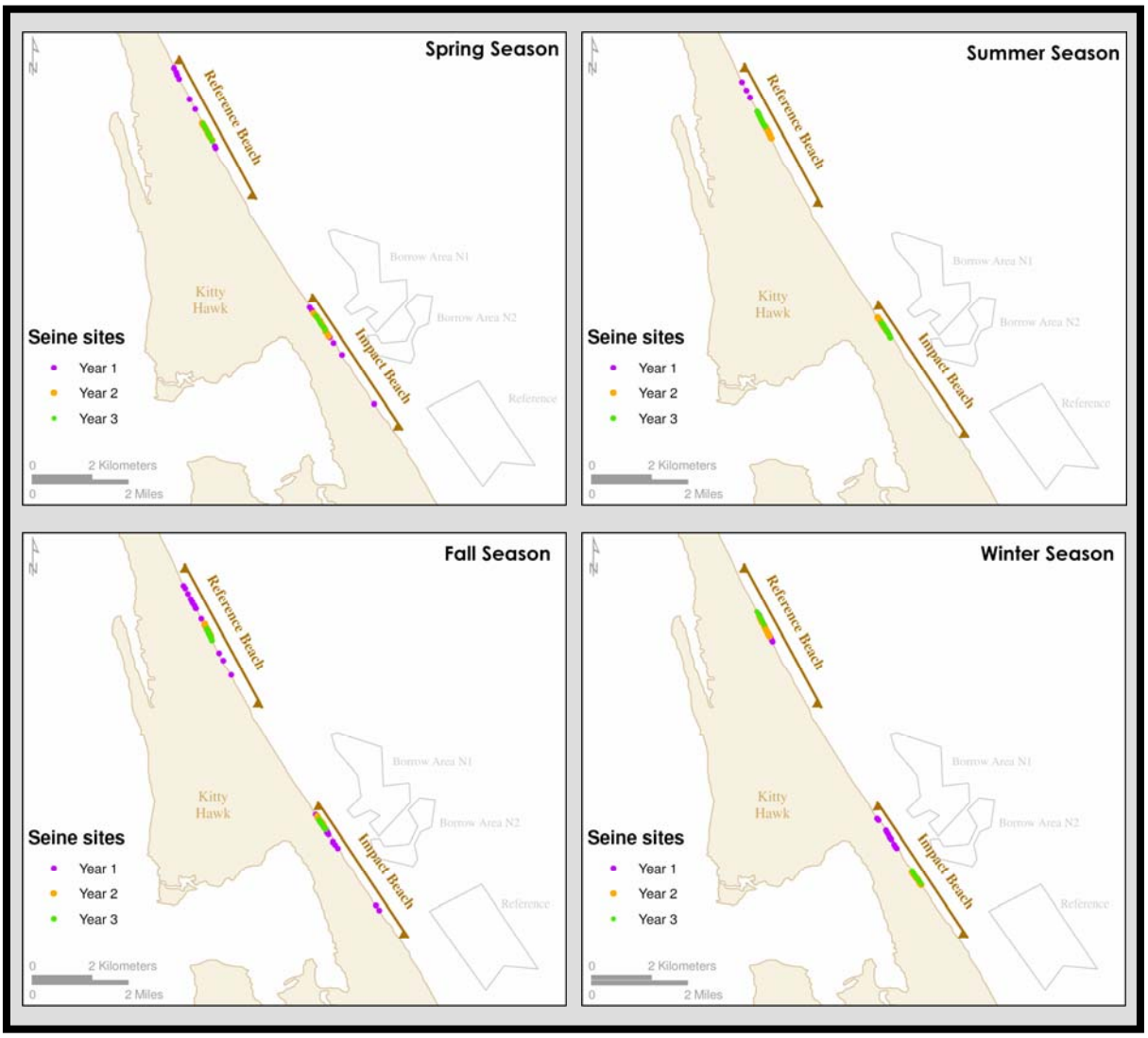


Figure 2-6. Maps showing the locations of three years of seasonal beach seines pulled in the surf zone at the impact beach and reference beach located in Kill Devil Hills and Southern Shores, NC

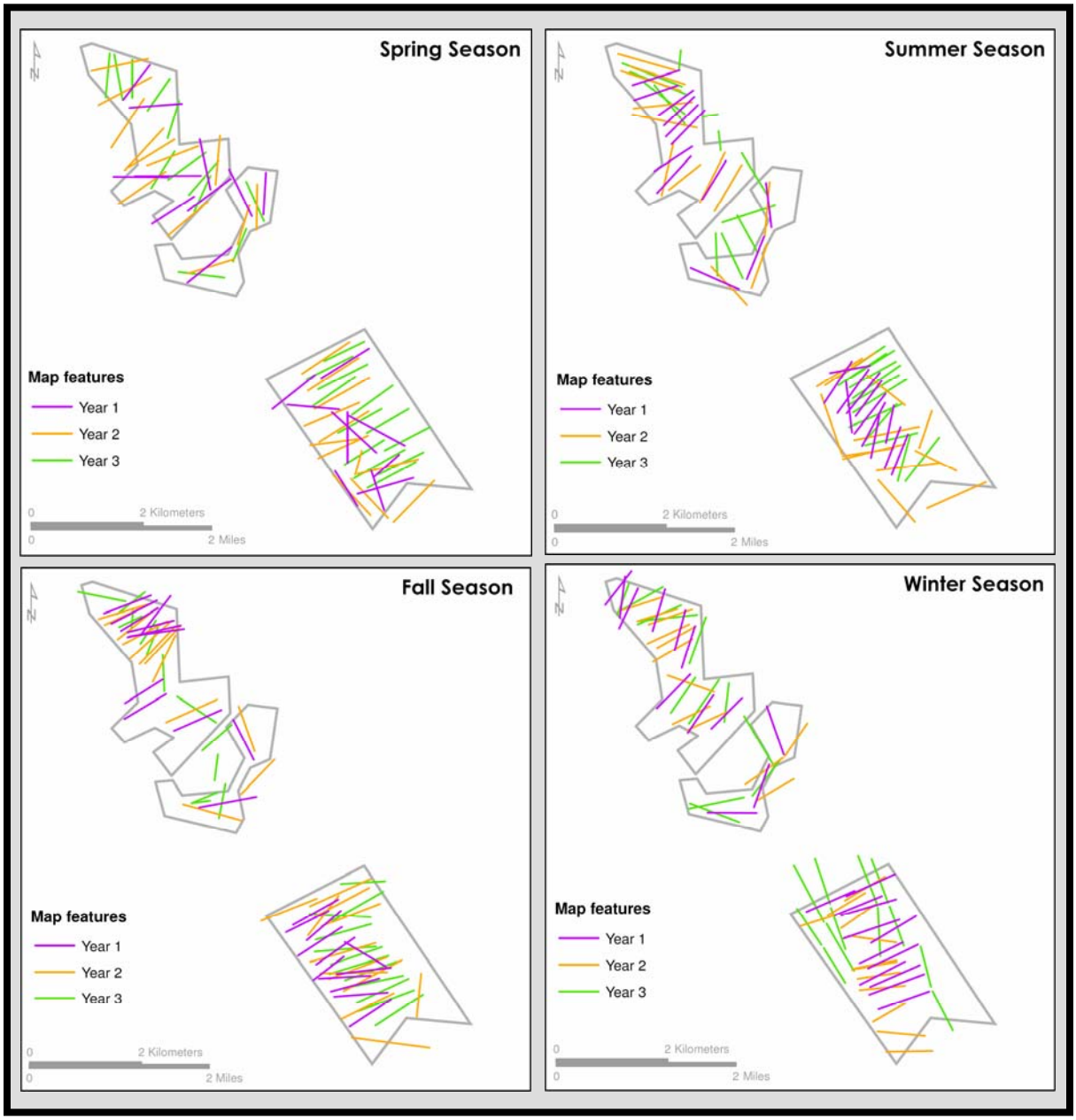


Figure 2-7. Maps showing the locations of three years of seasonal trawls conducted at an ocean borrow site and a reference borrow site located offshore of Kitty Hawk, NC

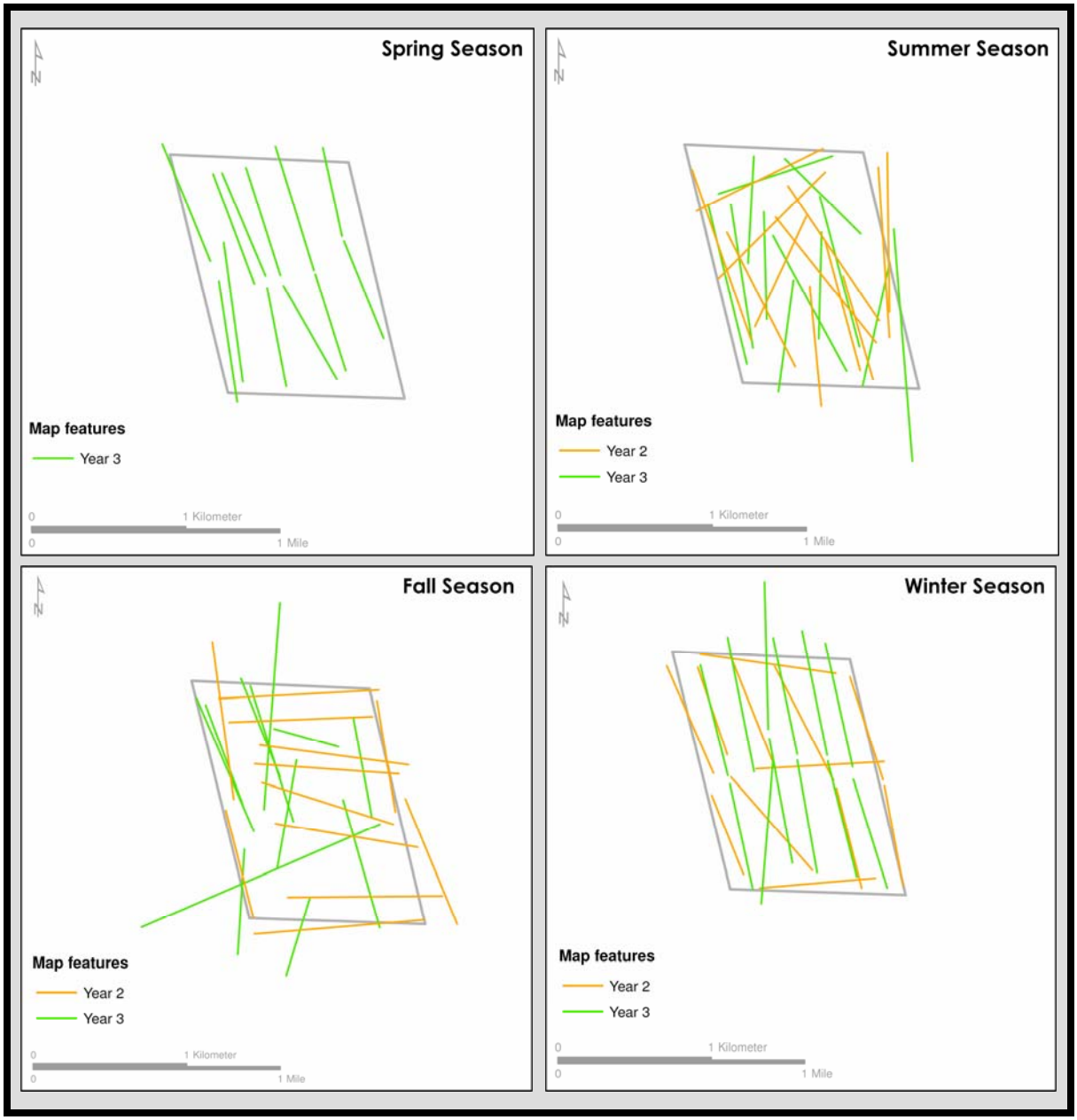


Figure 2-8. Maps showing the locations of one and three quarters years of seasonal trawls conducted at the S1 ocean borrow site and a reference borrow site located offshore of Nags Head, NC

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 (Fig. 2-9). 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.

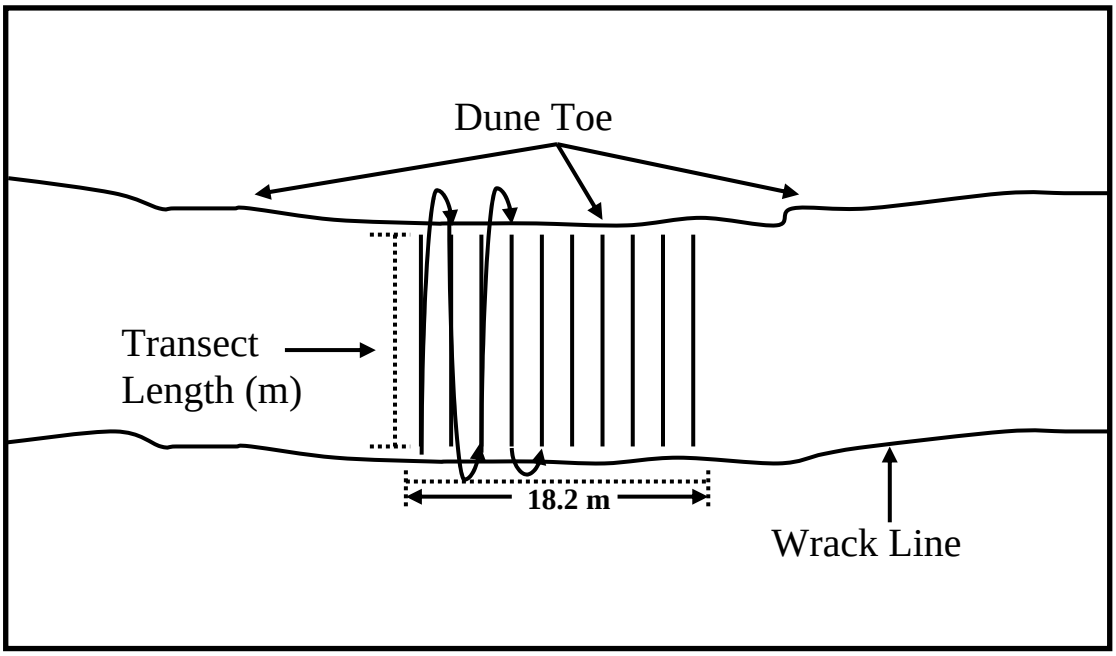


Figure 2-9. Diagram of ghost crab hole transect counts which were conducted for three years at 10 stations at the impact beach (Kitty Hawk) and 10 stations at the reference beach (Southern Shores)

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 (Fig. 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) throughout the three years 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 (Fig. 2-10). 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.

	Weeks	Days of the Week						
Season		1	2	3	4	5	6	7
	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 2-10. 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, NC

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 was 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 (Fig. 2-11). For example, if 8 am was chosen as the start on the pier, then the beach was 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 (Fig. 2-11). Angler interviews were conducted either before or after instantaneous counts were performed.

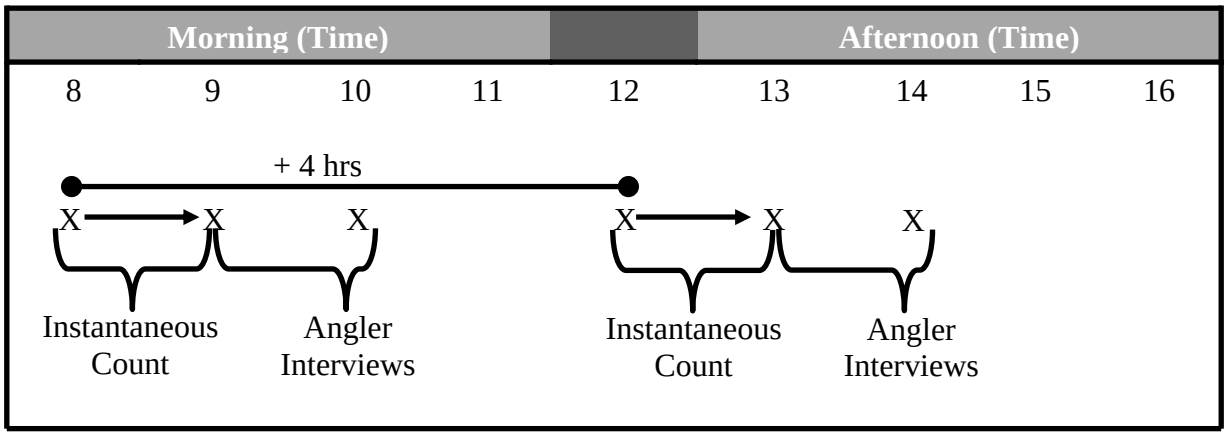


Figure 2-11. Diagram describing the schedule and timing of daily angler counts and interviews conducted at the impact (Kitty Hawk) and reference creel (Nags Head) survey beaches

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 ~ 0.5 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 study at the impact and reference beaches (Fig. 2-1). The methods were similar to those used in a recent study conducted in Brunswick County, North Carolina (CZR 2003). 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 (Fig. 2-11). 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 all seasons; 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 two separate microhabitat zones defined as: 1) the beach (the physical habitat residing between the dune and present swash/intertidal zone), and 2) 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, or flying), and location of birds within a habitat (beach, surf, and intertidal zone) was documented within each of the 10 transects. Total number of pets and people using the beaches was also documented during each survey. In addition, the presence of local beach construction activities occurring (e.g., dune building) and other pertinent information such as tide state, wind speed and direction, or air temperature was also noted.

2.4.6 Underwater Video Surveys

During the three year project a total of two under water video survey's were conducted to gather baseline information on seasonal physical and biological features residing on the substrate at the borrow and reference sites. Both surveys were conducted using benthic video sleds equipped with two video cameras mounted in two different configurations to provide: 1) near bottom horizontal view to see fish over the bottom and bed form types, and 2) a vertical high resolution view for sediment type and biogenic features (Fig. 2-12). The near bottom horizontal camera provided 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 between 0.045 m^2 and 0.06 m^2 per camera. Illumination for the vertical and horizontal cameras was provided by ambient light and stationary lights regulated from the towing vessel.

The first survey was conducted between the 8th and 9th of December 2004 using a benthic video sled provided by the Virginia Institute of Marine Science (VIMS). 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. Video data was collected at all the sites following a transect survey design outlined by Versar. Approximately 48 km of bottom habitat was covered during the first survey (Fig. 2-12). 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 second video survey was conducted between the 6th and 10th of June 2006. Video data was collected using Versar's towed benthic video sled. The sled was deployed from the stern of the 8 m vessel *R/V Integrity* and towed at speed of 1 to 2 knots. A total of 55 km of transects were covered during the survey. During the four day field effort 20 km of transects were covered in the N1 & N2 borrow site, 20 km at the reference site, and 15km at the S1 borrow site.

The video sleds were linked to the surface via two cables that provided power to both cameras and the lights. 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.

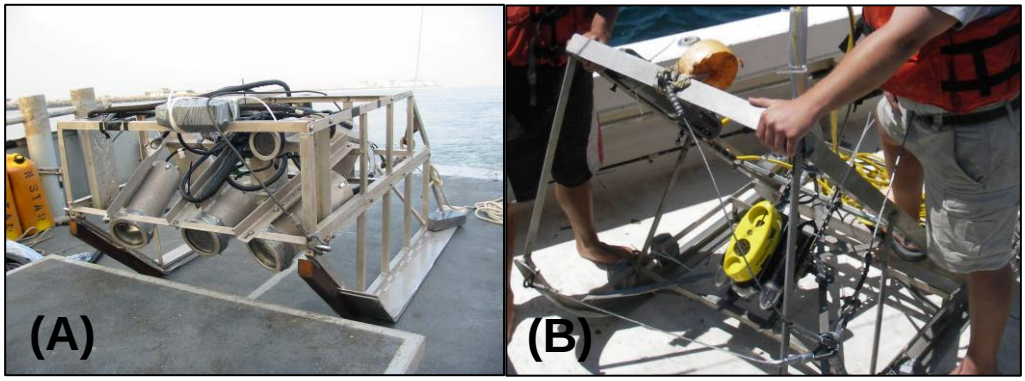


Figure 2-12. Video sleds used to characterize benthic habitats. In the picture, both video sleds are facing forward. In caption A, the overview camera is at the top right corner of the sled, horizontal camera is in the front center and flanked by two electronic video strobes, close-up vertical camera is in the center of the sled, behind the horizontal camera. Sled runners are 0.8 m apart. In caption B the forward facing camera is the ROV attached to the mid section of the sled and the downward looking camera is below the ROV attached to a cross bar.

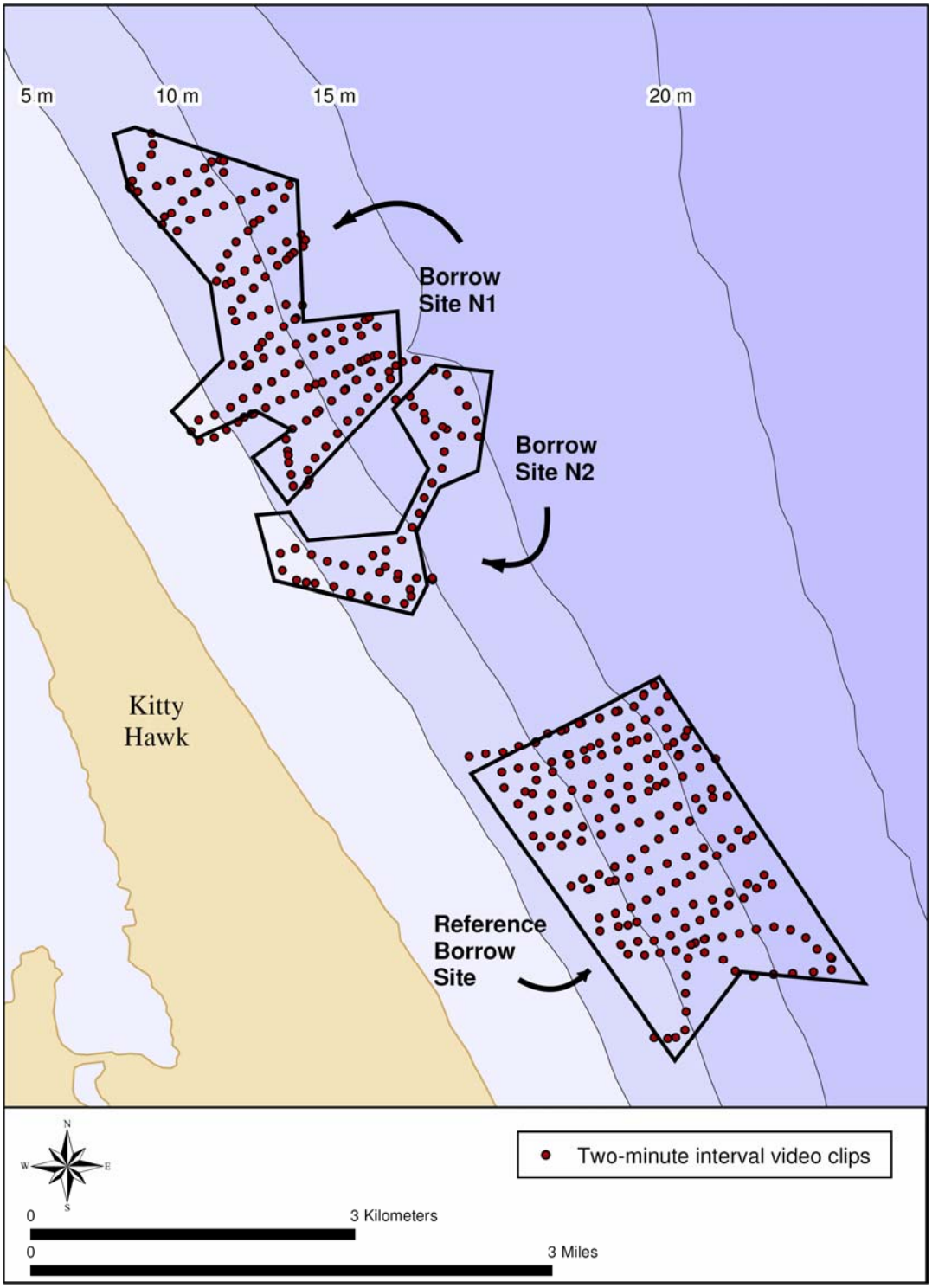


Figure 2-13. Video sled transect lines covered during the December 2004 bottom survey of the Dare County beach replenishment borrow sites N1 and N2 and the nearby reference area. Points represent locations of 2-minute video clips analyzed from the video.

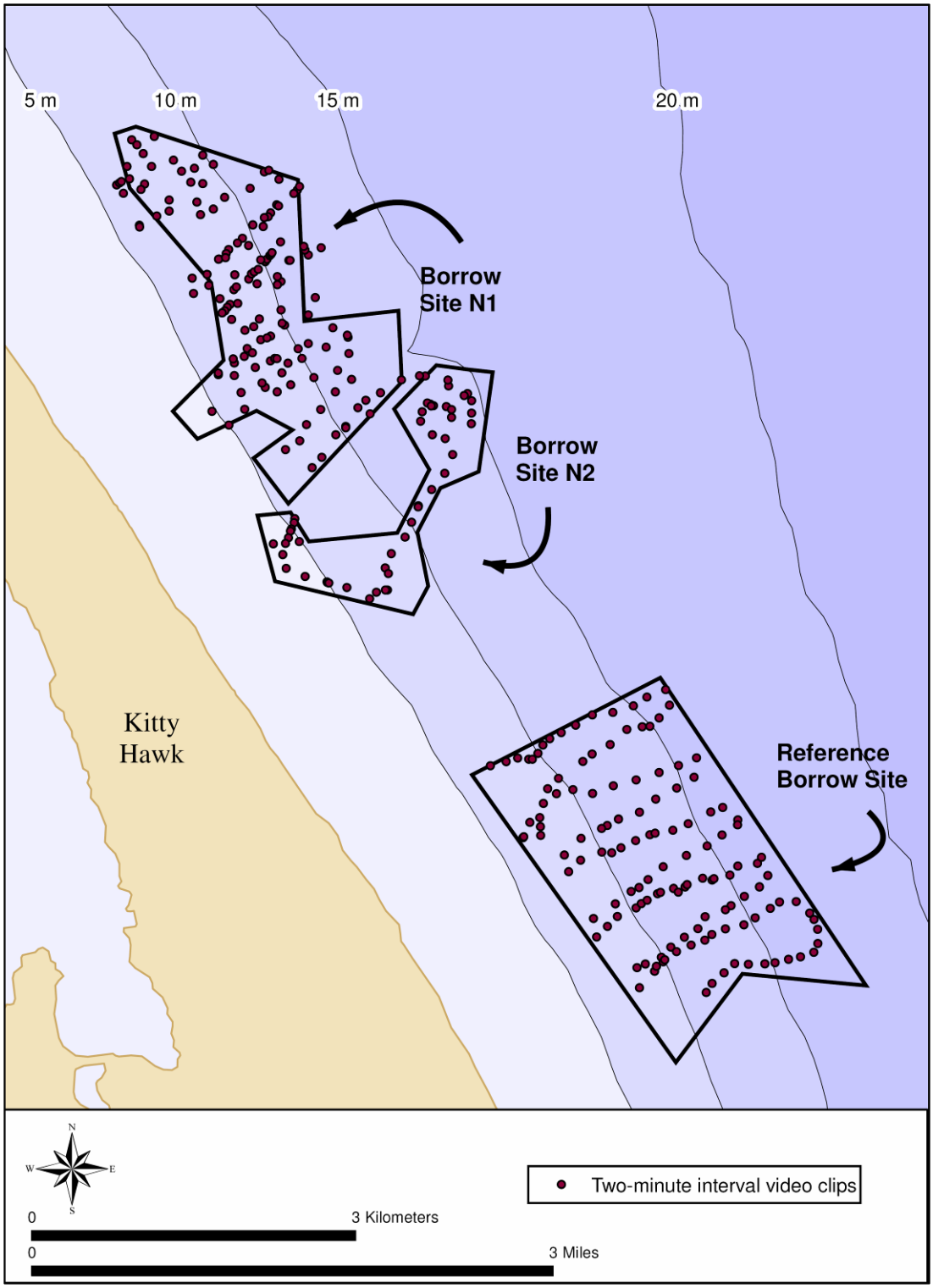


Figure 2-14. Video sled transect lines covered during the June 2006 bottom survey of the Dare County beach replenishment borrow sites N1, N2, and S1and the nearby reference area. Points represent locations of 2-minute video clips analyzed from the video.

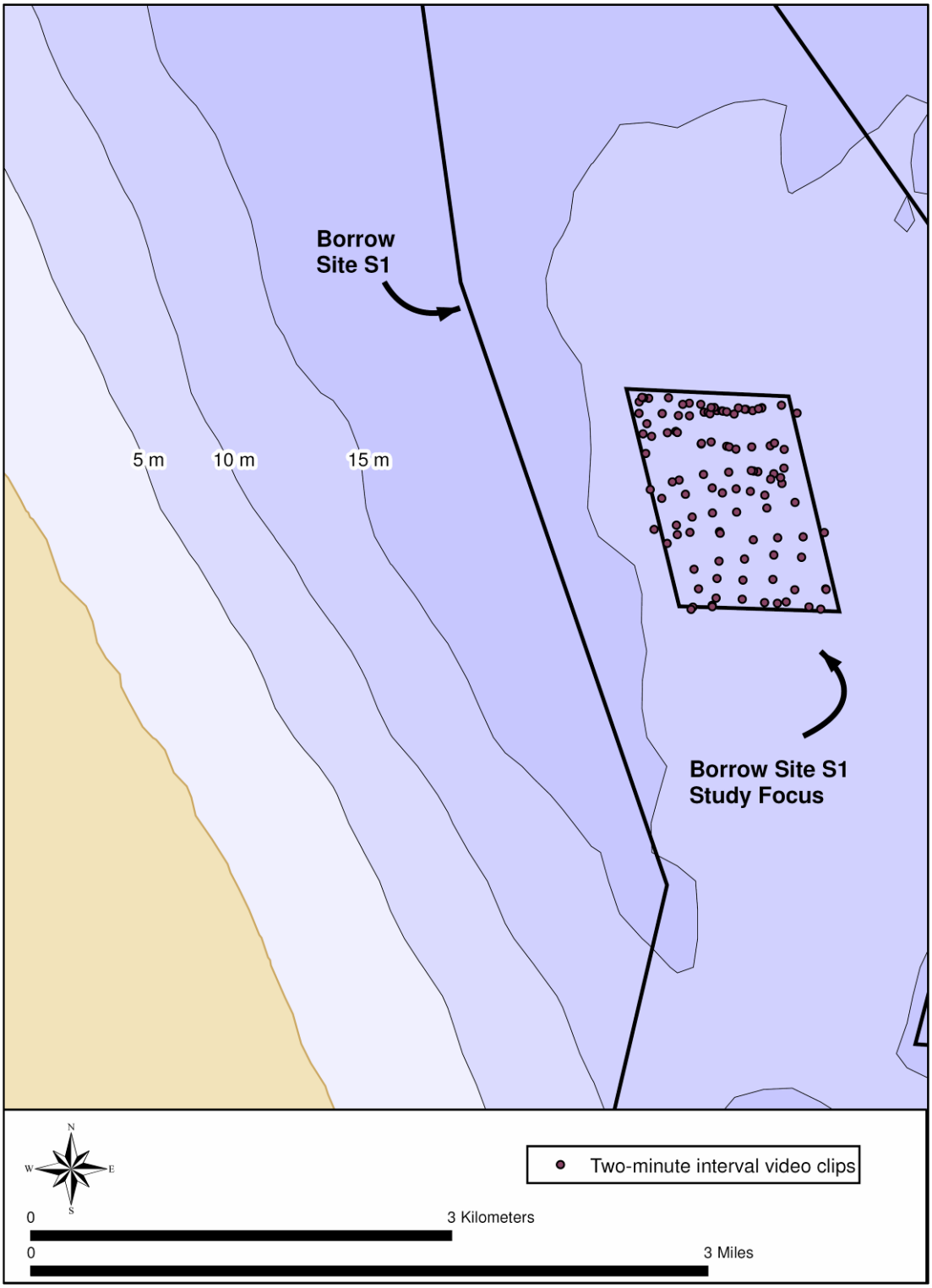


Figure 2-14. (Continued)

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 infaunal and epifaunal organisms, and the mean number of species were calculated and presented. Total community diversity was also calculated 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^2 and seine data was standardized to catch per 10,000 m^2 swept area. 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. All three years of catch 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.

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:

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

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 (Cortes 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:

$$\text{Abundance m}^2 = \frac{\text{Count}}{\text{Length x Distance Between Transects}}$$

where:

Abundance m²	=	ghost crab abundance per square meter,
Count	=	number of ghost crabs per transect, and
Length	=	length of each transect (meters)
Distance Between Transects	=	1.82.

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 genus – 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 control), and season, for spring 2004 (incomplete) through winter 2006-2007. 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 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:

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

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

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:

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

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

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:

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

$$k = (1,2,\ldots n)$$

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

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:

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

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.

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

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 reduced by extracting 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, epifaunal and infaunal organisms, and fishes and rays were collected and entered into a relational database.

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). The video analysis was conducted using a Sony editing deck or a PC that could project video clips to a high-resolution video monitor.

Table 2-4. Physical and biological features documented in videotapes collected in two underwater video surveys.

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
Waveform of bedforms	0 = smooth rounded crest 1 = sharp peaked crest	Count of: Tubes
Shape of bedforms	0 = straight 1 = asymmetric	Count of: Mobile epifauna
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 of data collected from the three years of biological monitored 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 is to describe baseline conditions of 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. All the data collected during the monitoring program are summarized seasonally across years and presented as averages for four seasons. Site specific benthic and fisheries data collected during all seasonal sampling can be found in Appendix B through D. In addition, grain size data collected during benthic sampling is presented in Appendix A.

3.2 BENTHIC

3.2.1 Swash Area

Differences in community composition were apparent between seasons, but differences between the study (labeled as impact in figures) and reference beaches were minimal (Fig. 3-1). Oligochaete worms comprised about 80% of the total community abundance in both spring and fall at the study beach and between 46 and 65% in the same seasons at the reference beach (Fig. 3-1). Crustaceans made up a larger component of the community in the summer than in the other seasons and in winter the miscellaneous taxa dominated (Fig. 3-1).

Over the three year sampling record, 50 distinct macrobenthic taxa were collected from the swash beach area from both the impact and reference beaches (Appendix B, Table B-1), however, most of the taxa were rare in terms of both abundance and number of times collected (Appendix C). Seasonally, only about 3 to 7 taxa were numerically dominant within the habitat (Table 3-1). Individually, oligochaete and nemertina worms were numerically dominant in all seasons (Table 3-1). Both of these worm groups are comprised of very small individuals so they were not as dominant in terms of biomass (Table 3-2).

Some important benthic prey items for shorebirds, fish, and large benthic species were collected from the swash zone and contributed substantially to both the community abundance and biomass within the habitat. The mole crab, *Emerita talpoida* was one of the top taxa collected in all four seasons (Table 3-1) and was the dominant taxa in terms of biomass for all seasons (Table 3-2). The amphipod, *Amphiporeia virginiana*, was abundant in spring, summer, and fall and contributed substantially to biomass in both spring and fall. Other recognized prey

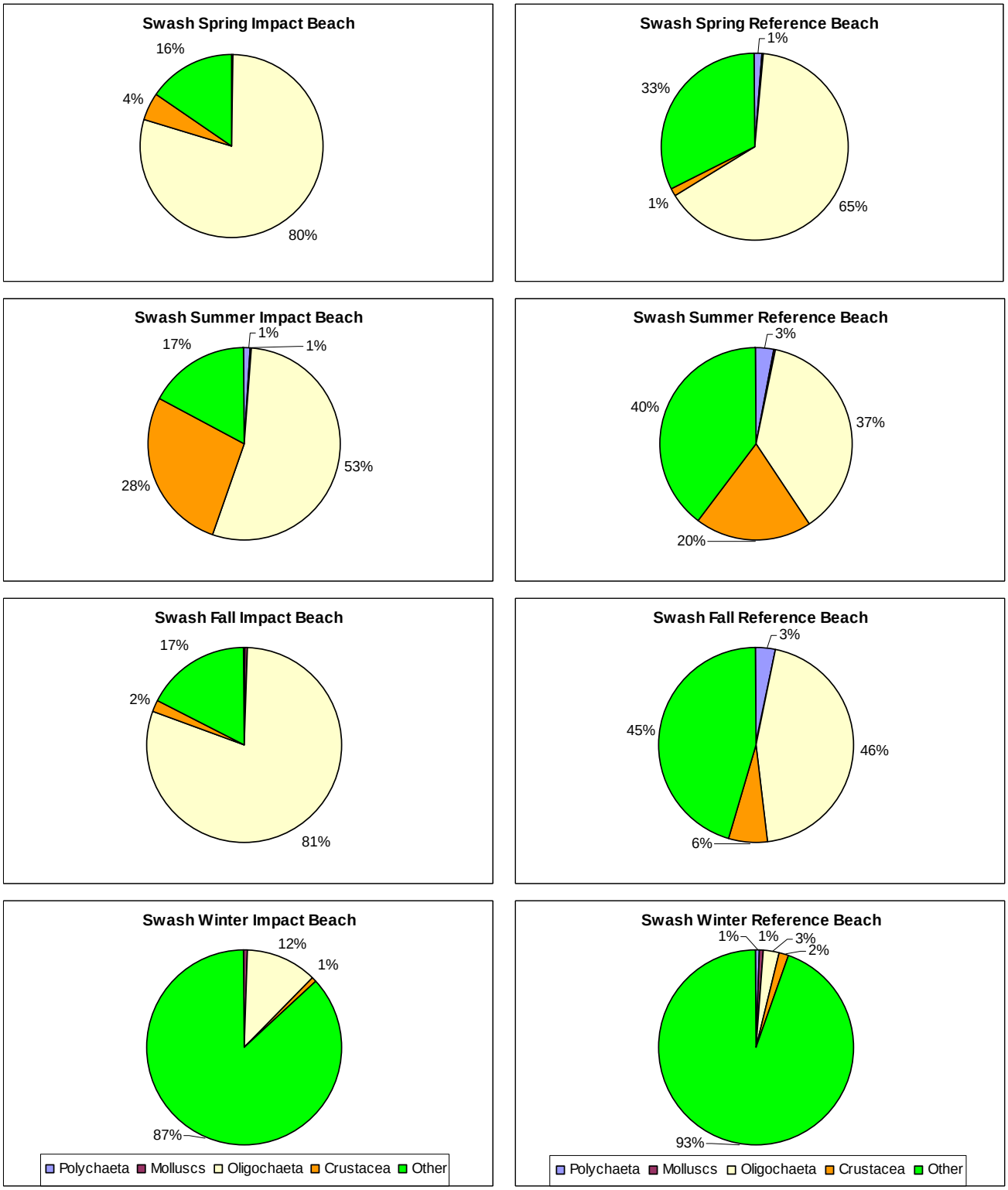


Figure 3-1. Community composition of benthic organisms collected seasonally for three years in the swash habitat of the impact and reference beaches in Dare County, NC

Table 3-1. Mean abundance (#/m^2) of the dominant* taxa collected seasonally for three years in the swash area in Dare County, NC. Means are provided for the top taxa per season at both the impact and reference beaches and at both beaches combined.

Season	Taxonomic Group	Taxon	Impact	Reference	All
Spring	Annelida : Oligochaeta	Oligochaeta	5810.7	4090.7	9901.3
	Nemertina	Nemertina	1141.3	1917.3	3058.7
	Arthropoda : Amphipoda	*Amphiporeia virginiana*	237.3	37.3	274.7
	Arthropoda : Decapoda	*Emerita talpoida*	85.3	34.7	120.0
	Annelida : Polychaeta	*Microphthalmus aberrans*	0.0	77.3	77.3
Summer	Annelida : Oligochaeta	Oligochaeta	3545.3	1670.7	5216.0
	Nemertina	Nemertina	850.7	1868.0	2718.7
	Arthropoda : Decapoda	*Emerita talpoida*	861.3	1234.7	2096.0
	Arthropoda : Amphipoda	*Amphiporeia virginiana*	300.0	198.7	498.7
	Annelida : Polychaeta	*Microphthalmus aberrans*	9.3	124.0	133.3
	Mollusca : Bivalvia	*Donax variabilis*	20.0	13.3	33.3
	Arthropoda : Amphipoda	*Haustorius canadensis*	12.0	18.7	30.7
	Annelida : Polychaeta	*Scolelepis squamata*	4.0	21.3	25.3
Fall	Annelida : Oligochaeta	Oligochaeta	4680.0	1562.7	6242.7
	Nemertina	Nemertina	1016.0	1588.0	2604.0
	Arthropoda : Decapoda	*Emerita talpoida*	105.3	197.3	302.7
	Annelida : Polychaeta	*Microphthalmus aberrans*	0.0	106.7	106.7
	Arthropoda : Amphipoda	*Amphiporeia virginiana*	1.3	16.0	17.3
Winter	Nemertina	Nemertina	2354.7	404.0	2758.7
	Annelida : Oligochaeta	Oligochaeta	5.3	305.3	310.7
	Arthropoda : Decapoda	*Emerita talpoida*	10.7	6.7	17.3

*Taxa are identified as dominant only if the overall mean abundance was 10 or more.

Table 3-2. Mean biomass (g/m^2) of the dominant* taxa by weight collected seasonally for three years in the swash area in Dare County, NC. Means are provided for the top taxa per season at both the impact and reference beaches and at both beaches combined. Epifaunal taxa are labeled as epi, all others are infaunal taxa.

Season	Taxonomic Group	Taxon	Impact	Reference	All
Spring	Arthropoda : Decapoda	*Emerita talpoida*	2.9899	5.6052	4.2976
	Arthropoda : Amphipoda	*Amphiporeia virginiana*	0.0604	0.0157	0.0380
	Nemertina	Nemertina	0.0295	0.0339	0.0317
	Annelida : Oligochaeta	Oligochaeta	0.0187	0.0179	0.0183
	Arthropoda : Amphipoda	*Haustorius canadensis*	0.0091	0.0261	0.0176
Summer	Arthropoda : Decapoda	*Emerita talpoida*	8.6267	6.9111	7.7689
	Annelida : Polychaeta	*Microphthalmus aberrans*	0.0021	0.4929	0.2475
	Mollusca : Bivalvia	*Donax variabilis*	0.0547	0.0618	0.0582
	Arthropoda : Amphipoda	*Haustorius canadensis*	0.0384	0.0321	0.0352
	Annelida : Oligochaeta	Oligochaeta	0.0623	0.0046	0.0334
	Nemertina	Nemertina	0.0233	0.0233	0.0233
	Arthropoda : Amphipoda	*Amphiporeia virginiana*	0.0292	0.0082	0.0187
Fall	Arthropoda : Decapoda	*Emerita talpoida*	3.8360	6.3481	5.0921
	Mollusca : Bivalvia	*Donax variabilis*	0.0413	0.0059	0.0236
	Nemertina	Nemertina	0.0152	0.0302	0.0227
	Annelida : Oligochaeta	Oligochaeta	0.0247	0.0077	0.0162
Winter	Arthropoda : Decapoda	*Emerita talpoida*	0.0697	0.7816	0.4256
	Chordata : Ascidiacea	Molgulidae (epi)	0.2739	0.0000	0.1369
	Nemertina	Nemertina	0.0348	0.0053	0.0230

*Taxa are identified as dominant only if the overall mean biomass was 0.0100 g/m^2 or more.

items such as haustorid amphipods (i.e., *Haustorius canadensis*) and the bean clam *Donax variabilis* also utilized the habitat in summer and fall and were high in both numbers and weight in these seasons (Tables 3-1 and 3-2). All of these taxa essentially disappeared from the habitat, presumably moving into deeper waters, during the winter months (Tables 3-1 and 3-2).

Overall, more infauna organisms were collected in spring and mean infauna abundance declined through the summer into the fall and winter (Fig. 3-2). Epifauna taxa were not a major component of the benthic community within this habitat, and were low during all seasons with the exception of a peak of abundance collected from the reference area in summer (Fig. 3-3). Mean infauna biomass did not follow the same pattern as infauna abundance. Biomass was highest in the summer when growth is at its peak, was similar in spring and fall and was lowest in winter (Fig. 3-4). Error bars about the three year means for both abundance and biomass were very large indicating high variability in both counts and weights of macrobenthic taxa within the swash habitat (Figs. 3-2 to 3-4). Mean number of infauna taxa collected per sample was low ranging from a mean of about 3.5/station in the summer, to a low of about 1.25/station in winter (Fig. 3-5). The Shannon Weiner diversity index (H') was very low in all seasons following the same seasonal pattern as number of taxa (Fig. 3-6). In the swash habitat, a low H' is indicative of a benthic community with high abundances spread among few taxa.

3.2.2 Shallow Area

The macrobenthic community composition within the shallow area of the coastline varied greatly between seasons and between study and reference beach. Miscellaneous taxa (such as Nemertina worms) dominated the community composition at the reference beach in all seasons but were only the dominant taxa at the study beach during the spring and winter sampling events (Fig. 3-7). Crustaceans were dominant in summer and fall within the study beach area but were not as important a component at the reference beach during these seasons (Fig. 3-7). Polychaete worms and molluscs did not dominate any season but were a substantial component of the community in all seasons.

Sixty distinct infauna and epifauna macrobenthic taxa were collected from the shallow area during the three year sampling record. Fifteen of the taxa were classified as epifauna taxa and forty-five were classified as infauna taxa (Appendix B, Table B-2). Nemertina worms were the most abundant infauna taxa collected during all seasons (Table 3-3). During the summer sampling period, eight taxa had mean abundances above $100/m^2$ whereas only about 2-4 had similar high abundances during the other sampling seasons (Table 3-3). Substantial biomass (defined as a species with an overall mean biomass greater than $0.01\ g/m^2$) was mostly concentrated within a few taxa in each season (Table 3-4). However, during the summer, biomass was distributed more evenly among eight taxa compared to only 2 to 6 taxa during the other sampling seasons (Table 3-4).

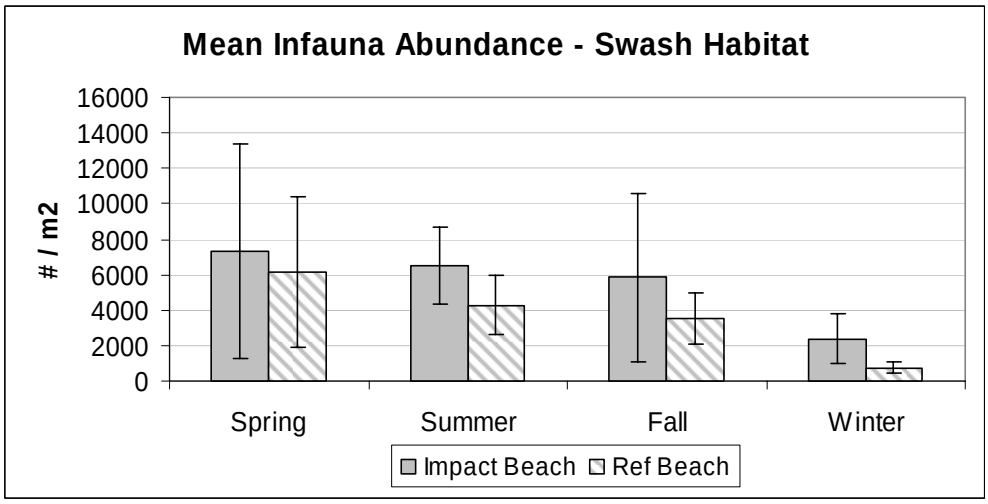


Figure 3-2. Mean total infauna abundance collected seasonally for three years in the swash habitat at the impact and reference beaches in Dare County, NC

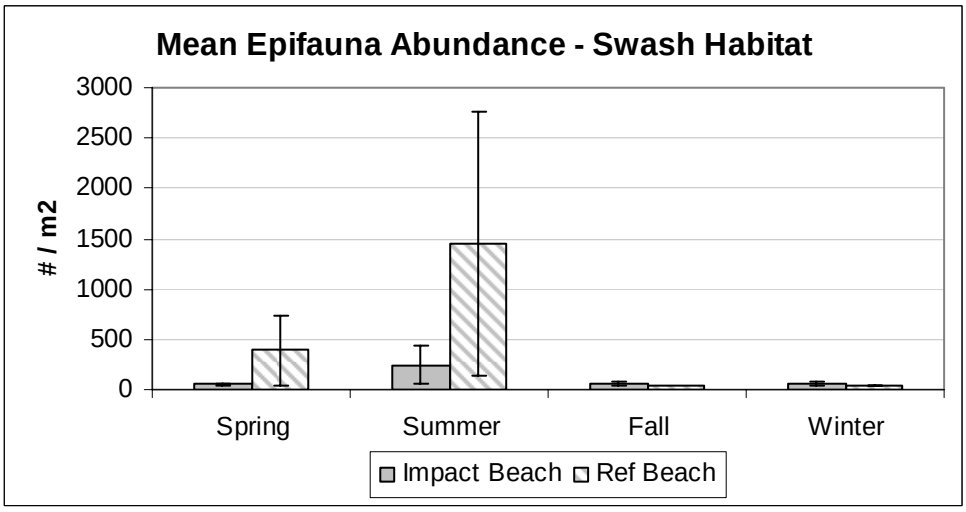


Figure 3-3. Mean total epifauna abundance collected seasonally for three years in the swash habitat at the impact and reference beaches in Dare County, NC

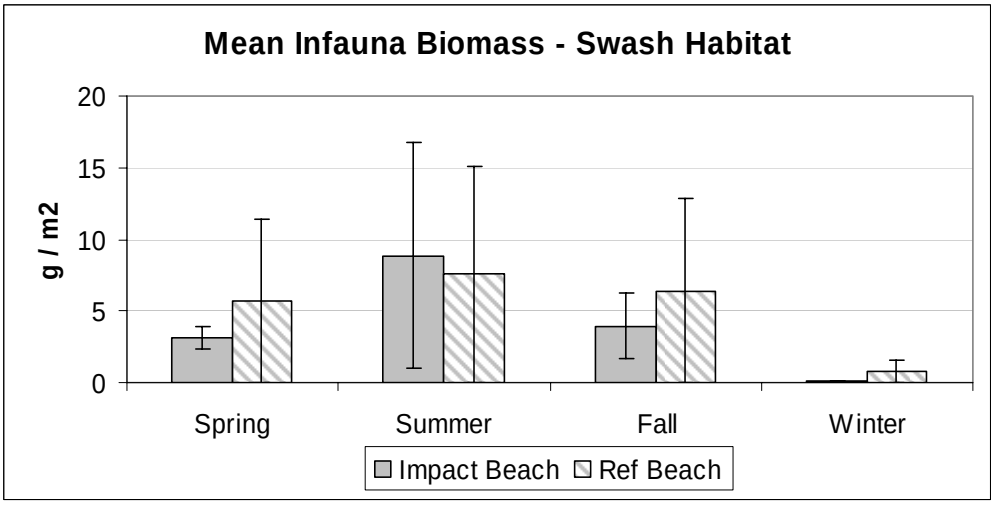


Figure 3-4. Mean total infauna biomass collected seasonally for three years in the swash habitat at the impact and reference beaches in Dare County, NC

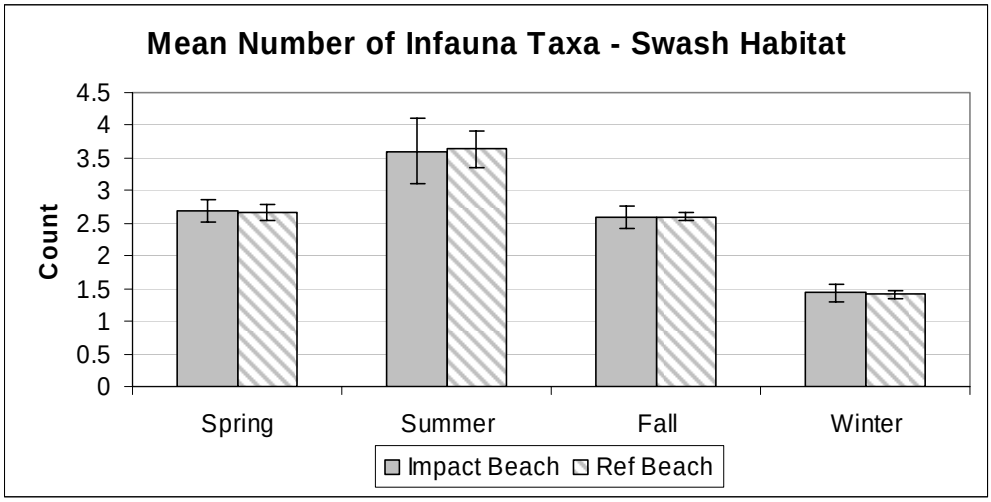


Figure 3-5. Mean number of infauna taxa collected seasonally for three years in the swash habitat at the impact and reference beaches in Dare County, NC

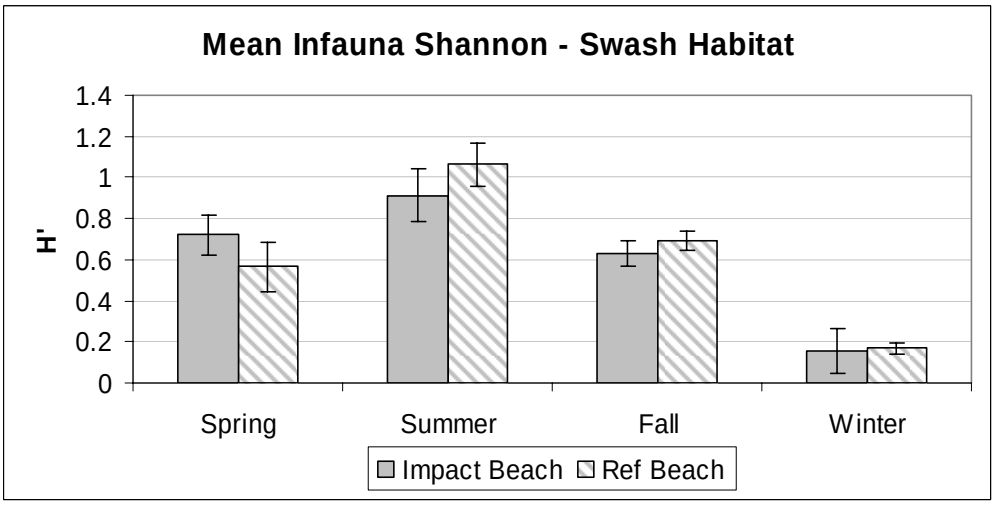


Figure 3-6. Mean Shannon Wiener Diversity Index measured from three years of seasonal sampling in the swash habitat at the impact and reference beaches in Dare County, NC

Figure 3-7. Community composition of benthic organisms collected seasonally for three years in the shallow habitat of the impact and reference beaches in Dare County, NC

Table 3-3. Mean abundance (#/m^2) of the dominant* taxa collected seasonally for three years in the shallow area in Dare County, NC. Means are provided for the top taxa per season at both the impact and reference beaches and at both beaches combined. Epifaunal taxa are labeled as epi, all others are infaunal taxa.

Season	Taxonomic Group	Taxon	Impact	Reference	All
Spring	Nemertina	Nemertina	420.0	300.0	720.0
	Arthropoda : Amphipoda	*Amphiporeia virginiana*	80.0	129.3	209.3
	Mollusca : Bivalvia	*Donax variabilis*	50.7	77.3	128.0
	Annelida : Polychaeta	*Microphthalmus aberrans*	78.7	42.7	121.3
	Platyhelminthes : Turbellaria	Turbellaria (epi)	46.7	30.7	77.3
	Annelida : Polychaeta	*Scolelepis squamata*	44.0	10.7	54.7
	Mollusca : Bivalvia	*Mytilus edulis* (epi)	9.3	36.0	45.3
	Annelida : Oligochaeta	Oligochaeta	4.0	18.7	22.7
	Arthropoda : Decapoda	*Emerita talpoida*	4.0	16.0	20.0
	Arthropoda : Amphipoda	*Haustorius canadensis*	4.0	16.0	20.0
Summer	Nemertina	Nemertina	149.3	473.3	622.7
	Mollusca : Bivalvia	Arcidae	229.3	8.0	237.3
	Mollusca : Bivalvia	*Donax variabilis*	150.7	60.0	210.7
	Annelida : Polychaeta	*Scolelepis squamata*	112.0	68.0	180.0
	Platyhelminthes : Turbellaria	Turbellaria (epi)	68.0	73.3	141.3
	Arthropoda : Amphipoda	*Microprotopus raneyi* (epi)	104.0	25.3	129.3
	Arthropoda : Amphipoda	*Haustorius canadensis*	42.7	65.3	108.0
	Arthropoda : Decapoda	*Emerita talpoida*	37.3	64.0	101.3
	Arthropoda : Amphipoda	*Tiron tropakis*	72.0	1.3	73.3
	Arthropoda : Mysidacea	*Neomysis americana* (epi)	40.0	28.0	68.0
Fall	Platyhelminthes : Turbellaria	Turbellaria (epi)	0.0	194.7	194.7
	Nemertina	Nemertina	36.0	145.3	181.3
	Arthropoda : Mysidacea	*Neomysis americana* (epi)	4.0	57.3	61.3
	Annelida : Oligochaeta	Oligochaeta	30.7	20.0	50.7
	Arthropoda : Decapoda	*Emerita talpoida*	28.0	21.3	49.3
	Annelida : Polychaeta	*Microphthalmus aberrans*	0.0	14.7	14.7
	Mollusca : Bivalvia	*Donax variabilis*	4.0	5.3	9.3
	Annelida : Polychaeta	*Polygordius* spp.	2.7	6.7	9.3
	Arthropoda : Amphipoda	*Haustorius canadensis*	0.0	8.0	8.0
	Annelida : Polychaeta	*Protodorvillea kefersteini*	0.0	6.7	6.7

Table3-3. (Continued)

Season	Taxonomic Group	Taxon	Impact	Reference	All
Winter	Nemertina	Nemertina	406.7	285.3	692.0
	Annelida : Oligochaeta	Oligochaeta	2.7	178.7	181.3
	Mollusca : Bivalvia	*Mytilus edulis* (epi)	61.3	70.7	132.0
	Arthropoda : Decapoda	*Emerita talpoida*	38.7	5.3	44.0
	Annelida : Polychaeta	*Polygordius* spp.	14.7	1.3	16.0
	Annelida : Polychaeta	*Scolelepis squamata*	5.3	4.0	9.3
	Annelida : Polychaeta	*Tharyx* sp. A Morris	9.3	0.0	9.3
	Annelida : Polychaeta	*Amastigos caperatus*	6.7	1.3	8.0
	Mollusca : Bivalvia	*Spisula solidissima*	1.3	6.7	8.0
	Arthropoda : Amphipoda	*Microprotopus raneyi* (epi)	4.0	0.0	4.0

Table 3-4. Mean biomass (g/m^2) of the dominant* taxa collected seasonally for three years in the shallow area in Dare County, NC. Means are provided for the top taxa per season at both the impact and reference beaches and at both beaches combined. Epifaunal taxa are labeled as epi, all others are infaunal taxa.

Season	Taxonomic Group	Taxon	Impact	Reference	All
Spring	Arthropoda : Decapoda	*Emerita talpoida*	0.8823	0.4719	0.6771
	Arthropoda : Decapoda	*Ovalipes stephensoni* (epi)	0.1972	0.9405	0.5689
	Arthropoda : Amphipoda	*Haustorius canadensis*	0.0153	0.0788	0.0471
	Annelida : Polychaeta	*Scolelepis squamata*	0.0583	0.0138	0.0360
	Mollusca : Bivalvia	*Donax variabilis*	0.0169	0.0273	0.0221
	Arthropoda : Amphipoda	*Amphiporeia virginiana*	0.0237	0.0188	0.0213
Summer	Chordata : Ascidiacea	Ascidiacea (epi)	0.0244	0.1052	0.0648
	Arthropoda : Amphipoda	*Microprotopus raneyi* (epi)	0.0021	0.0991	0.0506
	Annelida : Polychaeta	*Scolelepis squamata*	0.0457	0.0412	0.0435
	Arthropoda : Amphipoda	*Haustorius canadensis*	0.0453	0.0012	0.0233
	Mollusca : Bivalvia	*Donax variabilis*	0.0272	0.0106	0.0189
	Arthropoda : Decapoda	*Emerita talpoida*	0.0215	0.0088	0.0151
	Arthropoda : Amphipoda	*Unciola irrorata*	0.0144	0.0109	0.0126
	Annelida : Polychaeta	*Polydora* spp.	0.0138	0.0069	0.0104
Fall	Arthropoda : Decapoda	*Emerita talpoida*	3.4972	0.9815	2.2393
	Annelida : Polychaeta	*Scolelepis squamata*	0.0000	0.0223	0.0111
Winter	Annelida : Polychaeta	*Protodrilus* spp. (epi)	0.4485	0.0000	0.2243
	Arthropoda : Decapoda	*Emerita talpoida*	0.0000	0.0760	0.0380
	Mollusca : Bivalvia	*Macoma tenta*	0.0000	0.0216	0.0108

*Taxa are identified as dominant only if the overall mean biomass was 0.0100 g/m^{2}or more.

Crustaceans, an important prey item for fish communities, represented five of the top 10 dominant taxa during the summer sampling period (Table 3-3). Crustaceans were also an important component of the benthic community in both spring and fall. Bivalves, also a prey item for fish, crabs, and shore birds, were present in high numbers especially in summer and spring and less so in fall and winter (Table 3-3).

Although the number of taxa collected from the shallow beach area was greater than at the swash habitat, mean abundance of infauna organisms in the shallow habitat was about an order of magnitude lower than in the swash habitat (Figs. 3-2 and 3-8). In contrast to the swash habitat, epifauna taxa comprised a substantial portion of the total benthic community within the shallow habitat (Fig. 3-9). The summer season harbored the highest abundances within the shallow habitat for both infauna and epifauna taxa (Figs. 3-8 and 3-9). Error bars around the mean abundances of both infauna and epifauna species were, in general, less than in the swash, an indication of smaller yearly differences in abundance in the shallow habitat. Mean biomass was lowest in summer and greatest in spring and fall (Fig. 3-10). Mean biomass within the shallow habitat was variable within each season as indicated by the large error bars around the means (Fig. 3-10). When examining future impacts from beach construction activities, rare but large species should be dropped from the means to decrease variability around the biomass mean. As with the swash habitat, both the mean number of taxa and the Shannon Weiner diversity index (H') were low in the shallow habitat and both metrics were highest on average during the summer sampling season (Figs. 3-11 and 3-12). In the shallow habitat, a low H' is indicative of a benthic community with high abundances spread among few taxa.

3.2.3 Borrow Area

The benthic community composition within the offshore area was very different from the community collected at the swash and shallow habitats. Polychaete worms dominated the community at both the northern (N) borrow and reference sampling areas and was a substantial component within the southern (S) borrow area (Fig. 3-13). Polychaete worms dominated seasonally at both the N borrow and reference areas but was only dominant during the summer at the S borrow area (Fig. 3-13). Miscellaneous taxa and oligochaete worms comprised a larger component of the community within the S borrow compared to both the northern areas. Because of the clear differences in benthic community composition between the N reference and S borrow area, care will need to be taken if this reference area is used to assess potential impacts to the borrow area as a result of sand mining activities.

A total of 234 distinct taxa were collected from the three offshore sampling locations of which 181 were infauna and 53 were epifauna taxa (Appendix B, Table B-3). Of the 181 infauna taxa collected, 147 were collected from the N borrow site, 128 were collected within the reference area, and only 102 were collected from the S borrow area. The lower number of distinct taxa collected from the S borrow is most likely a function of sample size. Since this area was not sampled until year 2 of the project, many fewer samples were collected from the

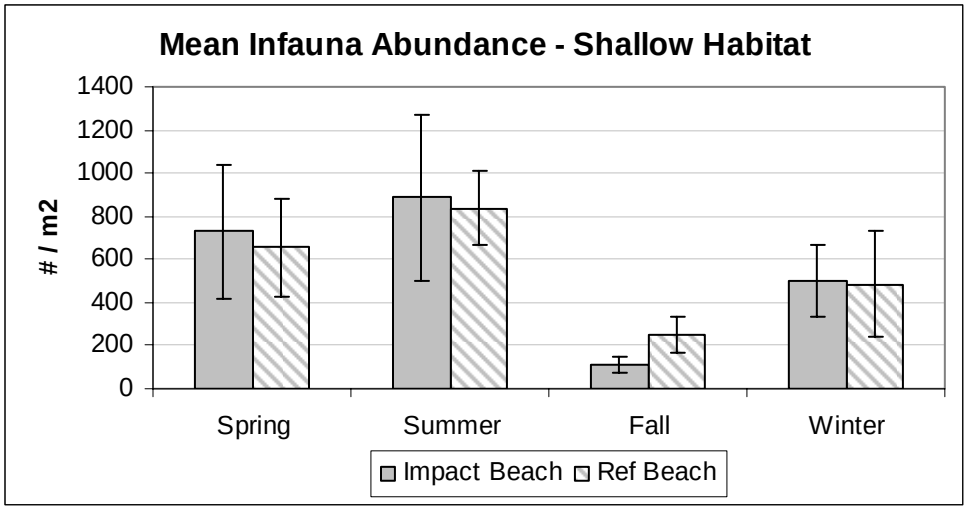


Figure 3-8. Mean total infauna abundance collected seasonally for three years in the shallow habitat at the impact and reference beaches in Dare County, NC

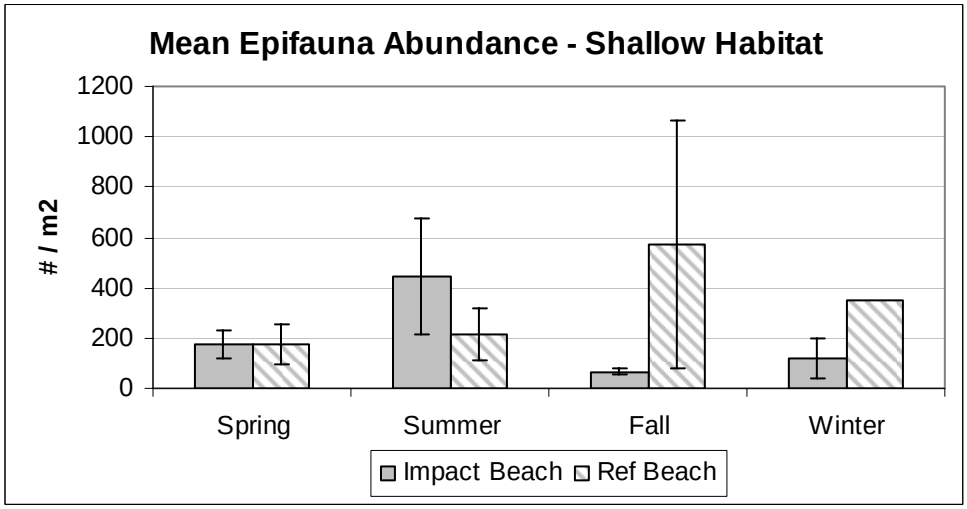


Figure 3-9. Mean total epifauna abundance collected seasonally for three years in the shallow habitat at the impact and reference beaches in Dare County, NC

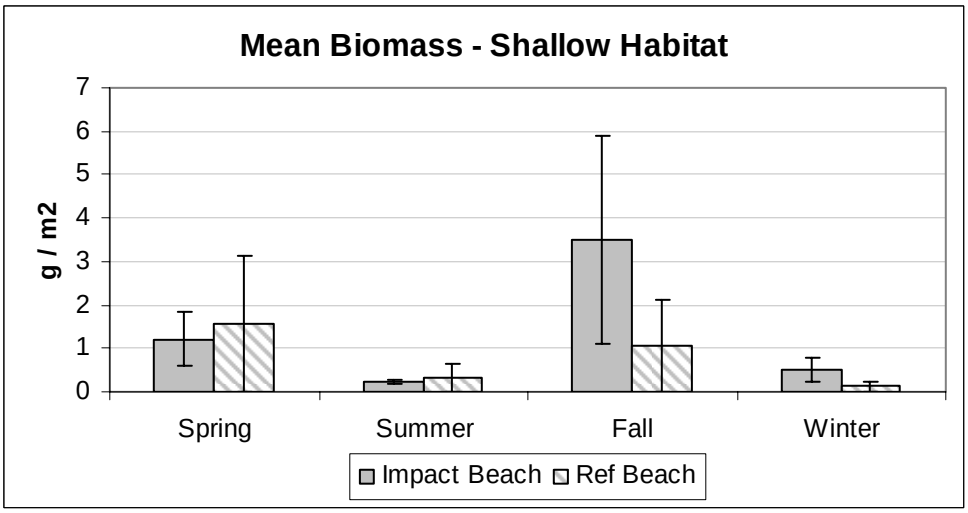


Figure 3-10. Mean total infauna biomass collected seasonally for three years in the shallow habitat at the impact and reference beaches in Dare County, NC

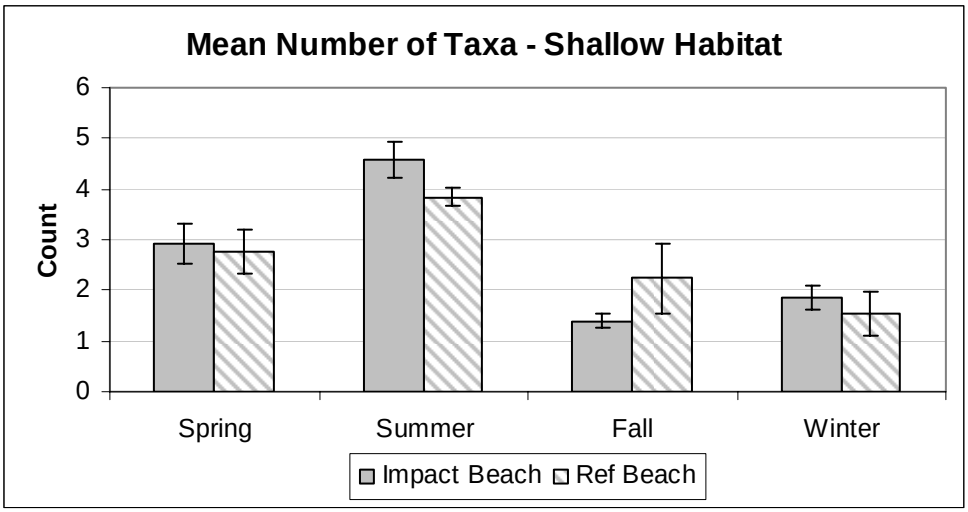


Figure 3-11. Mean number of infauna taxa collected seasonally for three years in the shallow habitat at the impact and reference beaches in Dare County, NC

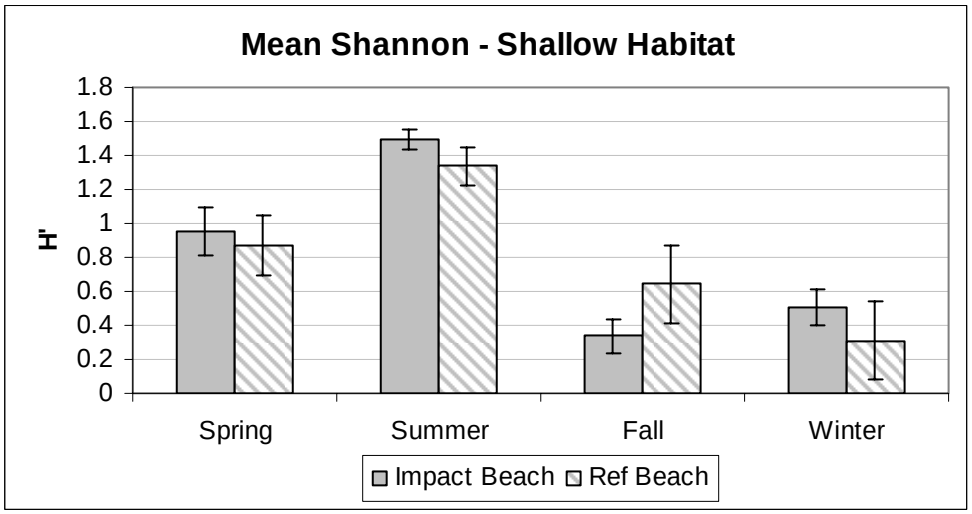


Figure 3-12. Mean Shannon Wiener Diversity Index measured from three years of seasonal sampling in the shallow habitat at the impact and reference beaches in Dare County, NC

Figure 3-13. Community composition of benthic organisms collected seasonally for three years in the borrow and reference borrow sites offshore of Dare County, NC

S borrow area compared to the northern areas (see Methods section for explanation of sampling regime).

Large differences in individual taxa abundances were apparent within the three sampling areas that will complicate interpretation of sand mining activities within the borrow areas. For example, several species such as the polychaete worms, *Tharyx* sp. A, *Amastigos caperatus*, and *Apoprionospio pygmaea*, were dominant in the S borrow area during several seasons but were much less abundant in the N borrow and reference areas during the same seasons (Table 3-5). Alternately, *Amastigos caperatus* and *Apoprionospio pygmaea* were much more abundant in the fall in the reference area compared to both borrow areas (Table 3-5). Of the dominant infauna taxa collected from the sampling areas, the majority were polychaete worms (Table 3-5).

Although collected in much smaller numbers than the infauna taxa, epifauna taxa were a substantial component of the benthic community in the offshore sampling areas (Table 3-6). As with the infauna community, substantial differences in abundances and occurrence of epifauna taxa within the borrow and reference area were apparent and will need to be considered when evaluating sand mining impacts within the borrow areas.

The top ten dominant taxa by weight were much different than the total abundance counts. Many large benthic specimens were collected from the offshore sampling areas and differences between areas were apparent. For example, the surf clam, *Spisula solidissima*, was the top species at the N borrow during the spring but not so in the reference or S borrow (Table 3-7). The sand dollar, *Mellita quinquiesperforata*, was dominant in the spring at the S borrow but was dominant in the summer at both the N borrow and reference areas (Table 3-7). As with the shallow area, large, rare species may need to be dropped from the biomass when examining future impacts from beach construction activities.

In all sampling areas, mean benthic infauna abundance was highest in summer, averaging over 5,000 individuals/m^2 at both the N borrow and reference areas and over 4,000 individuals/m^2 at the S borrow area (Fig. 3-14). Both the N borrow and reference area consistently had more organisms per season than the S borrow area (Fig. 3-14). Epifauna were, on average, more abundant in the summer than in other seasons (Fig. 3-15). However, at the S borrow, epifauna abundance peaked at about 750 individuals/m^2 in spring 2006 (the only spring sampling event at the area). Mean total biomass was also highest in summer and lowest in fall and winter at all sampling areas (Fig. 3-16). Error bars about the mean were much greater at the reference area than at both borrows, an indication of higher variability in mean biomass at the reference area (Fig. 3-15). The mean number of taxa collected from each offshore sampling area was highest in the summer with a mean of over 25 individual taxa collected per area (Fig. 3-17). On average, more taxa were collected per sampling event at the reference area in all seasons compared to both borrow areas (Fig. 3-17). Error bars around these means were small indicating that these differences were most likely significant. The Shannon Weiner Diversity Index (H') was high in all seasons with means mostly above 3 (Fig. 3-18). A high H' suggests that the benthic community inhabiting the offshore areas is well sorted with high abundances evenly spread over many taxa instead of a few as in the swash and shallow habitats.

Table 3-5. Mean abundance (#/m^2) of the dominant* taxa collected seasonally for three years in the offshore area in Dare County, NC. Means are provided for each season at both borrow areas (N and S), the reference area, and for all areas combined.

Season	Taxonomic Group	Taxon	N Borrow	S Borrow	N Reference	All
Spring	Annelida : Polychaeta	*Amastigos caperatus*	2283.3	2036.4	79.5	1862.7
	Annelida : Polychaeta	*Tharyx* sp. A Morris	237.9	950.0	22.7	512.3
	Annelida : Polychaeta	*Apoprionospio pygmaea*	335.6	818.2	6.8	495.5
	Annelida : Polychaeta	*Mediomastus ambiseta*	187.1	334.8	0.0	223.7
	Annelida : Polychaeta	*Polygordius* spp.	374.2	80.3	86.4	207.1
	Annelida : Polychaeta	*Spiophanes bombyx*	115.2	339.4	13.6	196.8
	Annelida : Polychaeta	*Caulleriella* sp. B (Blake)	68.9	271.2	6.8	146.8
	Annelida : Oligochaeta	Oligochaeta	139.4	73.5	120.5	108.4
	Annelida : Polychaeta	*Aricidea catherinae*	82.6	147.7	6.8	99.7
	Annelida : Polychaeta	Nephtyidae	55.3	150.0	13.6	89.9
Summer	Annelida : Polychaeta	*Tharyx* sp. A Morris	922.7	4528.8	509.1	2171.6
	Annelida : Polychaeta	*Amastigos caperatus*	603.0	2183.3	50.0	1057.4
	Annelida : Polychaeta	*Polygordius* spp.	1608.3	382.6	683.0	917.3
	Annelida : Polychaeta	*Apoprionospio pygmaea*	471.2	1513.6	48.9	756.5
	Annelida : Polychaeta	*Mediomastus ambiseta*	636.4	371.2	11.4	380.7
	Annelida : Polychaeta	*Owenia fusiformis*	225.0	681.8	112.5	368.2
	Mollusca : Bivalvia	*Tellina agilis*	250.0	357.6	36.4	236.9
	Annelida : Polychaeta	*Caulleriella* sp. B (Blake)	8.3	553.0	11.4	213.4
	Annelida : Oligochaeta	Oligochaeta	101.5	122.7	375.0	177.8
	Nemertina	Nemertina	140.2	51.5	396.6	171.0
Fall	Annelida : Polychaeta	*Apoprionospio pygmaea*	109.8	0.0	2156.8	850.0
	Annelida : Polychaeta	*Amastigos caperatus*	311.4	3.4	1289.4	601.1
	Annelida : Polychaeta	*Tharyx* sp. A Morris	155.3	88.6	743.2	359.1
	Annelida : Oligochaeta	Oligochaeta	300.0	408.0	88.6	247.7
	Annelida : Polychaeta	*Polygordius* spp.	337.1	13.6	203.8	206.2
	Nemertina	Nemertina	175.8	172.7	25.8	118.7
	Annelida : Polychaeta	*Spiophanes bombyx*	72.7	2.3	238.6	117.3
	Annelida : Polychaeta	*Owenia fusiformis*	18.2	0.0	272.0	108.8
	Arthropoda : Tanaidacea	*Tanaissus psammophilus*	191.7	61.4	14.4	92.6
	Annelida : Polychaeta	*Mediomastus ambiseta*	134.8	4.5	108.3	92.3

Table 3-5. (Continued)

Season	Taxonomic Group	Taxon	N Borrow	S Borrow	N Reference	All
Winter	Annelida : Polychaeta	*Amastigos caperatus*	250.8	15.9	2036.4	861.6
	Annelida : Polychaeta	*Apoprionospio pygmaea*	291.7	2.3	1532.6	684.7
	Annelida : Polychaeta	*Spiophanes bombyx*	1237.1	4.5	456.8	636.4
	Annelida : Polychaeta	*Tharyx* sp. A Morris	47.0	69.3	718.2	304.3
	Nemertina	Nemertina	443.9	160.2	26.5	216.5
	Annelida : Polychaeta	*Aricidea catherinae*	82.6	1.1	375.0	171.9
	Annelida : Polychaeta	*Polygordius* spp.	118.9	26.1	291.7	160.5
	Annelida : Polychaeta	Nephtyidae	78.8	2.3	297.0	141.5
	Annelida : Oligochaeta	Oligochaeta	125.8	160.2	69.7	113.4
	Annelida : Polychaeta	*Caulleriella* sp. B (Blake)	34.8	3.4	234.8	102.0

*Taxa are identified as dominant only if the overall mean biomass was 0.0100 g/m^{2}or more.

Table 3-6. Mean abundance (#/m^2) of the dominant* taxa collected seasonally for three years in the offshore area in Dare County, NC. Means are provided for each season at both borrow areas (N and S), the reference area, and for all areas combined.

Season	Taxonomic Group	Taxon	N Borrow	S Borrow	Reference	All
Spring	Chordata : Ascidiacea	Ascidiacea	83.3	1.5	752.3	143.8
	Mollusca : Gastropoda	*Cylichnella bidentata*	20.5	17.4	0.0	16.2
Summer	Mollusca : Gastropoda	*Cylichnella bidentata*	219.7	256.1	21.6	183.8
	Chordata : Ascidiacea	Molgulidae	0.0	0.0	181.8	45.5
	Chordata : Ascidiacea	Ascidiacea	13.6	22.0	76.1	32.4
	Arthropoda : Isopoda	*Edotea triloba*	11.4	47.0	14.8	25.6
	Arthropoda : Amphipoda	*Microprotopus raneyi*	3.8	15.2	35.2	15.9
	Arthropoda : Decapoda	*Pagurus* spp.	22.7	13.6	2.3	14.2
	Mollusca : Gastropoda	*Odostomia* spp.	15.9	18.9	0.0	13.1
Fall	Arthropoda : Decapoda	*Pagurus longicarpus*	22.0	1.1	22.7	17.0
	Annelida : Polychaeta	*Polydora websteri*	20.5	0.0	24.2	16.8
	Mollusca : Gastropoda	*Cylichnella bidentata*	3.0	0.0	40.9	16.5
	Mollusca : Gastropoda	*Crepidula* spp.	9.1	8.0	24.2	14.5
Winter	Chordata : Ascidiacea	Molgulidae	13.6	113.6	0.0	33.5
	Mollusca : Gastropoda	*Cylichnella bidentata*	13.6	0.0	37.9	19.3

*Taxa are identified as dominant only if the overall mean biomass was 0.0100 g/m^{2}or more.

Table 3-7. Mean biomass (g/m^2) of the dominant* taxa collected seasonally for three years in the offshore area Dare County, NC. Means are provided for each season at both borrow areas (N and S), the reference area, and for all areas combined. Epifaunal taxa are labeled as epi, all others are infaunal taxa.

Season	Taxonomic Group	Taxon	Borrow N	Borrow S	Reference	All
Spring	Mollusca : Bivalvia	*Spisula solidissima*	0.7771	0.0000	0.0008	0.3334
	Echinodermata : Echinoidea	*Mellita quinquiesperforata*	0.0000	1.7870	0.0026	0.2564
	Mollusca : Gastropoda	*Nassarius trivittatus*	0.0630	0.0007	0.2632	0.1399
	Annelida : Polychaeta	*Glycera dibranchiata*	0.1093	0.0000	0.1500	0.1112
	Annelida : Polychaeta	*Tharyx* sp. A Morris	0.0465	0.0081	0.1817	0.0989
	Annelida : Polychaeta	*Amastigos caperatus*	0.1352	0.0026	0.0791	0.0922
	Annelida : Polychaeta	*Nephtys picta*	0.0630	0.0000	0.1346	0.0847
	Annelida : Polychaeta	*Apoprionospio pygmaea*	0.0486	0.0009	0.1060	0.0664
	Annelida : Polychaeta	*Owenia fusiformis*	0.0160	0.0000	0.1242	0.0601
	Nemertina	*Micrura* spp.	0.0093	0.2989	0.0070	0.0497
Summer	Mollusca : Bivalvia	*Spisula solidissima*	1.0824	1.7141	0.0070	0.8371
	Echinodermata : Echinoidea	*Mellita quinquiesperforata*	0.5141	0.0000	0.8699	0.5190
	Mollusca : Gastropoda	*Nassarius trivittatus*	0.5517	0.0618	0.6224	0.4558
	Mollusca : Gastropoda	*Polinices duplicatus*	0.3842	0.2526	0.0175	0.2138
	Annelida : Polychaeta	*Tharyx* sp. A Morris	0.0655	0.0657	0.3963	0.1896
	Mollusca : Bivalvia	*Ensis directus*	0.1180	0.0078	0.1896	0.1173
	Annelida : Polychaeta	*Nephtys picta*	0.0831	0.0008	0.1883	0.1020
	Annelida : Polychaeta	*Apoprionospio pygmaea*	0.0589	0.0010	0.1596	0.0822
	Annelida : Polychaeta	*Scoletoma acicularum*	0.0000	0.0009	0.1970	0.0741
	Annelida : Polychaeta	*Owenia fusiformis*	0.0178	0.0112	0.1647	0.0713
Fall	Annelida : Polychaeta	*Glycera dibranchiata*	0.0894	0.0000	0.2816	0.1391
	Mollusca : Gastropoda	*Nassarius trivittatus*	0.1098	0.1002	0.1867	0.1363
	Annelida : Polychaeta	*Apoprionospio pygmaea*	0.0126	0.0000	0.2392	0.0944
	Annelida : Polychaeta	*Owenia fusiformis*	0.0006	0.0000	0.2372	0.0892
	Annelida : Polychaeta	*Nephtys picta*	0.0532	0.0000	0.1760	0.0859
	Mollusca : Bivalvia	*Spisula solidissima*	0.1259	0.0799	0.0033	0.0685
	Annelida : Polychaeta	*Tharyx* sp. A Morris	0.0263	0.0574	0.0907	0.0582
	Chordata : Cephalochordata	*Branchiostoma caribaeum*	0.0813	0.0064	0.0026	0.0331
	Annelida : Polychaeta	*Diopatra cuprea*	0.0742	0.0055	0.0033	0.0304
	Annelida : Polychaeta	*Sigalion arenicola*	0.0030	0.1110	0.0000	0.0289

Table 3-7. (Continued)

Season	Taxonomic Group	Taxon	Borrow N	Borrow S	Reference	All
Winter	Mollusca : Bivalvia	*Spisula solidissima*	0.3608	0.0006	0.0010	0.1358
	Echinodermata : Echinoidea	*Mellita quinquiesperforata*	0.0000	0.1586	0.2898	0.1483
	Mollusca : Gastropoda	*Nassarius trivittatus*	0.1305	0.0000	0.2080	0.1269
	Mollusca : Gastropoda	*Polinices duplicatus*	0.0000	0.0000	0.1608	0.0603
	Annelida : Polychaeta	*Tharyx* sp. A Morris	0.0113	0.0554	0.1010	0.0560
	Mollusca : Bivalvia	Ensis directus	0.0033	0.0000	0.0004	0.0014
	Annelida : Polychaeta	*Nephtys picta*	0.0345	0.0000	0.1739	0.0782
	Annelida : Polychaeta	*Apoprionospio pygmaea*	0.0371	0.0002	0.1922	0.0860
	Annelida : Polychaeta	*Scoletoma acicularum*	0.0030	0.0000	0.0023	0.0020
	Annelida : Polychaeta	*Owenia fusiformis*	0.0003	0.0001	0.1987	0.0747

*Taxa are identified as dominant only if the overall mean biomass was 0.0100 g/m^2 or more.

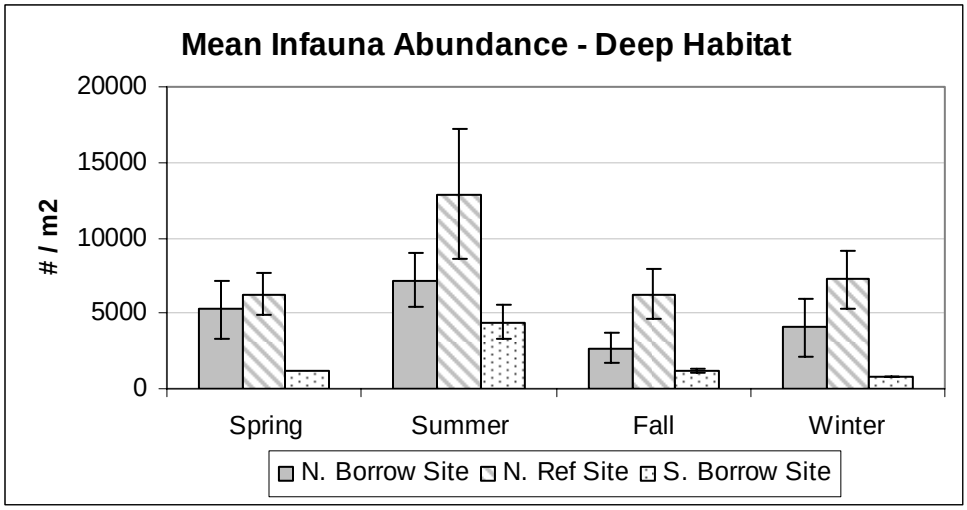


Figure 3-14. Mean total infauna abundance collected seasonally for three years in the borrow and reference sites

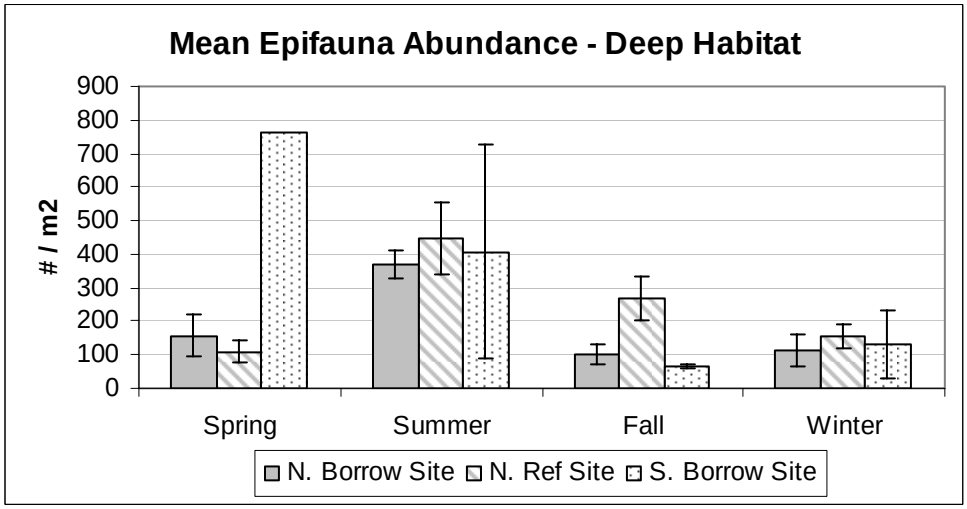


Figure 3-15. Mean total epifauna abundance collected seasonally for three years in the borrow and reference sites

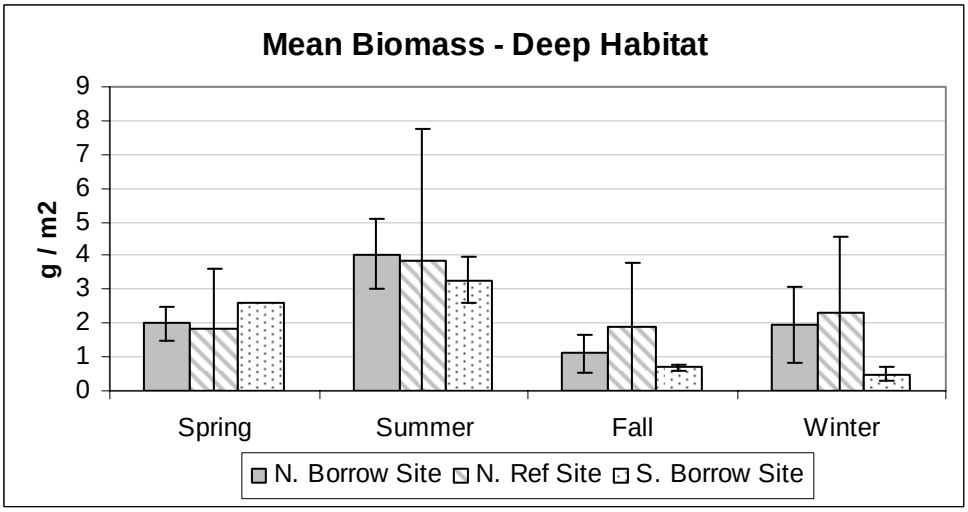


Figure 3-16. Mean total infauna biomass collected seasonally for three years in the borrow and reference borrow sites offshore of Dare County, NC

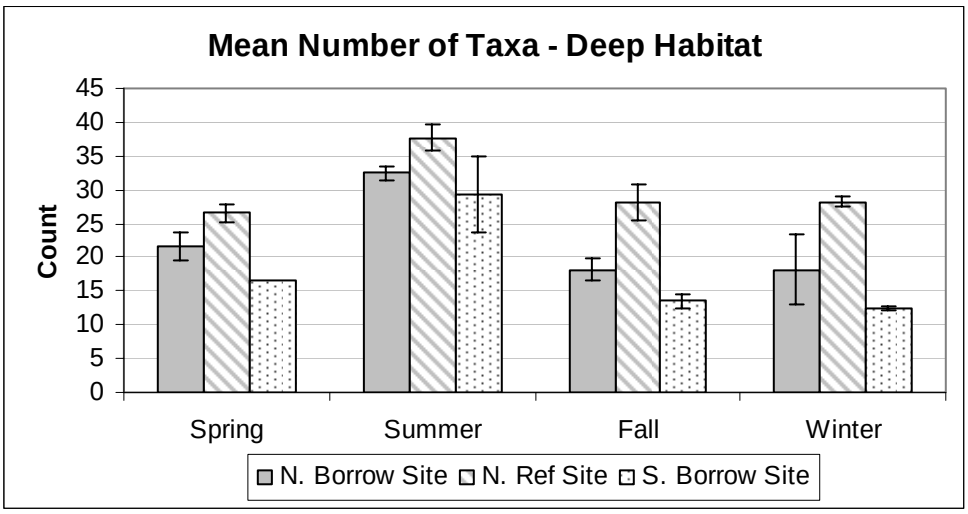


Figure 3-17. Mean total number of infauna taxa collected seasonally for three years in the borrow and reference borrow sites offshore of Dare County, NC

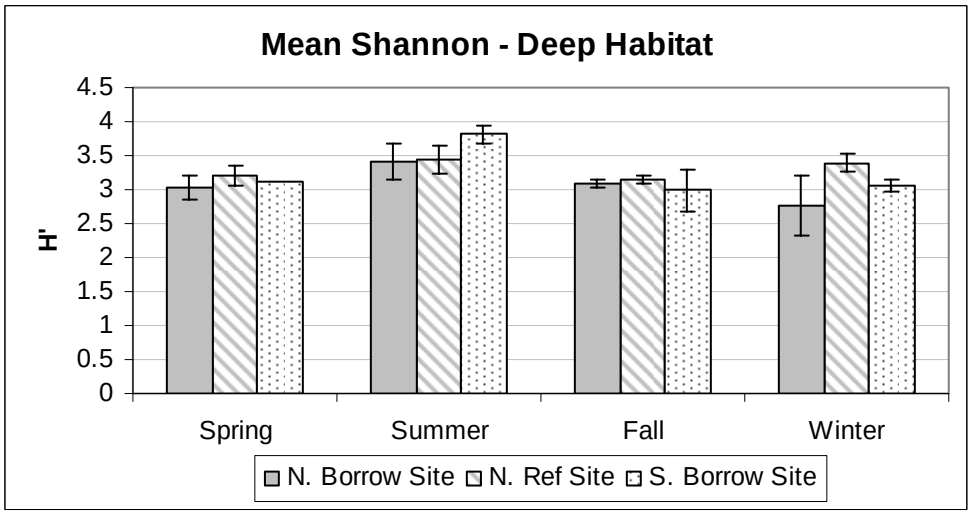


Figure 3-18. Mean Shannon Wiener Diversity Index from three years of seasonal sampling in borrow and reference borrow sites offshore of Dare County, NC

3.3 WATER QUALITY

Water quality data collected during benthic sampling does not show any differences between the borrow sites or the reference site (Table 3-8). All measurements varied seasonally, but values were typical of oceanic conditions in all seasons. Mean temperature ranged from a low of 6.08 ^{o}C in the winter to a high of 28.5 ^{o}C in the summer. Seasonal salinities fluctuated from 40 ppt to 27 ppt among the sites (Table 3-8). Dissolved oxygen (DO) values were good at each of the sites and remained relatively constant throughout the sampling period. The northern reference and borrow sites both exhibited a rise in DO levels of nearly 2 mg/L during the winter, but this observation was not evident at the southern borrow site. Values of pH at the borrow sites and reference sites were nearly neutral (pH values between 7 and 8) during all seasons (Table 3-8).

Table 3-8. Summary of water quality profile values collected in the spring, summer, fall and winter during three years of monitoring at the northern borrow, southern borrow and northern borrow reference sites offshore of Dare County, NC

				Temperature (°C)		Conductivity (mC/cm)		Salinity (ppt)		DO (mg/L)		PH	
Season	**Site**	**Location**	**N**	**Mean**	**Stderr**	**Mean**	**Stderr**	**Mean**	**Stderr**	**Mean**	**Stderr**	**Mean**	**Stderr**
Spring	N Borrow Site	Surface	4	15.48	0.17	48.69	1.27	31.68	0.78	8.66	0.53	8.07	0.01
		Mid	13	13.02	0.21	48.46	0.08	31.57	0.07	10.15	0.23	7.03	0.16
		Bottom	4	12.20	0.98	50.08	0.71	32.68	0.44	8.60	0.40	7.96	0.01
	N Ref Site	Surface	4	15.84	0.36	49.03	1.29	32.10	0.97	9.09	0.63	8.08	0.00
		Mid	13	12.37	1.01	46.65	1.33	31.17	0.09	10.14	0.17	7.08	0.16
		Bottom	4	12.21	0.98	50.19	0.77	32.97	0.68	8.94	0.46	8.01	0.01
	S Borrow Site	Surface	3	15.44	0.04	48.28	0.01	31.52	0.01	10.17	0.11	8.08	0.00
		Mid	3	14.40	0.20	48.82	0.25	31.89	0.18	10.10	0.13	8.07	0.00
		Bottom	3	12.97	0.04	49.52	0.03	32.35	0.02	11.82	0.66	8.03	0.00
Summer	N Borrow Site	Surface	1	27.17		42.50		27.25		7.97		8.18	
		Mid	11	19.37	0.61	59.30	1.13	39.72	0.84	7.37	0.35	8.01	*
		Bottom	10	16.96	0.26	50.09	0.06	32.86	0.04	8.42	0.08	7.91	0.01
	N Ref Site	Surface	3	27.64	0.12	42.46	0.04	27.21	0.03	8.17	0.10	8.18	0.00
		Mid	13	20.24	0.70	57.82	1.51	38.64	1.13	8.00	0.10	7.98	0.02
		Bottom	10	16.42	0.24	50.09	0.08	32.86	0.05	9.04	0.10	7.88	0.01
	S Borrow Site	Surface	3	28.50	0.37	43.55	0.17	27.96	0.13	8.05	0.09	8.15	0.02
		Mid	3	20.17	0.28	49.46	0.10	32.41	0.07	8.98	0.17	7.94	0.02
		Bottom	9	17.07	0.07	50.03	0.02	32.82	0.01	9.82	0.12	7.92	0.01

Table 3-8. (Continued)

Season	Site	Location	N	Temperature (°C)		Conductivity (mC/cm)		Salinity (ppt)		DO (mg/L)		PH	
				Mean	Stderr	Mean	Stderr	Mean	Stderr	Mean	Stderr	Mean	Stderr
Fall	N Borrow Site	Surface	6	17.38	0.25	47.93	0.61	31.26	0.46	8.23	0.12	7.95	0.07
		Mid	16	15.61	0.31	47.65	0.24	31.01	0.18	7.80	0.10	8.11	0.05
		Bottom	6	17.02	0.42	48.30	0.59	31.56	0.43	7.88	0.10	7.90	0.08
	N Ref Site	Surface	6	17.34	0.38	47.95	0.56	31.30	0.41	8.13	0.18	7.95	0.07
		Mid	16	15.54	0.33	47.25	0.31	30.75	0.22	8.32	0.13	8.09	0.04
		Bottom	6	17.08	0.45	48.31	0.62	31.56	0.45	7.95	0.17	7.91	0.08
	S Borrow Site	Surface	3	18.53	0.05	49.47	0.12	32.42	0.09	7.64	0.14	7.79	0.01
		Mid	3	18.28	0.07	49.53	0.08	32.47	0.06	7.54	0.09	7.79	0.01
		Bottom	3	18.41	0.06	49.83	0.08	32.68	0.06	7.73	0.07	7.76	0.00
Winter	N Borrow Site	Surface	5	7.79	0.52	48.19	0.50	30.64	0.55	9.64	0.56	7.85	0.07
		Mid	5	7.66	0.48	49.49	0.92	31.40	0.83	10.07	0.19	7.83	0.06
		Bottom	5	7.70	0.48	49.56	0.81	31.44	0.79	10.89	0.53	7.76	0.06
	N Ref Site	Surface	5	8.18	0.62	47.97	0.39	30.64	0.42	11.50	0.47	7.88	0.10
		Mid	5	6.13	1.51	49.04	0.78	31.31	0.61	11.04	0.46	7.89	0.08
		Bottom	5	6.08	1.49	49.58	0.85	31.57	0.72	13.42	1.56	7.85	0.08
	S Borrow Site	Surface	4	9.50	0.56	47.38	0.20	30.61	0.15	11.01	0.42	7.90	0.02
		Mid	4	8.44	0.51	48.62	0.24	31.43	0.22	11.06	0.45	7.86	0.04
		Bottom	4	8.52	0.53	49.20	0.37	31.85	0.31	11.21	0.57	7.80	0.04

* Only one pH value taken.

3.4 FISH

3.4.1 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. Over the three years, a total of 7,601 individuals were collected from a combination of 117 seines at the impact beach site and 120 seines at the reference beach. A total of ten seines were conducted at each beach during each seasonal sampling event, however, on occasion not all ten seines could be conducted. In the collections there were a total of 48 species of fish including 8 species of sharks, skates, and rays (Table 3-9, Appendix D). In addition, there were 7 invertebrate species, represented by 6 decapod crustaceans 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 (Fig. 3-19). For both beaches, the mean CPUE varied greatly between seasons and was highest in the spring. The second highest CPUE was observed during Summer at both beaches, and declined during the fall and winter. On the impact beach, the winter months had the lowest CPUE, while the CPUE was lowest for the reference beach during Fall. 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 (Fig. 3-19). In general, differences in measured values between beaches showed greater variation during the spring and summer months than during the fall and winter months, with higher mean numbers of species and higher mean diversity found at the reference beach.

Several commercial, recreational, and ecologically important species were collected at both beaches. In particular, spot were abundant in the spring and summer surveys (Table 3-9), and comprised a large percentage of the catch in both seasons (Fig. 3-20). Florida pompano, an important recreational fish, was also abundant at both beaches in the summer (Table 3-9). The Atlantic menhaden was collected at both beaches, but was most abundant in the spring and summer at the impact beach (Table 3-9 and Fig. 3-20). In the winter, the hickory shad dominated the catch at both impact and reference beaches (91 and 74 percent, respectively; Fig. 3-20).

There were several invertebrate species collected in the seines throughout the three years of monitoring (Table 3-9). 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 3-9 and Fig. 3-20).

Table 3-9. Seasonal mean catch per unit effort (CPUE) of fish and mobile benthos collected in the haul seines conducted during three years of monitoring 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	0.006						0.025	
Alosa sapidissima	American shad	0.044	0.06	0.036					0.01
Squatina dumeril	Atlantic angel shark		0.01						
Micropogonias undulatus	Atlantic croaker	0.006	0.04	0.045	0.017	0.006		0.013	0.05
Brevoortia tyrannus	Atlantic menhaden	1.838	0.03	4.164	0.241			0.032	0.01
Selene setapinnis	Atlantic moonfish			0.027	0.088				
Strongylura marina	Atlantic needlefish	0.006							
Menidia menidia	Atlantic silverside	0.013							
Chaetodipterus faber	Atlantic spadefish	0.038			0.011				
Dasyatis sabina	Atlantic stingray	0.032	0.06	0.009	0.041				
Opisthonema oglinum	Atlantic thread herring	0.418			0.038				
Larimus fasciatus	Banded drum			0.013	0.101				
Pogonias cromis	Black drum			0.259	0.095	0.19	0.01	0.006	
Pomatomus saltatrix	Bluefish	0.082	9.5	0.045	0.155	0.013	0.01		
Myliobatis freminvillei	Bullnose ray	0	0.01						
Peprilus triacanthus	Butterfish	0.013	0.03	0.036					
Raja eglanteria	Clearnose skate	0.038	0.14	0.009		0.038			0.01
Rhinoptera bonasus	Cownose ray	1.844	0.06		0.016				
Caranx hippos	Crevalle jack			0.009	0.006				
Trachinotus carolinus	Florida pompano		0.01	0.562	0.42				
Dorosoma cepedianum	Gizzard shad	0.013	0.01	0.235	0.127	0.063	0.22	0.006	0.03
Menticirrhus littoralis	Gulf kingfish	0.019	0.02	0.085	0.086		0.01		
Peprilus alepidotus	Harvestfish	0.71	0.58	0.317	0.136				
Alosa mediocris	Hickory shad		0.01		0.021	0.114	0.07	0.97	0.82
Euthynnus alletteratus	Little tunny			0.108					
Selene vomer	Lookdown			0.061	0.143				
Menticirrhus saxatilis	Northern kingfish	0.019	0.02		0.006				
Sphoeroides maculatus	Northern puffer	0.051	0.09		0.005	0.006			
Orthopristis chrysoptera	Pigfish				0.005				

Table 3-9. (Continued)

Taxonomic Name	Common Name	Spring		Summer		Fall		Winter	
		Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.
Fish (Continued)									
Sciaenops ocellatus	Red drum		0.08	0.043		0.051	0.02		0.08
Archosargus probatocephalus	Sheepshead		0.03			0.013			
Bairdiella chrysoura	Silver perch		0.01						
Gymnura micrura	Smooth butterfly ray		0.02	0.019	0.133				
Mustelus canis	Smooth dogfish	0.032	0.13						
Menticirrhus americanus	Southern kingfish	0.032	0.05	0.127	0.09				0.01
Dasyatis americana	Southern stingray	0.127	0.51	0.019	0.011				
Scomberomorus maculatus	Spanish mackerel		0.01	0.009	0.024				
Gymnura altavela	Spiny butterfly ray				0.006				
Squalus acanthias	Spiny dogfish					0.006			
Leiostomus xanthurus	Spot	4.398	7.09	1.312	2.241	0.127			
Cynoscion nebulosus	Spotted seatrout	0.019	0.04	0.027	0.037	0.019	0.03	0.013	0.03
Morone saxatilis	Striped bass	0.006	0.01	0.079	0.012	0.019	0.08		0.04
Chilomycterus schoepfi	Striped burrfish	1.622	1.14						
Mugil cephalus	Striped mullet			0.072	0.021	0.019			0.01
Paralichthys dentatus	Summer flounder	0.006	0.01	0.058	0.036	0.019		0.006	
Cynoscion regalis	Weakfish	0.139	0.38	0.036	0.025		0.01		
Mugil curema	White mullet				0.012				
Scophthalmus aquosus	Windowpane	0.006		0.128	0.062	0.013	0.03		0.01
Invertebrates									
Cancer irroratus	Atlantic rock crab		0.02			0.013	0.01		
Callinectes sapidus	Blue crab	0.032	0.07	0.034	0.011	0.006	0.01	0.006	0.01
Ovalipes stephensoni	Coarsehand lady crab					0.013			
Limulus polyphemus	Horseshoe crab		0.01						
Ovalipes ocellatus	Lady crab	0.07	0.04	0.158	0.284	1.179	0.27		
Libinia emarginata	Portly spider crab					0.006			
Arenaeus cribrarius	Speckled swimming crab				0.018				

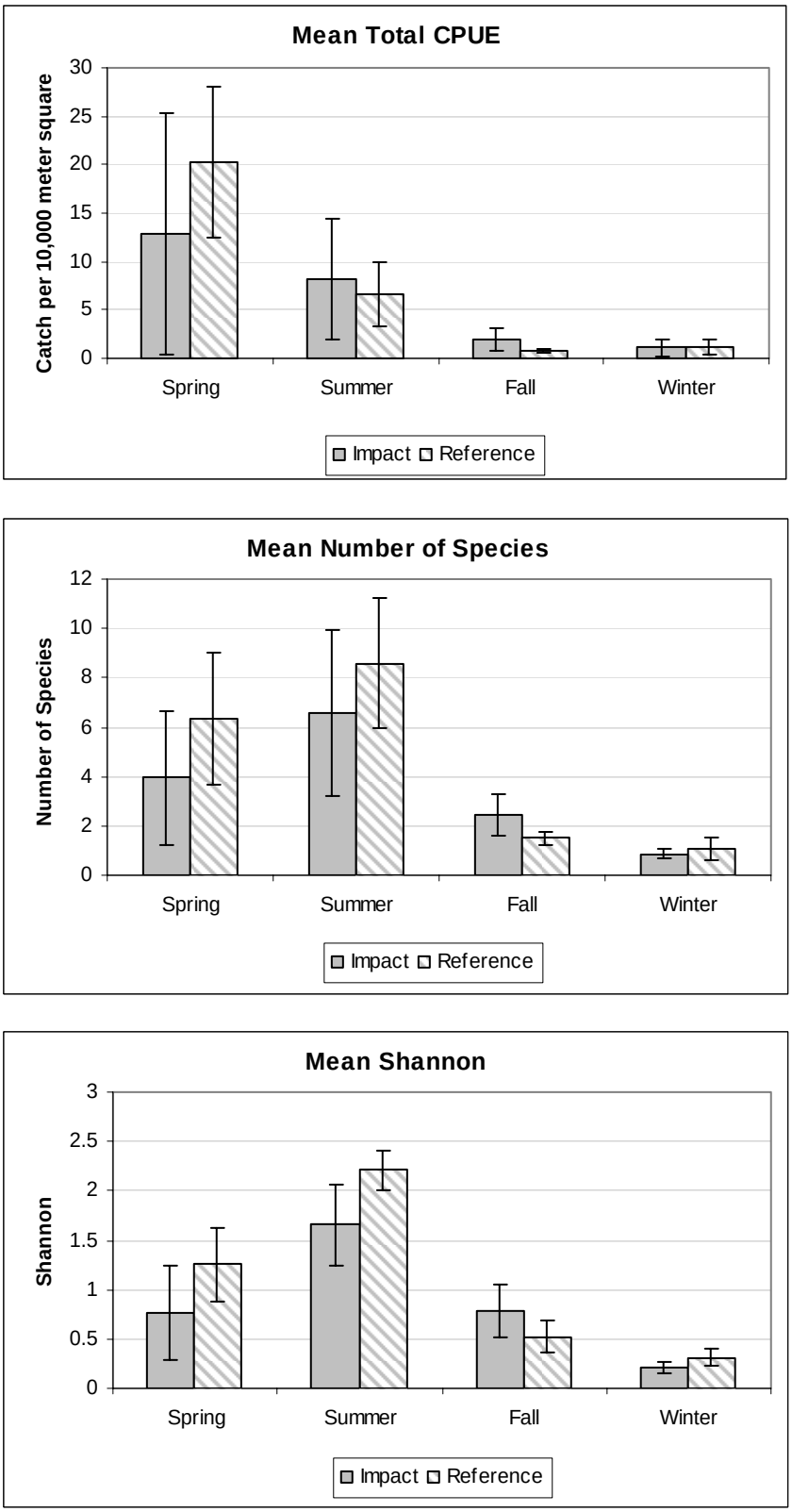


Figure 3-19. Seasonal mean total species CPUE, number of species, and species diversity collected in the haul seines conducted during three years of monitoring at the impact and reference beaches in Dare County, NC

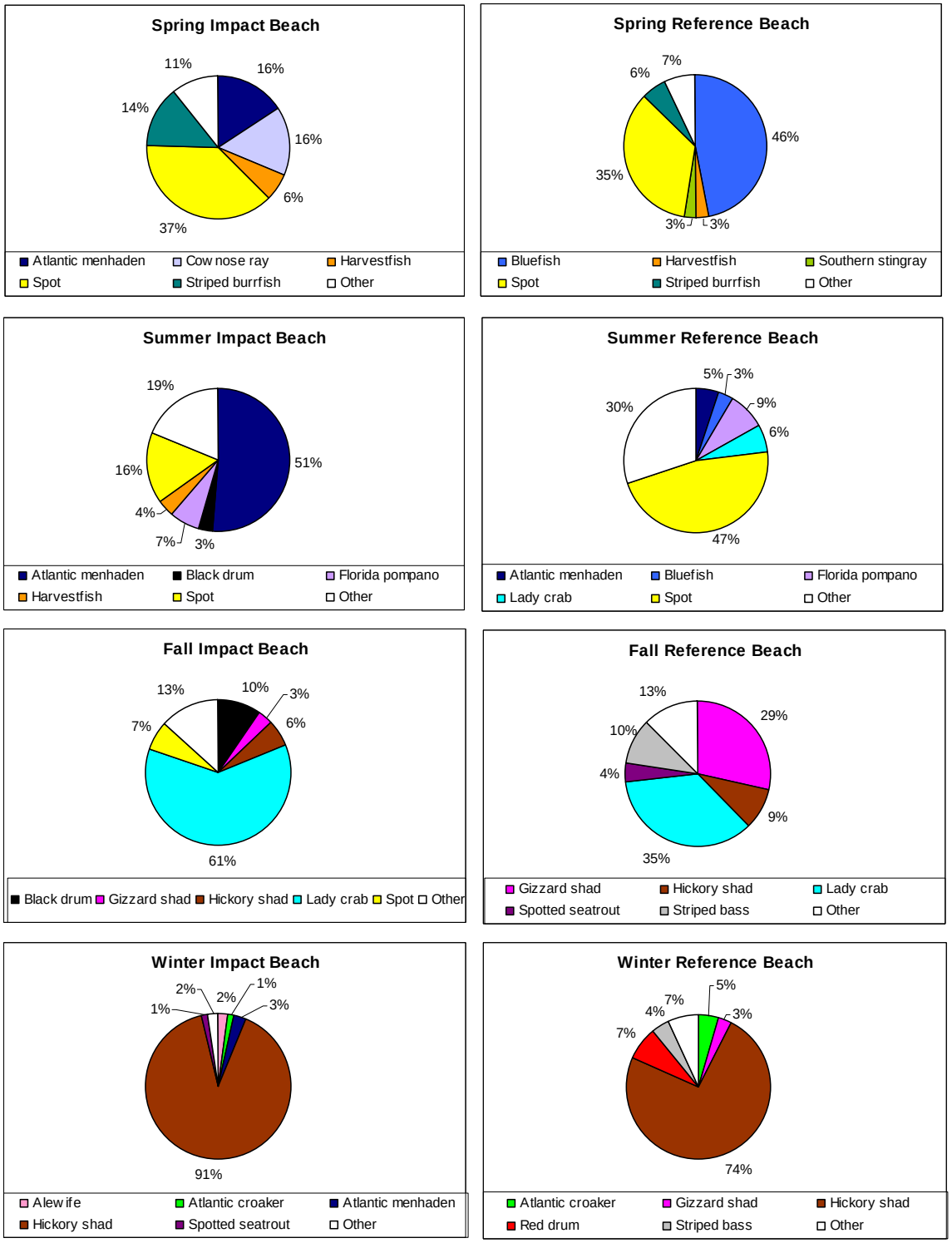


Figure 3-20. Community composition of fish and mobile benthos collected in the haul seines conducted during three years of monitoring at the impact and reference beaches in Dare County, NC

3.4.2 Ocean Borrow and Reference Sites

Trawling was conducted at the borrow and reference sites to characterize seasonal densities of large fish and invertebrate species residing offshore. Over the three years, a total of 745 individuals were collected from a combination of 226 trawls at the borrow sites (142 at the northern site and 84 at the southern) and 142 at the reference site. In the collections there were a total of 38 species of fish including 7 species of sharks, skates, and rays (Table 3-10, Appendix D). In addition, there were 9 invertebrate species, represented by 6 decapod crustaceans, horseshoe crabs, starfish, and squid.

The seasonal catches at the borrow sites and the reference site followed similar trends of total species relative abundance (CPUE), mean numbers of species, and community diversity (Fig. 3-21). The mean CPUE varied greatly between seasons and was highest in the spring for the northern borrow and reference sites, but highest in the summer at the southern borrow site. Catches were lowest in the winter surveys at all sites. During each season, mean number of species was greatest at the reference site (Fig. 3-21). The highest mean number of species was collected at the reference site in the fall. During the spring, the reference site had a slightly higher number of species than the northern borrow site, while the southern borrow site had much fewer species. The mean number of species for the borrow sites was highest in the spring at the northern site, but higher in the summer at the southern site. Community diversity trends were similar to mean number of species at both sites, with the highest diversities collected in the fall and spring and the lowest in the winter (Fig. 3-21).

In the spring collections at the northern borrow site, weakfish and spotted hake had the highest CPUE and were responsible for 44% and 31%, of the total catch, respectively. Spotted hake had the highest CPUE at the reference site and accounted for over 40% of the total catch. At the southern borrow site, the clearnose skate and smooth dogfish were the only species caught in the spring, with slightly more clearnose skate (52% of total catch) than smooth dogfish (48% of total catch; Table 3-10 and Fig. 3-22). Harvestfish and scup were the most abundant species at the northern borrow site in the summer, while the Atlantic croaker accounted for over one-quarter of the catch at the reference site. Scup dominated the catch at the southern borrow site during the summer, accounting for almost 90% of the catch (Table 3-10 and Fig. 3-22). In the fall, weakfish, Atlantic croaker, butterfish and bay anchovy were collected in similar numbers at the northern borrow and reference sites comprising over two-thirds of the catches at both sites. Squid dominated the fall catch at the southern borrow site; the most abundant fish species was the bay anchovy, comprising 18% of the catch (Table 3-10 and Fig. 3-22). In the winter, diversity decreased at all sites. At the northern borrow site, windowpanes accounted for 64% of the catch, while bay anchovy made up the rest. The reference site was dominated by Atlantic croaker, comprising 75% of the total catch. Spiny dogfish was the most abundant species at the southern borrow site in the winter, followed by clearnose skate and spiny dogfish (45%, 29%, and 26% of the catch, respectively; Table 3-10 and Fig. 3-22).

Table 3-10. Seasonal mean catch per unit effort (CPUE) of fish and mobile benthos collected in trawls conducted during three years of monitoring at the northern borrow, southern borrow, and northern borrow reference sites offshore of Dare County, NC

		Spring Sites			Summer Sites			Fall			Winter		
Taxonomic_Name	**Common_Name**	**N Borrow**	**N Ref**	**S Borrow**	**N Borrow**	**N Ref**	**S Borrow**	**N Borrow**	**N Ref**	**S Borrow**	**N Borrow**	**N Ref**	**S Borrow**
Fish													
Micropogonias undulatus	Atlantic croaker	0.041	0.092		0.121	0.334		0.187	0.278			0.466	0.091
Trichiurus lepturus	Atlantic cutlassfish					0.026	0.113						
Clupea harengus harengus	Atlantic herring		0.230										
Brevoortia tyrannus	Atlantic menhaden											0.037	
Selene setapinnis	Atlantic moonfish				0.027								
Chaetodipterus faber	Atlantic spadefish				0.030								
Larimus fasciatus	Banded drum				0.082	0.125			0.069				
Anchoa mitchilli	Bay anchovy	1.100				0.050		0.121	0.759	0.180	0.033		
Centropristis striata	Black sea bass	0.048											
Pomatomus saltatrix	Bluefish	0.026						0.093	0.031				
Peprilus triacanthus	Butterfish	1.076	0.092		0.084	0.135		0.229	0.248				
Raja eglanteria	Clearnose skate	0.269	0.438	0.427			0.049	0.033				0.034	0.102
Rhinoptera bonasus	Cownose ray	0.078				0.107							
Menticirrhus littoralis	Gulf kingfish	0.046											
Peprilus alepidotus	Harvestfish				0.150			0.033					
Selene vomer	Lookdown					0.131							
Sphoeroides maculatus	Northern puffer		0.052										
Orthopristis chrysoptera	Pigfish				0.033	0.030		0.027					
Lagodon rhomboides	Pinfish	0.046	0.052		0.100		0.049						
Dasyatis centroura	Roughtail stingray		0.050										
Stenotomus chrysops	Scup				0.133	0.053	2.130						
Bairdiella chrysoura	Silver perch				0.056			0.162					
Gymnura micrura	Smooth butterfly ray							0.030					
Mustelus canis	Smooth dogfish		0.218	0.396									
Menticirrhus americanus	Southern kingfish								0.037				
Dasyatis americana	Southern stingray	0.038	0.153										
Scomberomorus maculatus	Spanish mackerel					0.025							
Gymnura altavela	Spiny butterfly ray		0.025										
Squalus acanthias	Spiny dogfish	0.047						0.060	0.169	0.046		0.035	0.161

Table 3-10. (Continued)

Taxonomic_Name	Common_Name	Spring Sites			Summer Sites			Fall			Winter		
		N Borrow	N Ref	S Borrow	N Borrow	N Ref	S Borrow	N Borrow	N Ref	S Borrow	N Borrow	N Ref	S Borrow
Fish (Continued)													
Leiostomus xanthurus	Spot	0.142	0.030			0.034			0.122				
Urophycis regia	Spotted hake	4.480	1.366					0.025	0.151				
Anchoa hepsetus	Striped anchovy	0.306			0.058	0.077				0.096			
Chilomycterus schoepfi	Striped burrfish				0.033				0.029				
Prionotus evolans	Striped searobin							0.027					
Paralichthys dentatus	Summer flounder								0.031				
Cynoscion regalis	Weakfish	6.379	0.120		0.056	0.028		0.443	0.650				
Scophthalmus aquosus	Windowpane									0.041	0.059		
Raja ocellata	Winter skate											0.021	
Invertebrate													
Callinectes sapidus	Blue crab					0.024			0.020				
Penaeus aztecus	Brown shrimp				0.031								
Ovalipes stephensoni	Coarsehand lady crab						0.036						
Limulus polyphemus	Horseshoe crab								0.025				
Ovalipes ocellatus	Lady crab					0.027			0.024				
Libinia emarginata	Portly spider crab											0.034	
Crangon septemspinosa	Sand shrimp	0.043	0.043										
Cephalopoda	Squids	0.139	0.218				0.069		0.133	0.623			
Asteroidea	Starfishes		0.030										

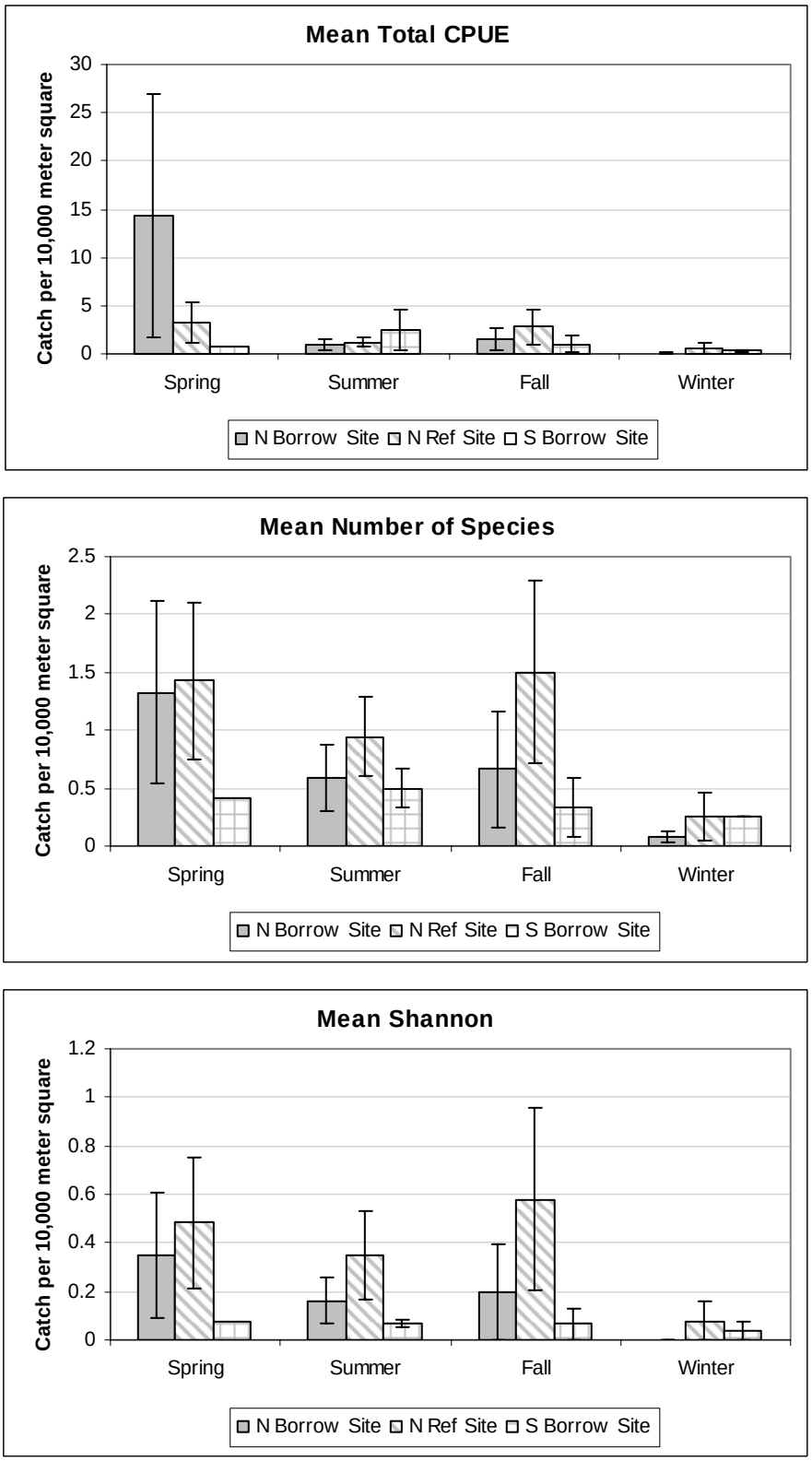


Figure 3-21. Seasonal mean total species CPUE, number of species, and species diversity of species collected in trawls conducted during three years of monitoring at the northern borrow, southern borrow, and northern borrow reference sites offshore of Dare County, NC

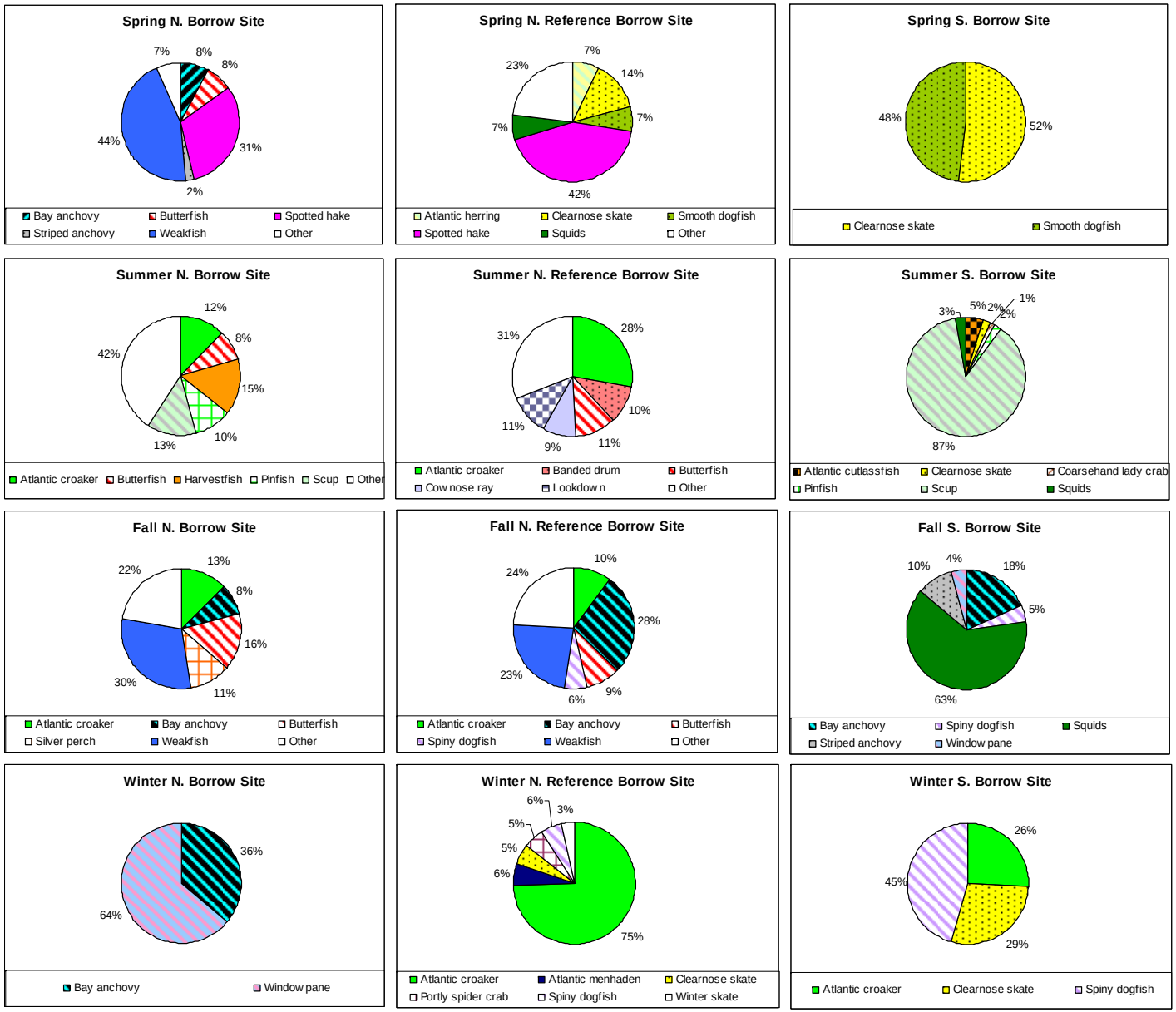


Figure 3-22. Community composition of fish and mobile benthos collected in trawls conducted during three years of monitoring at the northern borrow, southern borrow, and northern borrow reference sites offshore of Dare County, NC

Some invertebrate species were also collected in the trawls throughout the three years of monitoring (Table 3-10). The squid was the most frequently occurring, collected at the northern borrow and reference sites in the spring, at the southern borrow site in the summer, and again at the reference and southern borrow sites in the fall survey. Two species of shrimp were collected; the brown shrimp collected at the northern borrow site in the summer and the sand shrimp collected at the northern borrow and reference sites in the spring. The lady crab and the blue crab were collected at the reference site in the summer and fall but were not found at the borrow sites.

3.5 STOMACH CONTENTS

A total of 682 individual fish from a variety of species were collected at the beaches and ocean borrow sites for stomach content analysis during three years of sampling (Tables 3-11 and 3-12). Nine species were collected in the seines and eight were collected in the trawls. Sixty-three percent of all stomachs collected contained prey items. Based on the diets of the targeted species, seven major prey groups were identified. Besides these seven major groups, other prey items were found in the stomachs examined. These other prey items consisted of unknown items, which were usually unidentifiable because of advanced digestion, and a group named "Other" that consisted of insignificant prey species that were identifiable but were found in limited numbers and could not be classified in any of the other groups. For all the fishes studied, shrimp (including mysids) was the most frequently consumed prey item occurring in over 30% of all stomachs containing prey items (Fig. 3-23). Emerita, polychaetes, and crabs were also common, occurring in 12.5%, 7%, and 5% of stomachs, respectively. Tables 3-11 and 3-12 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 when target fish for stomach analysis were present in the collections. The food habits of all targeted fish species collected with prey items in their stomachs are described below. Diets for species collected along the beaches are analyzed together and compared with diets for species collected at the ocean borrow sites.

3.5.1 Atlantic croaker

A total of 67 Atlantic croaker were collected; 21 at the beaches and 46 at the borrow sites (Tables 3-11 and 3-12). Seventy-one percent of the stomachs collected at the beaches and 70% of the stomachs collected from the borrow sites contained prey. Atlantic croaker collected at the beaches consumed prey from six of the major categories, while six of the major prey items and some other species were found in the stomachs of fish collected at the borrow sites. For Atlantic croaker collected at the borrow sites, both polychaetes and shrimp dominated the diet in number (%N), and frequency of occurrence (%F), and polychaetes dominated the diet by weight (%W) (Table 3-11). Atlantic croaker with stomach contents were collected during all seasons at the beaches and chaetognaths and shrimp were numerically (%N) dominant, but bony fish

dominated by weight (91%) and was therefore more important (58 %IRI) to the diet than any other prey group (Table 3-12).

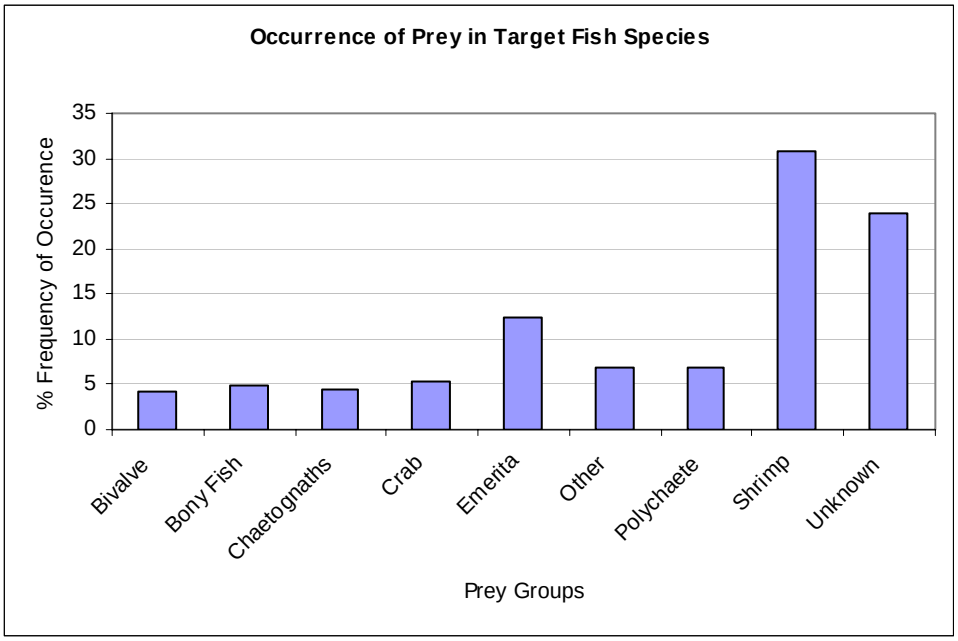


Figure 3-23. Frequency of occurrence (%) of prey groups in the stomachs of all target fish species collected in seines and trawls during three years of monitoring at the impact beach, reference beach, borrow site and borrow site reference in Dare County, NC

3.5.2 Black drum

A total of 25 banded drum were collected; 17 at the beaches and 8 at the borrow sites (Tables 3-11 and 3-12). Ninety-four percent of the stomachs collected at the beaches and 63% of the stomachs collected from the borrow sites contained prey. The stomach content of banded drum collected at the beaches consisted almost entirely of shrimp, which dominated the diet by number (99%) and weight (98%), and were therefore most important to the diet than any other prey group (98.7% IRI). At the borrow sites, stomach content consisted of species from four of the major categories, but was also dominated by shrimp in both number (85%) and weight (79%).

Table 3-11. Summary of prey items found in stomachs of target fish species collected in trawls during three years of monitoring at the borrow and reference borrow sites offshore of Dare County, NC. *n* = number of stomachs dissected, %full = percentage of stomachs with prey items, %N = percent numeric, %W=percent weight, %F= percent frequency, %IRI= percent of the index of relative importance.

					% N (mean)								% W (mean)							
Season	**Site**	**Fish Species**	***n***	**% Full**	**Bivalve**	**Bony Fish**	**Chaetog-naths**	**Crab**	**Emerita**	**Poly-chaete**	**Shrimp**	**Unknown**	**Bivalve**	**Bony Fish**	**Chaetog-naths**	**Crab**	**Emerita**	**Polyc-haete**	**Shrimp**	**Unknown**
Spring	N Borrow	Atlantic croaker	1	100.00	0.00	0.00	25.00	0.00	0.00	0.00	75.00	0.00	0.00	0.00	2.08	0.00	0.00	0.00	10.42	87.50
		Gulf kingfish	1	100.00	50.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	75.00	0.00
		Spot	4	100.00	21.43	28.57	0.00	7.14	7.14	0.00	35.71	0.00	11.40	62.52	0.00	0.22	0.03	0.00	1.26	24.57
		Spotted hake	18	100.00	1.18	3.53	3.53	2.35	0.00	0.00	89.41	0.00	0.48	30.26	0.00	0.21	0.00	0.00	24.47	44.58
	N Ref	Spot	1	0.00																
		Spotted hake	17	100.00	0.00	14.21	20.33	0.00	0.00	0.84	64.62	0.00	0.00	89.58	0.09	0.00	0.00	0.06	2.65	7.62
Summer	N Borrow	Atlantic croaker	4	100.00	0.00	0.00	0.87	6.96	0.00	36.52	0.00	0.00	0.00	0.00	0.06	1.06	0.00	58.82	0.00	16.18
		Banded drum	3	33.33	0.00	6.08	1.35	43.24	0.00	0.00	49.32	0.00	0.00	11.95	0.19	36.62	0.00	0.00	51.23	0.00
		Scup	2	50.00	0.00	0.00	55.95	0.00	0.00	1.19	0.00	0.00	0.00	0.00	59.09	0.00	0.00	4.55	0.00	0.00
		Silver perch	2	100.00	0.00	0.00	0.00	0.00	0.00	0.00	90.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	99.32	0.00
	N Ref	Atlantic croaker	13	84.62	0.22	1.12	0.45	0.00	0.00	13.87	58.61	0.00	0.00	0.00	0.00	0.00	0.00	99.98	0.00	0.01
		Banded drum	5	80.00	0.00	0.13	0.27	7.91	0.00	0.00	90.49	0.00	0.00	0.13	0.03	12.34	0.00	0.00	84.98	2.28
		Scup	2	50.00	0.00	0.00	91.43	0.00	0.00	2.86	0.00	0.00	0.00	0.00	25.00	0.00	0.00	69.23	0.00	0.00
	S Borrow	Scup	43	62.79	0.11	0.21	53.28	0.21	0.00	6.77	32.56	0.00	0.04	0.21	5.78	4.12	0.00	13.57	50.56	14.94
Fall	N Borrow	Atlantic croaker	6	100.00	0.00	0.00	0.00	1.10	0.00	74.73	24.18	0.00	0.00	0.00	0.00	0.23	0.00	83.35	4.35	12.07
		Silver perch	5	100.00	0.00	0.00	0.00	0.00	0.00	2.70	97.30	0.00	0.00	0.00	0.00	0.00	0.00	25.56	73.54	0.90
		Spotted hake	1	100.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
	N Ref	Atlantic croaker	9	88.89	0.00	0.00	0.69	0.00	0.00	92.36	6.94	0.00	0.00	0.00	0.24	0.00	0.00	68.03	0.19	31.53
		Southern kingfish	1	100.00	0.00	14.29	0.00	0.00	0.00	57.14	28.57	0.00	0.00	15.38	0.00	0.00	0.00	16.67	10.26	57.69
		Spot	5	0.00																
		Spotted hake	5	60.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
Winter	N Ref	Atlantic croaker	13	15.38	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00

Table 3-11. (Continued)

Season	Site	Fish Species	*n*	% Full	% F								% IRI							
					Bivalve	Bony Fish	Chaetog-naths	Crab	Emerita	Poly-chaete	Shrimp	Unknown	Bivalve	Bony Fish	Chaetog-naths	Crab	Emerita	Polyc-haete	Shrimp	Unknown
Spring	N Borrow	Atlantic croaker	1	100.00	0.00	0.00	33.33	0.00	0.00	0.00	33.33	33.33	0.00	0.00	13.54	0.00	0.00	0.00	42.71	43.75
		Gulf kingfish	1	100.00	50.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00	37.50	0.00	0.00	0.00	0.00	0.00	62.50	0.00
		Spot	4	100.00	16.67	16.67	0.00	16.67	16.67	0.00	16.67	16.67	16.41	45.55	0.00	3.68	3.59	0.00	18.49	12.28
		Spotted hake	18	100.00	20.00	20.00	0.00	20.00	0.00	0.00	20.00	20.00	0.84	17.20	0.00	1.30	0.00	0.00	57.96	22.69
	N Ref	Spot	1	0.00																
		Spotted hake	17	100.00	0.00	20.00	20.00	0.00	0.00	20.00	20.00	20.00	0.00	51.89	10.21	0.00	0.00	0.45	33.64	3.81
Summer	N Borrow	Atlantic croaker	4	100.00	0.00	0.00	20.00	20.00	0.00	20.00	0.00	20.00	0.00	0.00	0.46	4.01	0.00	47.67	0.00	8.09
		Banded drum	3	33.33	0.00	25.00	25.00	25.00	0.00	0.00	25.00	0.00	0.00	9.02	0.77	39.93	0.00	0.00	50.28	0.00
		Scup	2	50.00	0.00	0.00	33.33	0.00	0.00	33.33	0.00	0.00	0.00	0.00	57.52	0.00	0.00	2.87	0.00	0.00
		Silver perch	2	100.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	94.90	0.00
	N Ref	Atlantic croaker	13	84.62	14.29	14.29	14.29	0.00	0.00	14.29	14.29	14.29	0.11	0.56	0.22	0.00	0.00	56.93	29.31	0.00
		Banded drum	5	80.00	0.00	16.67	16.67	16.67	0.00	0.00	16.67	16.67	0.00	0.13	0.15	10.13	0.00	0.00	87.74	1.14
		Scup	2	50.00	0.00	0.00	33.33	0.00	0.00	33.33	0.00	0.00	0.00	0.00	58.21	0.00	0.00	36.04	0.00	0.00
	S Borrow	Scup	43	62.79	12.50	12.50	12.50	12.50	0.00	12.50	12.50	12.50	0.07	0.21	29.53	2.16	0.00	10.17	41.56	7.47
Fall	N Borrow	Atlantic croaker	6	100.00	0.00	0.00	0.00	25.00	0.00	25.00	25.00	25.00	0.00	0.00	0.00	0.66	0.00	79.04	14.27	6.04
		Silver perch	5	100.00	0.00	0.00	0.00	0.00	0.00	33.33	33.33	33.33	0.00	0.00	0.00	0.00	0.00	14.13	85.42	0.45
		Spotted hake	1	100.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
	N Ref	Atlantic croaker	9	88.89	0.00	0.00	25.00	0.00	0.00	25.00	25.00	25.00	0.00	0.00	0.47	0.00	0.00	80.20	3.57	15.77
		Southern kingfish	1	100.00	0.00	25.00	0.00	0.00	0.00	25.00	25.00	25.00	0.00	14.84	0.00	0.00	0.00	36.90	19.41	28.85
		Spot	5	0.00																
		Spotted hake	5	60.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
Winter	N Ref	Atlantic croaker	13	15.38	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00

Table 3-12. Summary of prey items found in stomachs of target fish species collected in seines during three years of monitoring 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, %W=percent weight, %F= percent frequency, %IRI= percent of the index of relative importance.

					% N (mean)								% W (mean)							
Season	**Site**	**Fish Species**	***n***	**Full**	**Bivalve**	**Bony Fish**	**Chaetog-naths**	**Crab**	**Emerita**	**Poly-chaete**	**Shrimp**	**Unknown**	**Bivalve**	**Bony Fish**	**Chaetog-naths**	**Crab**	**Emerita**	**Poly-chaete**	**Shrimp**	**Unknown**
Spring	Impact	Atlantic croaker	1	100.00									0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
		Black drum	4	80.00	30.00	0.00	0.00	0.00	30.00	0.00	40.00	0.00	30.23	0.00	0.00	0.00	65.82	0.00	3.95	0.00
		Gulf kingfish	3	100.00	5.41	0.00	52.25	0.00	4.50	30.63	7.21	0.00	0.76	0.00	1.13	0.00	44.68	2.09	6.46	44.88
		Northern kingfish	2	66.67	0.00	0.00	0.00	50.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	85.49	0.00	0.00	14.51
		Southern kingfish	1	50.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.63	0.00	0.00	0.00	68.37
		Spot	19	67.86	1.75	0.00	84.21	0.00	3.51	3.51	7.02	0.00	0.28	0.00	0.43	0.00	4.84	0.02	0.21	94.22
	Reference	Atlantic croaker	6	85.71	0.00	11.76	35.29	23.53	0.00	11.76	17.65	0.00	0.00	27.88	2.41	0.25	0.00	0.38	1.39	67.68
		Florida pompano	0	0.00																
		Gulf kingfish	2	50.00	2.22	0.00	0.00	0.00	28.89	0.00	0.00	0.00	0.23	0.00	0.00	0.00	93.94	0.00	0.00	0.00
		Northern kingfish	2	50.00	0.00	0.00	0.00	50.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	14.86	69.11	0.00	0.00	16.03
		Red drum	2	66.67	0.00	0.00	0.00	28.57	71.43	0.00	0.00	0.00	0.00	0.00	0.00	32.69	67.31	0.00	0.00	0.00
		Silver perch	2	100.00									0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
		Southern kingfish	4	66.67	0.00	0.00	0.00	2.23	13.01	78.07	6.69	0.00	0.00	0.00	0.00	11.60	30.23	24.65	5.13	28.38
		Spot	13	56.52	2.00	0.67	20.71	1.34	0.00	0.00	60.13	0.00	87.45	0.29	0.03	2.92	0.00	0.00	2.22	6.11
Summer	Impact	Banded drum	1	100.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
		Black drum	18	66.67	40.49	0.00	0.00	0.00	19.47	0.00	31.64	0.00	86.51	0.00	0.00	0.00	9.62	0.00	0.84	1.03
		Florida pompano	30	69.77	1.90	0.00	0.00	1.25	19.99	0.00	75.46	0.00	49.32	0.00	0.00	0.07	47.25	0.00	2.06	0.76
		Gulf kingfish	3	60.00	0.00	0.00	0.00	0.00	94.74	5.26	0.00	0.00	0.00	0.00	0.00	0.00	99.38	0.48	0.00	0.13
		Red drum	3	75.00	0.00	27.78	0.00	0.00	50.00	0.00	22.22	0.00	0.00	76.42	0.00	0.00	23.52	0.00	0.02	0.04
		Southern kingfish	6	66.67	0.00	0.00	0.00	37.50	50.00	0.00	12.50	0.00	0.00	0.00	0.00	56.38	34.51	0.00	0.05	9.07
		Spot	51	76.12	0.02	0.00	0.00	0.11	9.03	0.17	90.14	0.00	0.21	0.00	0.00	0.06	36.53	8.36	43.79	9.82
	Reference	Atlantic croaker	1	50.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
		Banded drum	15	93.75	0.02	0.02	0.00	0.02	0.06	0.03	99.81	0.00	0.89	0.19	0.00	0.04	0.11	0.02	97.96	0.30
		Black drum	6	60.00	21.43	0.00	0.00	0.00	0.00	7.14	57.14	0.00	90.48	0.00	0.00	0.00	0.00	0.87	1.73	0.00
		Florida pompano	17	48.57	0.36	0.00	0.00	0.00	92.12	0.00	5.74	0.00	2.63	0.00	0.00	0.00	93.93	0.00	0.15	2.96
		Gulf kingfish	10	90.91	0.00	0.00	0.00	2.63	97.37	0.00	0.00	0.00	0.00	0.00	0.00	2.08	97.83	0.00	0.00	0.08
		Northern kingfish	0	0.00																
		Southern kingfish	8	72.73	0.00	15.38	0.00	30.77	0.00	15.38	38.46	0.00	0.00	32.74	0.00	55.50	0.00	3.20	0.08	8.49
		Spot	43	34.40	0.31	0.00	0.03	0.09	0.08	0.12	99.35	0.00	19.23	0.00	0.02	0.51	0.26	0.11	65.47	14.22

Table 3-12. (Continued)

Season	Site	Fish Species	*n*	Full	% N (mean)								% W (mean)							
					Bivalve	Bony Fish	Chaetog-naths	Crab	Emerita	Poly-chaete	Shrimp	Unknown	Bivalve	Bony Fish	Chaetog-naths	Crab	Emerita	Poly-chaete	Shrimp	Unknown
Fall	Impact	Atlantic croaker	0	0.00																
		Black drum	9	69.23	0.00	0.00	0.00	0.00	56.52	0.00	43.48	0.00	0.00	0.00	0.00	0.00	91.02	0.00	5.36	3.62
		Red drum	6	85.71	0.00	14.58	0.00	14.58	66.67	0.00	4.17	0.00	0.00	36.91	0.00	14.87	45.63	0.00	0.00	2.59
		Spot	0	0.00																
	Reference	Black drum	0	0.00																
		Gulf kingfish	0	0.00																
		Red drum	1	33.33	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Winter	Impact	Atlantic croaker	2	100.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	97.21	0.00	0.00	0.00	0.00	0.00	2.79
		Black drum	1	100.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
	Reference	Atlantic croaker	5	62.50	0.00	37.50	18.75	0.00	0.00	0.00	37.50	0.00	0.00	92.87	0.00	0.00	0.00	0.00	0.15	6.62
		Red drum	13	100.00	0.00	94.75	0.00	0.29	4.66	0.00	0.29	0.00	0.00	46.86	0.00	9.64	42.69	0.00	0.81	0.00
		Southern kingfish	1	100.00	0.00	0.00	0.00	0.00	25.00	0.00	75.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00

Season	Site	Species	*n*	Full	% F (mean)								% IRI (mean)							
					Bivalve	Bony Fish	Chaetog-naths	Crab	Emerita	Poly-chaete	Shrimp	Unknown	Bivalve	Bony Fish	Chaetog-naths	Crab	Emerita	Poly-chaete	Shrimp	Unknown
Spring	Impact	Atlantic croaker	1	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Black drum	4	80.00	33.33	0.00	0.00	0.00	33.33	0.00	33.33	0.00	30.11	0.00	0.00	0.00	47.91	0.00	21.98	0.00
		Gulf kingfish	3	100.00	16.67	0.00	16.67	0.00	16.67	16.67	16.67	16.67	3.08	0.00	26.69	0.00	24.59	16.36	6.83	22.44
		Northern kingfish	2	66.67	0.00	0.00	0.00	0.00	50.00	0.00	0.00	50.00	0.00	0.00	0.00	0.00	90.33	0.00	0.00	9.67
		Southern kingfish	1	50.00	0.00	0.00	0.00	50.00	0.00	0.00	0.00	50.00	0.00	0.00	0.00	65.81	0.00	0.00	0.00	34.19
		Spot	19	67.86	16.67	0.00	16.67	0.00	16.67	16.67	16.67	16.67	1.01	0.00	42.32	0.00	4.18	1.77	3.61	47.11
	Reference	Atlantic croaker	6	85.71	0.00	16.67	16.67	16.67	0.00	16.67	16.67	16.67	0.00	19.82	18.85	11.89	0.00	6.07	9.52	33.84
		Florida pompano	0	0.00																
		Gulf kingfish	2	50.00	33.33	0.00	0.00	0.00	33.33	0.00	0.00	0.00	1.22	0.00	0.00	0.00	61.41	0.00	0.00	0.00
		Northern kingfish	2	50.00	0.00	0.00	0.00	33.33	33.33	0.00	0.00	33.33	0.00	0.00	0.00	32.43	59.56	0.00	0.00	8.02
		Red drum	2	66.67	0.00	0.00	0.00	50.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	30.63	69.37	0.00	0.00	0.00
		Silver perch	2	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Southern kingfish	4	66.67	0.00	0.00	0.00	20.00	20.00	20.00	20.00	20.00	0.00	0.00	0.00	6.92	21.62	51.36	5.91	14.19
		Spot	13	56.52	14.29	14.29	14.29	14.29	0.00	0.00	14.29	14.29	44.73	0.48	10.37	2.13	0.00	0.00	31.18	3.05

Table 3-12. (Continued)

Season	Site	Species	*n*	Full	% F (mean)								% IRI (mean)							
					Bivalve	Bony Fish	Chaetog-naths	Crab	Emerita	Poly-chaete	Shrimp	Unknown	Bivalve	Bony Fish	Chaetog-naths	Crab	Emerita	Poly-chaete	Shrimp	Unknown
Summer	Impact	Banded drum	1	100.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
		Black drum	18	66.67	20.00	0.00	0.00	0.00	20.00	0.00	20.00	20.00	63.50	0.00	0.00	0.00	14.54	0.00	16.24	0.52
		Florida pompano	30	69.77	16.67	0.00	0.00	16.67	16.67	0.00	16.67	16.67	25.61	0.00	0.00	0.66	33.62	0.00	38.76	0.38
		Gulf kingfish	3	60.00	0.00	0.00	0.00	0.00	33.33	33.33		33.33	0.00	0.00	0.00	0.00	97.06	2.87	0.00	0.07
		Red drum	3	75.00	0.00	25.00	0.00	0.00	25.00	0.00	25.00	25.00	0.00	52.10	0.00	0.00	36.76	0.00	11.12	0.02
		Southern kingfish	6	66.67	0.00	0.00	0.00	25.00	25.00	0.00	25.00	25.00	0.00	0.00	0.00	46.94	42.25	0.00	6.27	4.53
		Spot	51	76.12	14.29	0.00	0.00	14.29	14.29	14.29	14.29	14.29	0.11	0.00	0.00	0.08	22.78	4.27	66.96	4.91
	Reference	Atlantic croaker	1	50.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
		Banded drum	15	93.75	12.50	12.50	0.00	12.50	12.50	12.50	12.50	12.50	0.46	0.10		0.03	0.09	0.02	98.89	0.15
		Black drum	6	60.00	25.00	0.00	0.00	0.00	0.00	25.00	25.00	0.00	55.95	0.00	0.00	0.00	0.00	4.00	29.44	0.00
		Florida pompano	17	48.57	20.00	0.00	0.00	0.00	20.00	0.00	20.00	20.00	1.50	0.00	0.00	0.00	93.02	0.00	2.94	1.48
		Gulf kingfish	10	90.91	0.00	0.00	0.00	33.33	33.33	0.00	0.00	33.33	0.00	0.00	0.00	2.36	97.60	0.00	0.00	0.04
		Northern kingfish	0	0.00																
		Southern kingfish	8	72.73	0.00	20.00	0.00	20.00	0.00	20.00	20.00	20.00	0.00	24.06		43.13	0.00	9.29	19.27	4.24
		Spot	43	34.40	12.50	0.00	12.50	12.50	12.50	12.50	12.50	12.50	9.77	0.00	0.02	0.30	0.17	0.12	82.41	7.11
Fall	Impact	Atlantic croaker	0	0.00																
		Black drum	9	69.23	0.00	0.00	0.00	0.00	33.33	0.00	33.33	33.33	0.00	0.00	0.00	0.00	73.77	0.00	24.42	1.81
		Red drum	6	85.71	0.00	20.00	0.00	20.00	20.00	0.00	20.00	20.00	0.00	25.75	0.00	14.72	56.15	0.00	2.08	1.30
		Spot	0	0.00																
	Reference	Black drum	0	0.00																
		Gulf kingfish	0	0.00																
		Red drum	1	33.33	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Winter	Impact	Atlantic croaker	2	100.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	50.00	0.00	98.60	0.00	0.00	0.00	0.00	0.00	1.40
		Black drum	1	100.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
	Reference	Atlantic croaker	5	62.50	0.00	25.00	0.00	0.00	0.00	0.00	25.00	25.00	0.00	71.93	0.00	0.00	0.00	0.00	20.77	3.65
		Red drum	13	100.00	0.00	25.00	0.00	25.00	25.00	0.00	25.00	0.00	0.00	70.81	0.00	4.97	23.68	0.00	0.55	0.00
		Southern kingfish	1	100.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00

3.5.3 Florida pompano

A total of 79 Florida pompano were collected at the beach sites and none were collected at the borrow sites (Table 3-12). Sixty percent of Florida pompano stomachs contained prey. Florida pompano were only collected in the spring and summer. The Florida pompano diet consisted of four known prey groups; bivalves, Emerita, and shrimp. Very few unknown organisms were found (Table 3-12). Overall, Emerita dominated the diet by weight (83%W) and had the highest %IRI values in both seasons. Numerically (%N), more shrimp were found than Emerita, but shrimp did not contribute much to the overall weight (2%W). Bivalves contributed little to the diet of Florida pompano and were found in the stomachs only in the summer season (Table 3-12).

3.5.4 Gulf kingfish

A total of 25 gulf kingfish were collected; 24 at the beaches and one at the borrow sites (Tables 3-11 and 3-12). Seventy-five percent of the stomachs collected at the beaches and the one stomach from the borrow sites contained prey. Gulf kingfish were present during spring, summer, and fall 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. Bivalves, polychaetes, chaetognaths, shrimp, and crabs were also found in beach fish stomachs, along with some other prey items. Bivalves and shrimp were contained in the borrow site fish stomachs (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 while chaetognaths dominated in the spring. Emerita also comprised most of the biomass and had the highest % IRI for both seasons (Table 3-12).

3.5.5 Northern kingfish

A total of 8 northern kingfish were collected in the spring and summer at the beach sites and none were collected at the borrow sites (Table 3-12). Fifty 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 (72%W) and had the highest %IRI value (Table 3-12). Most (88%) of the northern kingfish collected at the beach sites were collected during the spring. The one northern kingfish collected at the beach during the summer had an empty stomach.

3.5.6 Red drum

A total of 30 red drum were collected at the beach sites during all four seasons and none were collected at the borrow sites (Table 3-12). Fifty percent of red drum stomachs contained bony fish, Emerita, crabs, and shrimp. Bony fish dominated the diet by number (85%N), but Emerita dominated by weight (54%W) Overall, bony fish had the highest %IRI value (58%), and therefore contributed most to the diet of the red drum (Table 3-12). Bony fish increased in number as the seasons progressed from spring to winter, constituting 0% of the red drum's diet in the spring, 28% in the summer, and 95% in the winter.

3.5.7 Scup

Forty-seven scup were collected at the borrow sites in the summer months while none were found at the beach sites (Table 3-11). Sixty-two percent of scup stomachs contained prey items. Scup diet was dominated by chaetognaths and shrimp, constituting 31% IRI and 39% IRI, respectively.

3.5.8 Silver Perch

A total of nine silver perch were collected; two at the beaches and seven at the borrow sites (Tables 3-11 and 3-12). All silver perch stomachs contained prey items. The two silver perch collected in the spring at the beaches contained 100% unknown organisms. Overall, shrimp was the dominant prey by number (95% N), weight (90%W), and IRI value (93% IRI) in the silver perch collected at the borrow sites during the summer and fall, along with some polychaetes and other species (Table 3-11).

3.5.9 Southern Kingfish

A total of 30 southern kingfish were collected; 29 at the beaches and one at the borrow sites (Tables 3-11 and 3-12). Sixty-nine percent of the stomachs collected at the beaches and the one stomach from the borrow sites contained prey. Southern kingfish with prey were collected in all seasons but fall 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). Unknown organisms contributed to the stomach content items of both the borrow site fish and the beach fish. All prey items but bivalves and chaetognaths were present in the stomachs of southern kingfish collected on the beach (Table 3-12). The spring collections at the beach sites indicated a diet dominated by polychaetes (52% IRI) with some Emerita, crabs, and shrimp. Summer diets were much more diverse with five known prey items in the stomachs. In the winter, the one southern kingfish collected had mostly shrimp and some Emerita in its stomach. Polychaetes were the dominant prey item by number (47%N), while crabs dominated by weight (39%W), thus these two prey items had the highest %IRI values overall (26%IRI, each). Bony fish were

second only to crabs in weight (%W) and %IRI in the summer, but were not present in any other season (Table 3-12).

3.5.10 Spot

A total of 263 spot were collected; 254 at the beaches and nine at the borrow sites (Tables 3-11 and 3-12). Fifty percent of the stomachs collected at the beaches and 40% of the stomachs from the borrow sites contained prey. Spot collected in fall at both the beaches and the borrow sites did not contain prey items in their stomachs. Spot stomachs collected at the borrow sites contained all prey items except chaetognaths and polychaetes (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, spring diets were dominated by bivalves (37%IRI), but consisted of organisms from all prey types (Table 3-12). Shrimp 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.

3.5.11 Spotted hake

A total of 41 spotted hake were collected at the borrow sites and none at the beaches (Table 3-11). Ninety-five percent of spotted hake stomachs contained prey. Spotted hake were only collected in the spring and fall. Unknown organisms contributed to a portion of the stomach content items during the spring. All prey items but Emerita were present in the stomachs of spotted hake in the spring while only shrimp were present in the fall. Shrimp dominated by number (69%N) in the spring, but bony fish contributed the highest weights (90%W) for all prey, thus having the highest %IRI (Table 3-11).

3.6 GHOST CRAB SURVEY

Ghost crabs, as inferred from ghost crab hole counts, were present in every season but winter (Figs. 3-24 and 3-25). Ghost crab abundance was highly variable between seasons and between beaches. During the first year of the survey, the abundance of ghost crabs was lower than their abundance during the second two years (Fig. 3-25). In general, the densities of ghost crabs were lower at the impact beach than the reference beach for most seasons and most years. This could be due to the increased activity and number of people visiting the impact beach. On both the impact and reference beach, the highest densities of ghost crabs were seen during the summer season (Fig. 3-24). At the reference beach during all years, densities of ghost crabs increased from spring to summer and then decreased in the fall, with no ghost crabs present during the winter (Fig. 3-25). However, no year-to-year pattern of the abundance of ghost crabs on the impact beaches could be discerned (Fig. 3-25).

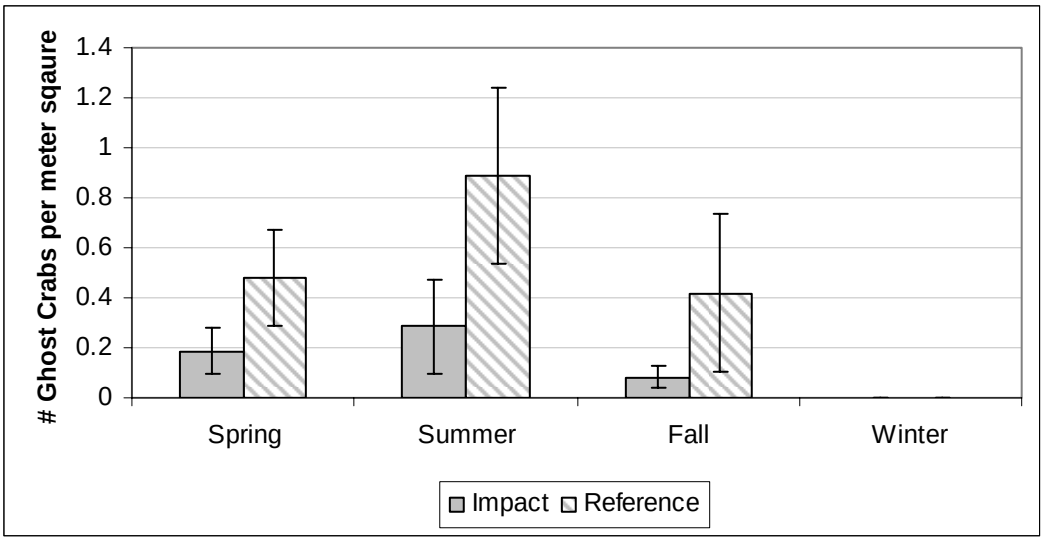


Figure 3-24. Three year averaged seasonal mean abundance of ghost crabs (inferred from ghost crab hole counts) observed over three years from the wrack line to the toe of the dune on the impact and reference beaches in Dare County, NC

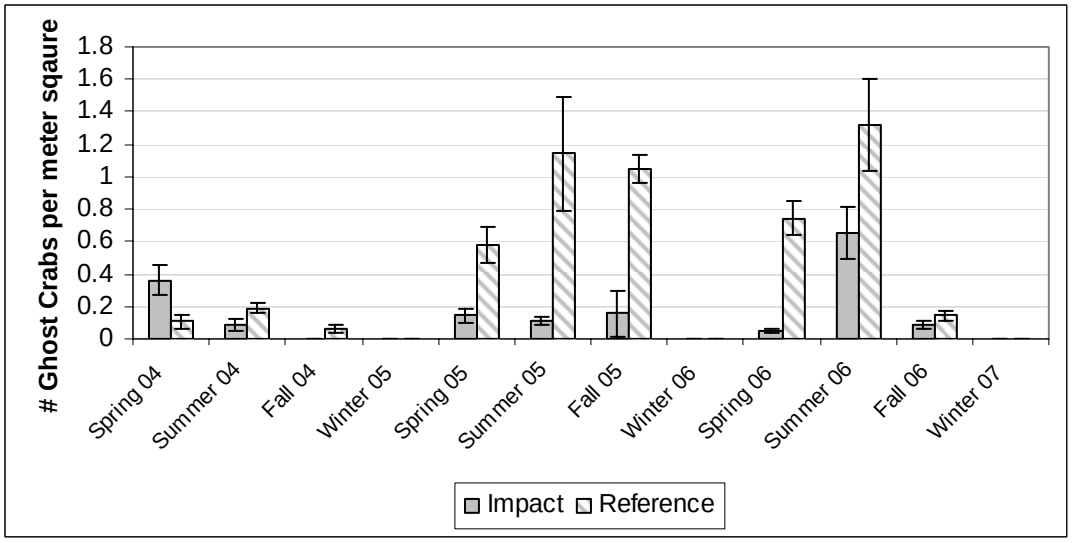


Figure 3-25. Seasonal mean abundance of ghost crabs (inferred from ghost crab hole counts) observed over three years from the wrack line to the toe of the dune on the impact and reference beaches in Dare County, NC

3.7 BIRD SURVEY

Nearly 35,000 birds were counted during three years of surveys conducted at the impact and reference beaches. A cumulative total of 46 species were documented consisting of 10 species of shorebird, 26 waterbirds, and 10 other species (Table 3-13). Four birds were unique to the impact beach including American crow, great cormorant, house sparrow, and mallard. Two birds, the black skimmer and the common goldeneye, were unique to the reference beach. In general, species composition was similar between the beaches in all seasons and years (Fig. 3-26).

There were no obvious differences in total species abundance between the beaches during any season (Fig. 3-27). The greatest bird abundance was evident during the fall season on both the impact and reference beaches, with an average of 23.4 and 24.6 birds/500 m, respectively (Table 3-14). During Year 3, a large flock of cormorant species passed through the area, adding a significant number of birds to the counts. Spring and summer abundance was lower, averaging between 14.1 and 20.5 birds/500 m. At both the impact and reference beaches, bird abundance was lowest during the winter months, with 13 birds/500 m and 12.4 birds/500 m, respectively (Table 3-14). Shorebird abundance was at a minimum during winter months, but relatively consistent during the other seasons (Fig. 3-30). During the spring and summer, shorebird abundance on reference beaches was greater than abundance on the impact beach, but abundances were similar between the beaches during the fall and winter (Fig. 3-30). Waterbird abundance was highest during the spring and fall months and decreased during the summer and winter (Fig. 3-33). 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 was fairly constant during spring, summer, and fall and declined during winter (Fig. 3-27). Total species richness was highest in the spring at the impact beach averaging 3.50 species/500 m and during the summer at the reference beach averaging 3.41 species/500 m. Species richness was lowest in the winter averaging 2.01 and 2.03 species/500 m at the impact and reference beaches, respectively (Table 3-14). Only minor differences in total species richness between the beaches were seen throughout the year (Fig. 3-27). Total species diversity was similar to species richness with fairly constant levels of diversity during spring, summer, and fall, which declined in the winter (Fig. 3-27). Shorebird and waterbird species richness and diversity followed the same seasonal trend and were similar at both beaches with fairly constant levels through spring, summer, and fall, and declining during winter (Figs. 3-30 and 3-33). At the reference beach, shorebird values were highest in the summer while waterbird values were at their peak during the fall. However, at the impact beach, shorebird richness and diversity were highest during the spring, while waterbird values were highest during spring and fall. On all beaches, waterbird values were fairly consistent during each season (Fig. 3-33).

Table 3-13. Seasonal mean abundance (birds/500 meters) of individual shorebirds, waterbirds, and other birds counted during a three year survey 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	0.037	0.014		0.01		0.004		0.004
Limosa haemastica	Hudsonian godwit	0.007	0.02		0.003				
Calidris minutilla	Least Sandpiper	0.01	0.02	0.007	0.007				
Arenaria interpres	Ruddy Turnstone	0.666	1.103	0.533	0.923	0.21	0.254		
Calidris alba	Sanderling	0.673	1.16	0.347	1.133	2.012	0.628	0.089	
Calidris pusilla	Semipalmated Sandpiper	2.052	1.968	1.343	3.088	0.851	1.155	0.089	0.127
Calidris mauri	Western Sandpiper	0.356	0.644	0.107	0.467	1.025	1.241	0.094	0.116
Numenius phaeopus	Whimbrel	0.143	0.022	0.013	0.02				
Calidris fuscicollis	White-rumped Sandpiper	0.022		0.017	0.043		0.03		
Catoptrophorus semipalmatus	Willet	0.1	0.09	0.163	0.474	0.518	0.92	0.263	0.435
Waterbird									
Melanitta nigra	Black Scoter	0.463	0.34			0.327			0.004
Rynchops niger	Black Skimmer								0.004
Pelecanus occidentalis	Brown Pelican	4.274	4.106	2.933	3.555	1.675	2.496	1.543	1.447
Sterna caspia	Caspian Tern	0.13	0.051	0.017	0.013	0.014	0.02		
Bucephala clangula	Common Goldeneye		0.03						
Gavia immer	Common Loon	0.053	0.033	0.003	0.02		0.003		
Sterna hirundo	Common Tern	0.293	0.017	0.283	0.424	0.181	0.389	0.017	0.119
Phalacrocorax spp.	Cormorant	0.622		0.003		0.952	1.198	0.05	0.062
Phalacrocorax auritus	Double Crested Cormorant	0.023	0.033			0.023			
Sterna forsteri	Forster's Tern	0.324	0.08	0.04	0.037	0.248	0.161	0.015	
Larus marinus	Great Black Backed Gull	1.123	0.99	0.427	0.548	1.41	1.173	0.871	0.778
Phalacrocorax carbo	Great Cormorant					0.003			
Larus spp.	Gull spp					0.333			
Larus argentatus	Herring Gull	1	0.907	0.193	0.198	0.986	0.992	0.583	0.598
Larus atricilla	Laughing Gull	4.536	5.217	4.79	5.085	7.666	7.825	4.333	3.36
Sterna antillarum	Least Tern			0.027	0.02	0.026	0.022		
Larus fuscus	Lesser Black Back Gull	0.007			0.012	0.031	0.059	0.02	0.007
Anas platyrhynchos	Mallard	0.003							

Table 3-13. (Continued)

Taxonomic Name	Common Name	Spring		Summer		Fall		Winter	
		Impact	Ref.	Impact	Ref.	Impact	Ref.	Impact	Ref.
Waterbird (Continued)									
Morus bassanus	Northern Gannet	0.513	0.283			0.023	0.133	0.16	0.207
Pandion haliaetus	Osprey	0.06	0.137	0.147	0.099	0.011	0.007		
Mergus serrator	Red-breasted Merganser	0.003	0.017						
Gavia stellata	Red-throated Loon	0.007			0.006				0.007
Larus delawarensis	Ring-billed Gull	1.491	0.908	0.19	0.18	2.13	2.95	3.434	4.036
Sterna maxima	Royal Tern					0.162	0.41		
Sterna sandvicensis	Sandwich Tern			0.023	0.067		0.01	0.022	0.033
Sterna spp.	Tern					0.005	0.029		
Other Bird									
Corvus brachyrhynchos	American Crow			0.003					
Riparia riparia	Bank Swallow	0.027		0.087	0.1		0.007		
Quiscalus major	Boat tailed Grackle	0.948	0.853	1.797	1.178	1.739	1.714	0.506	0.563
Quiscalus quiscula	Common Grackle					0.01			
Sturnus vulgaris	European Starling			0.1	0.047				
Corvus ossifragus	Fish Crow					0.019	0.024		
Quiscalus spp.	Grackle	0.044			0.007				
Passer domesticus	House Sparrow			0.017					
Zenaida macroura	Mourning Dove			0.07	0.003	0.03	0.044		
Columba livia	Pigeon	0.482	0.247	0.437	0.329	0.804	0.694	0.857	0.49

Table 3-14. Seasonal mean abundance (birds/500 meters) of all bird, shorebird and waterbird groups counted during a three year survey 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	20.49	19.29	14.12	18.10	23.43	24.60	12.95	12.40
	Richness	3.50	3.25	3.08	3.41	3.19	3.37	2.01	2.03
	Diversity	1.34	1.30	1.21	1.36	1.21	1.26	0.70	0.73
Shorebird	Abundance	4.07	5.04	2.53	6.17	4.62	4.23	0.54	0.68
	Richness	0.79	0.83	0.49	1.01	0.52	0.64	0.14	0.15
	Diversity	0.26	0.31	0.17	0.37	0.09	0.16	0.03	0.02
Waterbird	Abundance	14.93	13.15	9.08	10.26	16.21	17.88	11.05	10.66
	Richness	2.24	2.11	1.81	1.90	2.19	2.30	1.59	1.65
	Diversity	0.84	0.75	0.60	0.62	0.76	0.82	0.48	0.52

Species composition was similar between the impact and reference beaches within each of the four seasons, with the exception of an increased number of cormorant species seen during the fall at the reference beach. However, there were large changes in species composition between seasons at both beaches (Fig. 3-26). In the spring and summer, the brown pelican and laughing gull were the most abundant species accounting for the majority of the birds at both the beaches. During the fall and winter months, the brown pelican remained a dominant species along with the ring-billed gull (Fig. 3-26). These trends were the same for waterbirds; the brown pelican and laughing gull were the most abundant species in the spring and summer, while the ring-billed gull and the brown pelican were the most frequently documented waterbird species in the fall and winter (Fig. 3-32). The semipalmated sandpiper and the sanderling were the most prevalent species of shorebird documented during the spring and summer, while in the fall the western sandpiper and semipalmated sandpiper were the most abundant on the reference beach and the ruddy turnstone and semipalmated sandpiper dominated on the impact beach (Fig. 3-29). During the winter, the willet was the most prevalent species on both impact and reference beaches (Bird Fig. 3-29).

Overall, bird habitat use was similar between beaches and seasons (Fig. 3-28). A majority of birds were found using the surf/intertidal zone during the spring at both reference and impact beaches, while use was somewhat more evenly split between the beach and the surf/intertidal zone in the summer, fall, and winter months. Shorebirds on both the reference and impact beaches used the surf/intertidal zone more often than the beach area in all months, whereas waterbirds on both the reference and impact beaches used the surf/intertidal zone more often in the spring but fairly evenly used beach areas and surf/intertidal zones in other seasons (Figs. 3-31 and 3-34).

Bird activity was similar between beaches. During the winter, more birds were resting than flying or feeding, while activity was somewhat equally split between feeding, flying, and resting during other seasons (Fig. 3-28). Shorebirds, however, were found to be feeding more

often than flying or resting nearly all of the time on both the reference and impact beaches (Fig. 3-31). Waterbirds were resting or flying more than feeding except during the spring on the impact beach, where there was a large percentage of birds feeding (Fig. 3-34).

Pets and number of people were monitored to provide a means to assess their effects on bird counts. Pets (dogs specifically) are not allowed on Kill Devil Hills beaches (including this study's impact beaches) from Memorial Day to Labor Day each year. Dogs are allowed on the beaches in Nags Head (including this study's reference beaches) year round, however they must be on a leash from Memorial Day to Labor Day. On the reference beach, the largest abundance of pets was observed during summer months where there averaged 7.3 pets every 3.5 miles. At the impact beach, pets were most abundant during the spring, where almost 4 pets were observed every 3.5 miles. Pet abundance was the lowest during winter months at both reference and impact beaches, at under 2 pets per every 3.5 miles. During the fall, impact and reference beaches each averaged just over 3 pets throughout the length of the 3.5 mile transect. One interesting observation found in this study was that on the impact beaches, an average of 2 pets every 3.5 miles were observed during the summer months, despite the ban on pets.

The numbers of people varied over the year as well. The highest numbers are seen in the summer months (June to the end of August). High numbers are defined to be over 50 people per section (10 sections in a 3.5 mile transect) of the transect, and medium numbers are considered to be 26-49 people per section. Low numbers are considered to be 1-25 people per section, while "none" means zero people were observed in the section. During the summer, there were no occasions where no people were observed during the sampling. Most often, there was a high density of people. As expected, the opposite trend is observed during the winter. During the months of November through March, it is possible to walk a transect and not see a person or see only two or three. During the winter, the most frequent observation was that no people were on the beach at both beaches. There were no occasions during the winter when a high density of people were observed on the beach at either reference or impact beach.

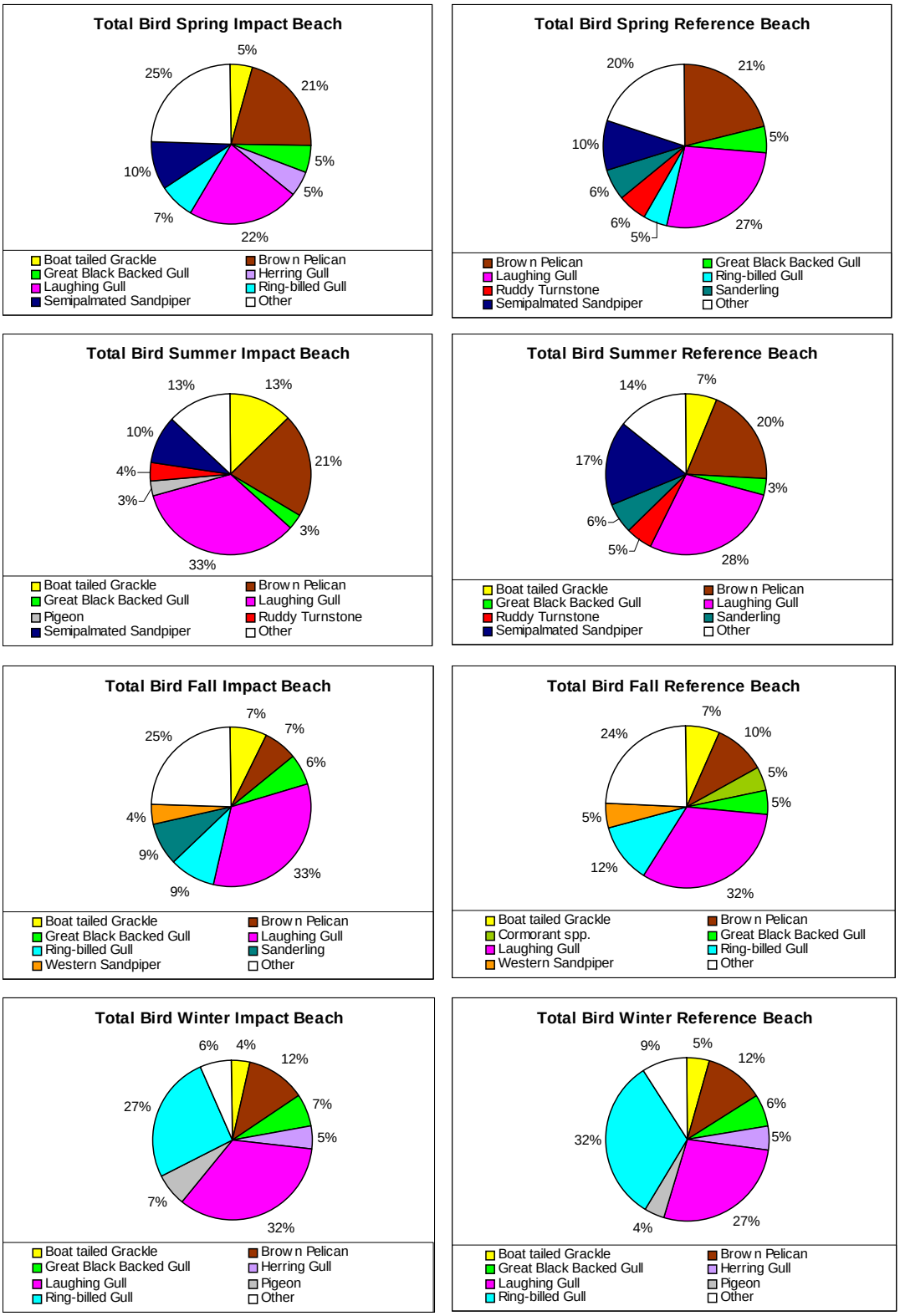


Figure 3-26. Seasonal mean total species composition occurring during a three year survey on the impact and reference beaches in Dare County, NC

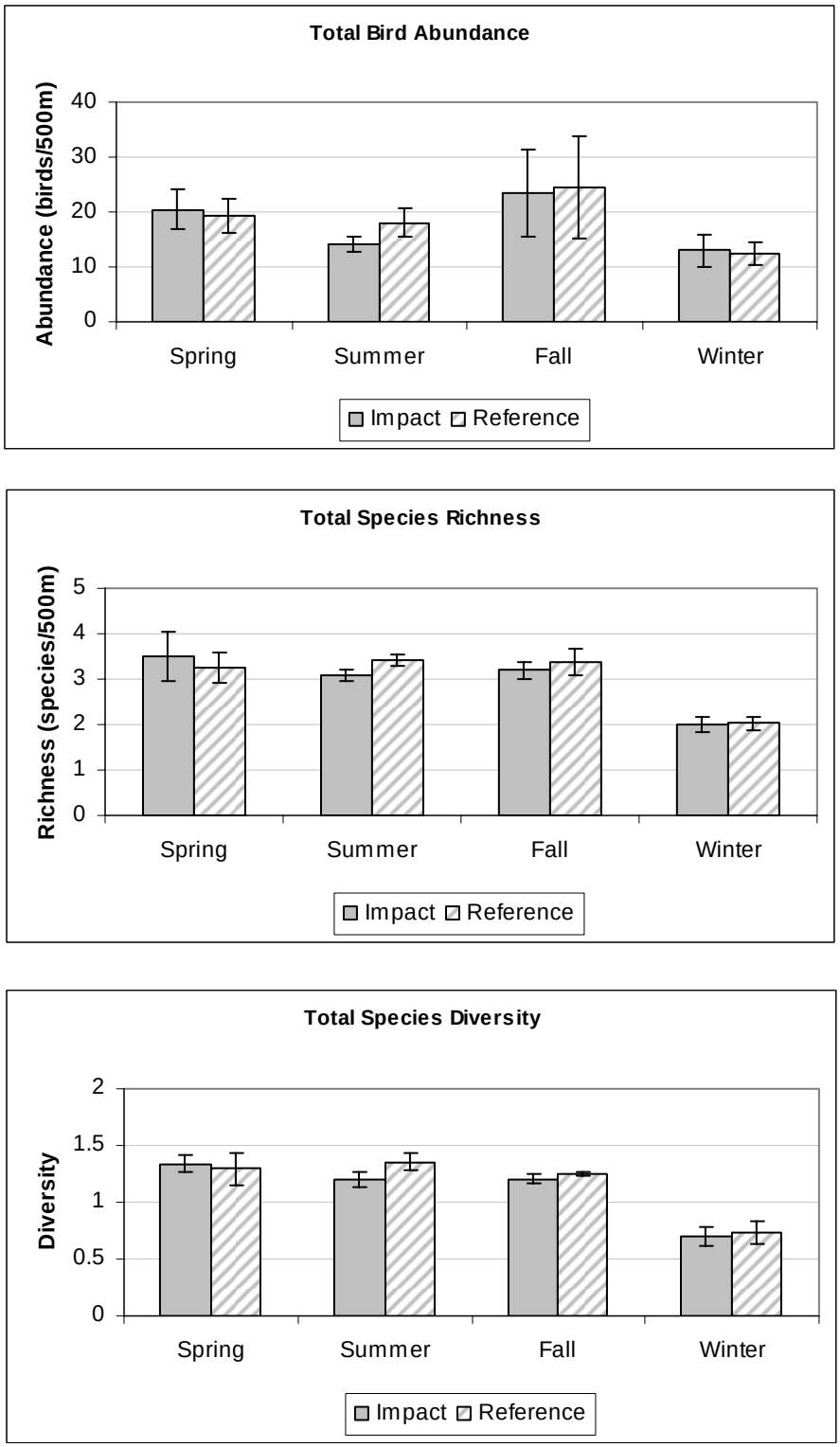


Figure 3-27. Seasonal mean total bird abundance, number of species, and species diversity occurring during a three year survey on the impact and reference beaches in Dare County, NC

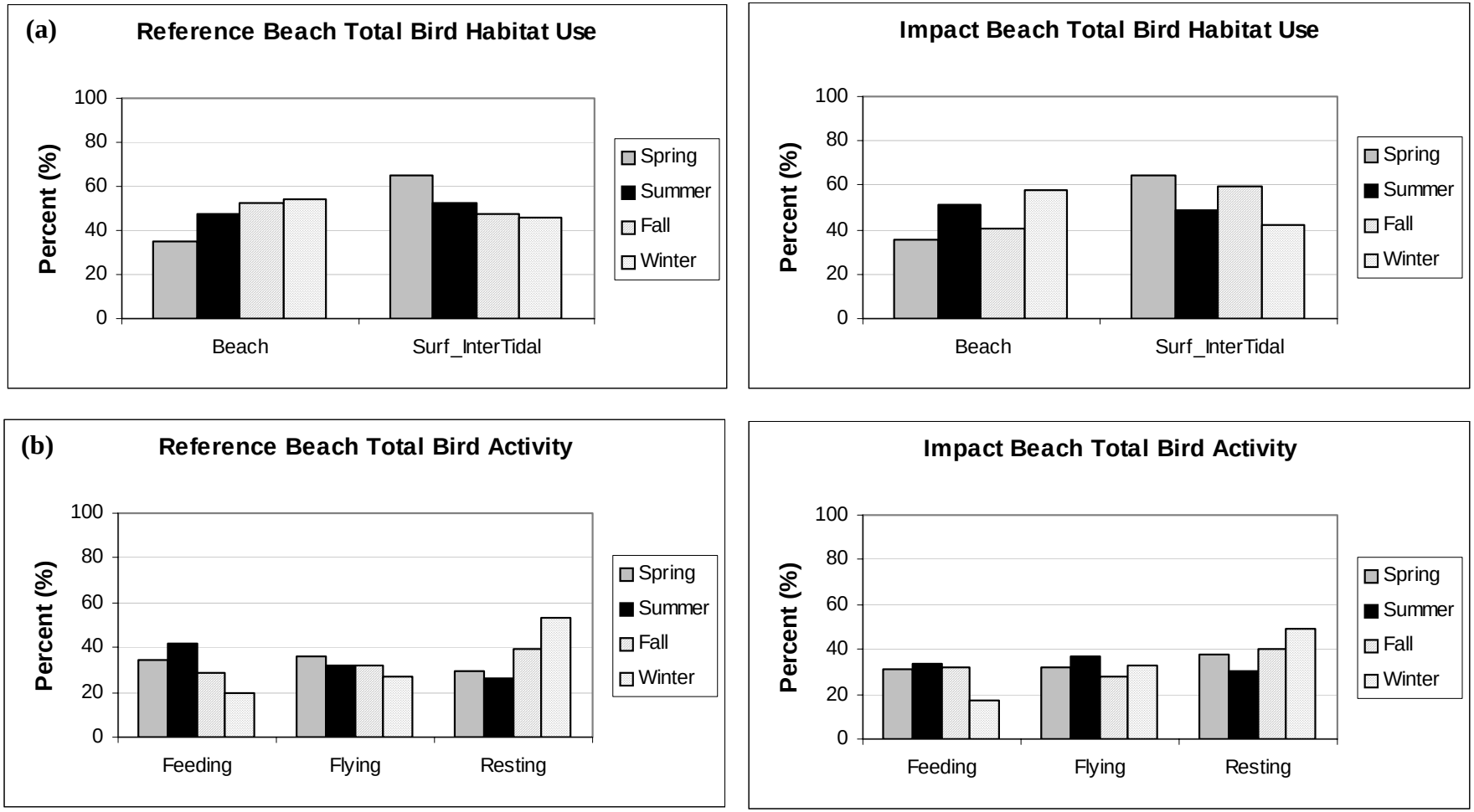


Figure 3-28. Seasonal mean habitat use by all birds counted on the impact and reference beaches in Dare County, NC (a). Seasonal activity of all birds counted during a three year survey on the impact and reference beaches in Dare County, NC (b).

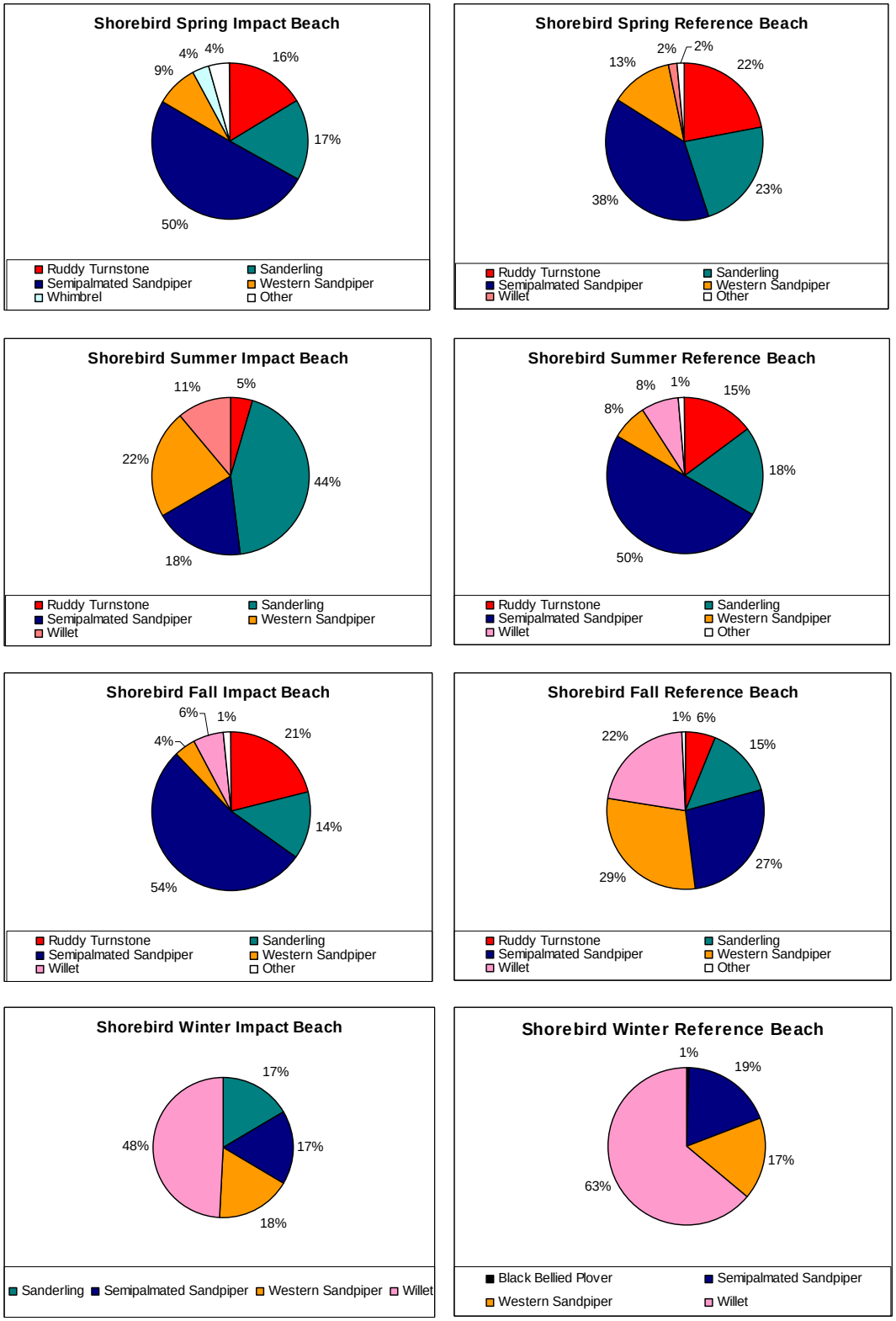


Figure 3-29. Seasonal mean shorebird species composition occurring during a three year survey on the impact and reference beaches in Dare County, NC

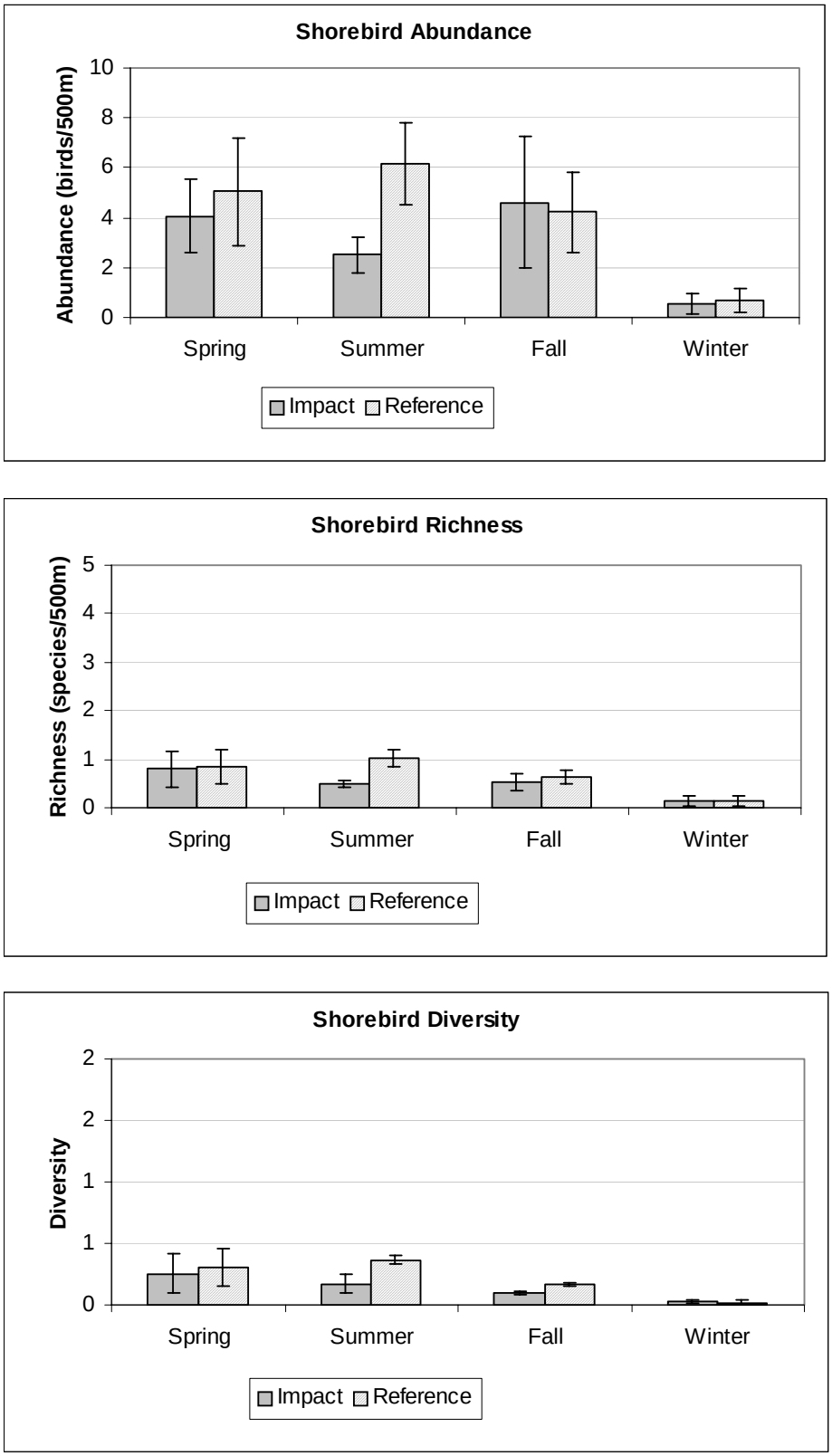


Figure 3-30. Seasonal mean shorebird abundance, number of species, and species diversity occurring during a three year survey on the impact and reference beaches in Dare County, NC

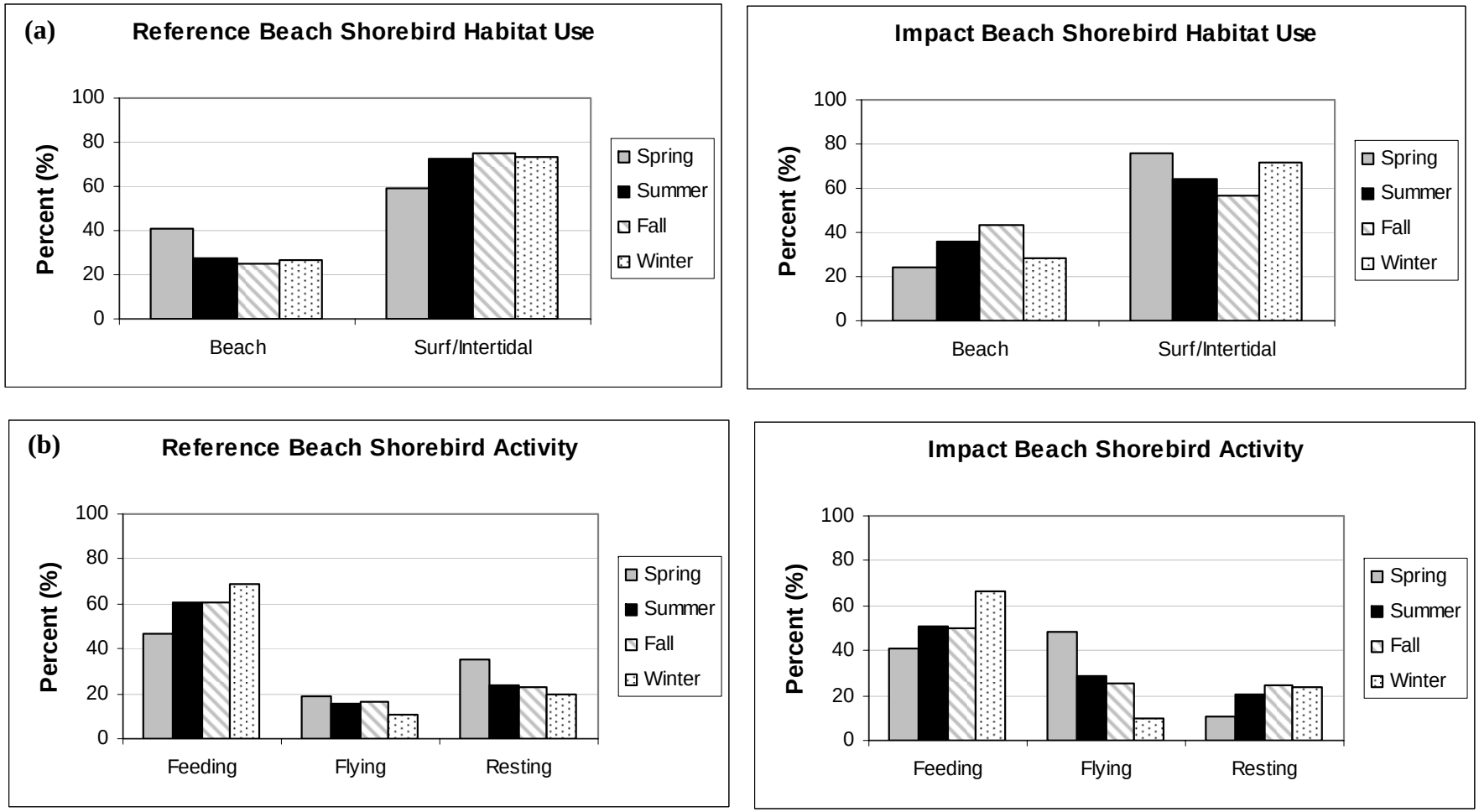


Figure 3-31. Seasonal mean habitat use by shorebirds during a three year survey on the impact and reference beaches in Dare County, NC (a). Seasonal activity of shorebirds on the impact and reference beaches in Dare County, NC (b).

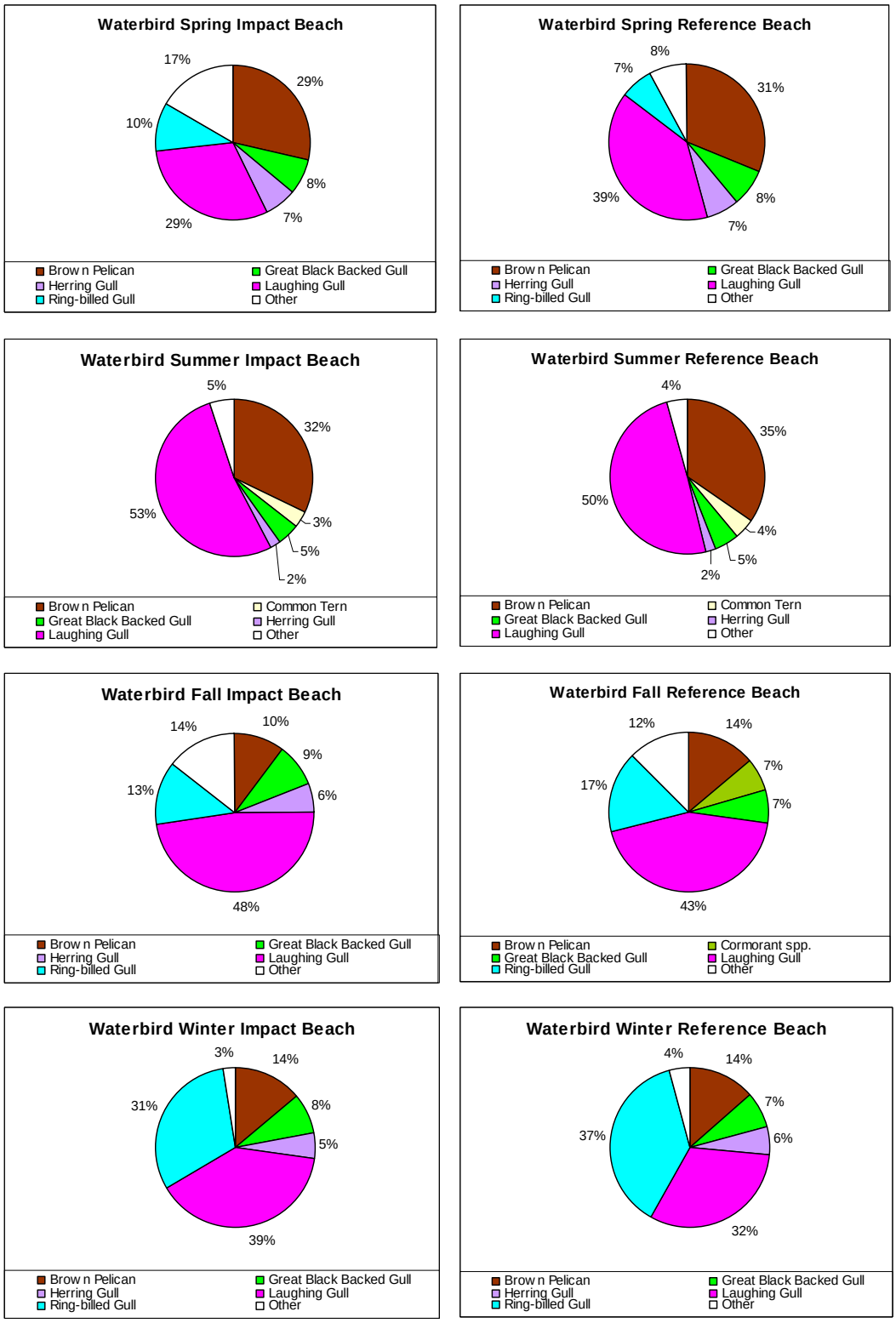
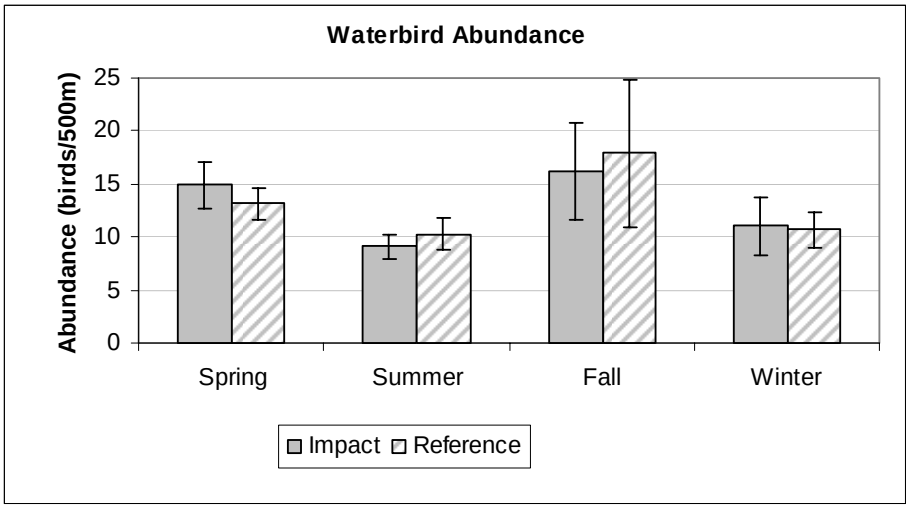
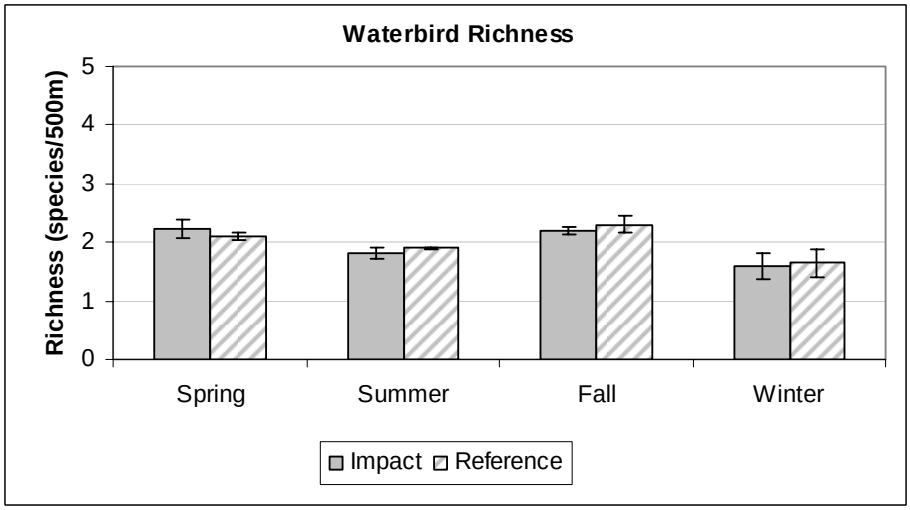


Figure 3-32. Seasonal mean waterbird composition during a three year survey occurring on the impact and reference beaches in Dare County, NC





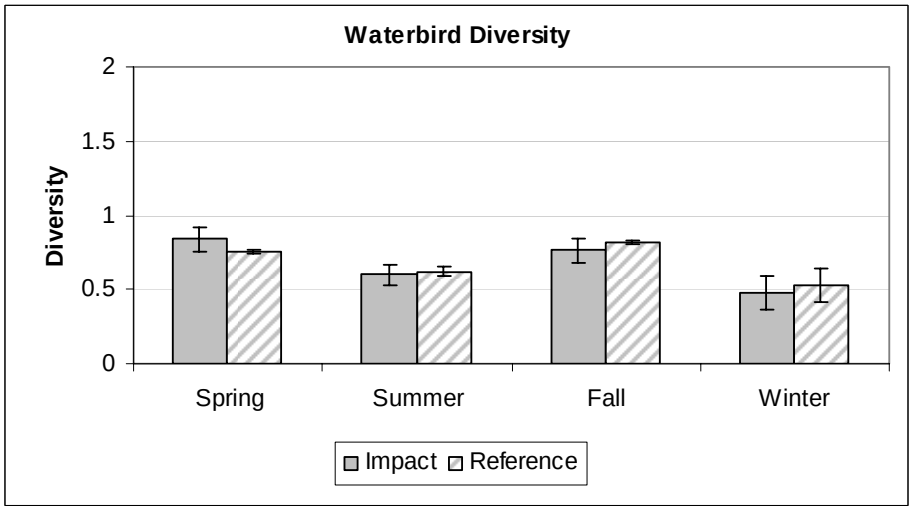


Figure 3-33. Seasonal mean waterbird abundance, number of species, and species diversity during a three year survey occurring on the impact and reference beaches in Dare County, NC

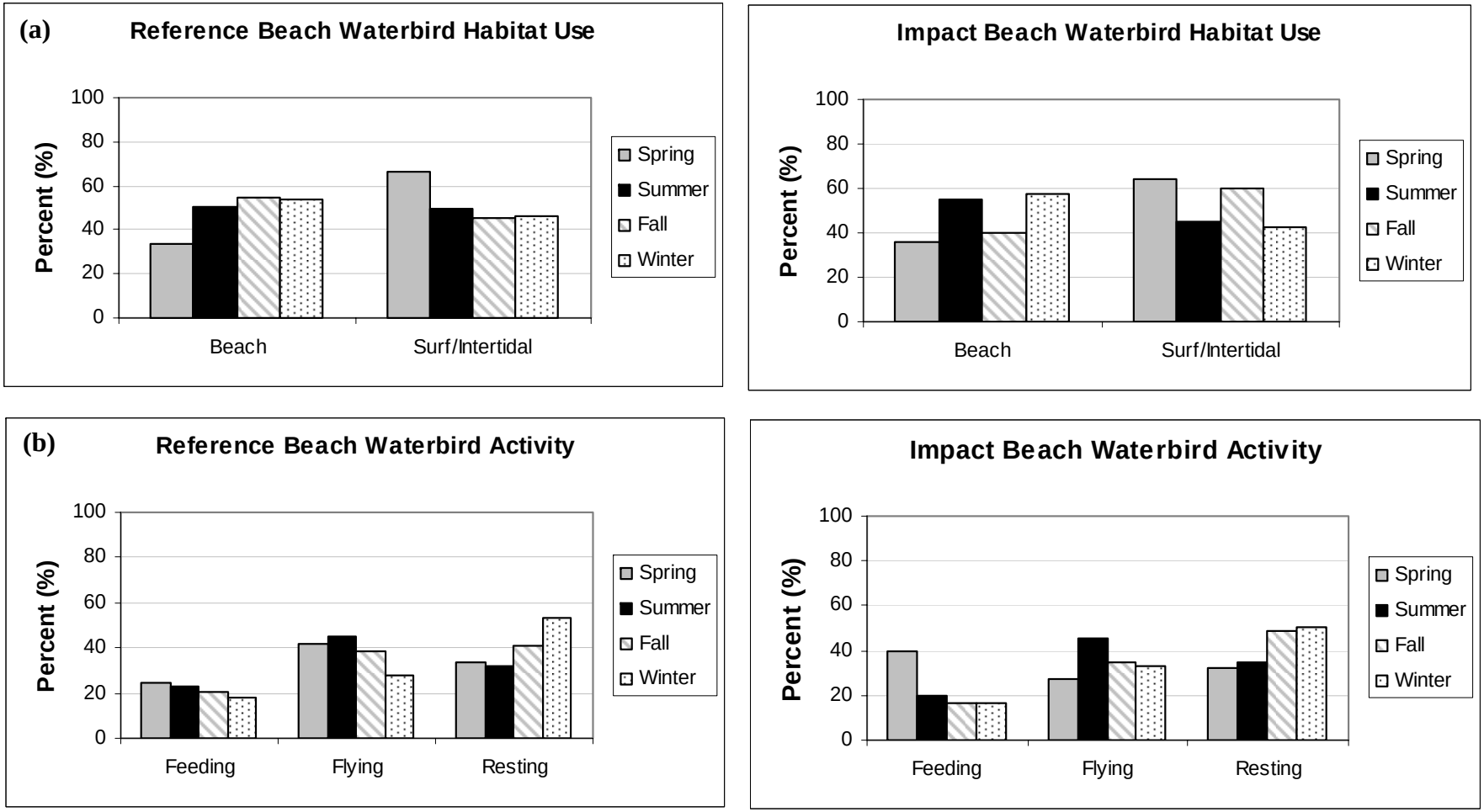


Figure 3-34. Seasonal mean habitat use by waterbirds during a three year survey on the impact and reference beaches in Dare County, NC (a). Seasonal activity of waterbirds on the impact and reference beaches in Dare County, NC (b).

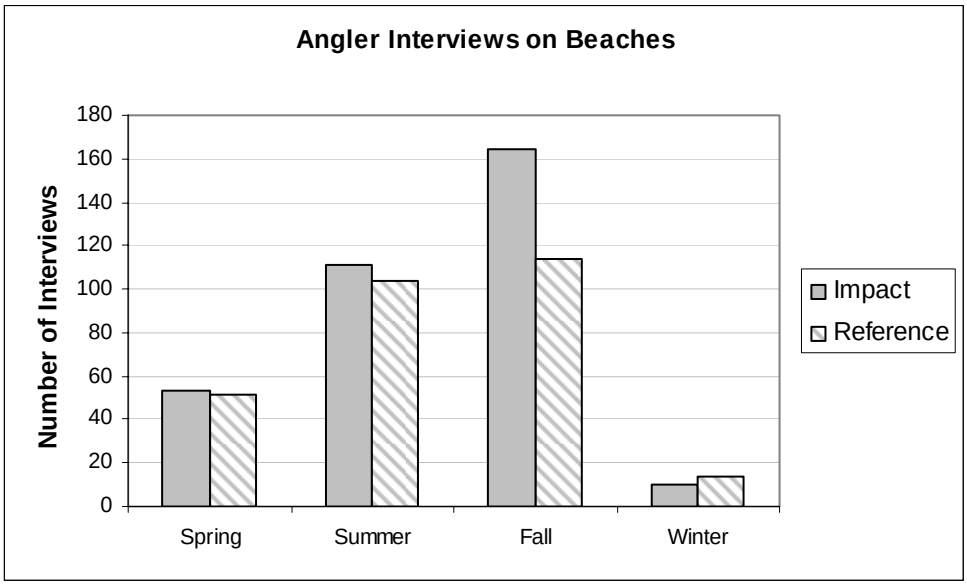
3.8 CREEL SURVEY

A total of 5,231 anglers were approached for interviews during 367 survey days from spring 2004 to winter 2007. Among them, 2,323 anglers were successfully interviewed and 401 declined to be interviewed. Over the course of the three years, trends in results of the creel survey stayed relatively consistent and no annual differences were detected. Fishing effort was generally greatest in the summer and fall with the majority of angler interviews occurring in those two seasons (Fig. 3-35). Catch and total fishing effort were much greater on the piers than on the beaches with 72.5% (n=1,684) of all interviews conducted at the piers (Figs. 3-35 and 3-36). Catches did not differ significantly between the impact and reference beaches or the impact and reference piers, as indicated by the highly overlapping confidence intervals (Fig. 3-36).

Over 85% of all anglers interviewed at the beaches and piers were males (Fig. 3-37). There was a slightly higher percentage of anglers that were female that were interviewed on the piers than at the beaches. The majority of the anglers interviewed at both the beaches and piers were adults between 18 and 50 years old (Fig. 3-38). Over the course of the three years of the study, the percentage of youth interviewed increased. Thirty-six percent of the anglers interviewed were over 50 (seniors) and only 3 percent of the anglers interviewed were youths younger than 18 years old.

Interviewed anglers were from twenty-nine states and the District of Columbia with the majority residing from North Carolina (36%), Virginia (30%), and Pennsylvania (10%) (Fig. 3-39). In general, there were higher numbers of out of state anglers interviewed at the piers, but overall, most of the anglers interviewed from season to season resided from North Carolina. Anglers who were from North Carolina resided in 70 different counties, some as far away as Graham (1%), but the majority of anglers were from Dare (39%), Currituck (9%), and Pasquotank (7%) counties (Fig. 3-40). Virginia anglers resided from 71 counties with the majority from Richmond (22%), Norfolk (11%), Virginia Beach (8%), and Roanoke (8%) (Fig. 3-41).

Anglers caught over 7,700 individual fish, skates and rays from 20 families during the study (Table 3-15). Over half of the catch (57%) was released because of size, undesirable species, or for conservation. The most commonly captured species were spot, bluefish, spotted seatrout, kingfish, and flounder (Fig. 3-36). Fishing effort and catch generally were greatest in the summer and fall on the beaches, with most of the catch consisting of spot, bluefish, and spotted seatrout. Fishing effort was also greatest during summer and fall on the piers, but harvest rates were more constant over the three seasons that the piers were open. The same species were commonly reported captured on the piers as the beaches, but Kingfish also constituted a large portion of the catch during spring.



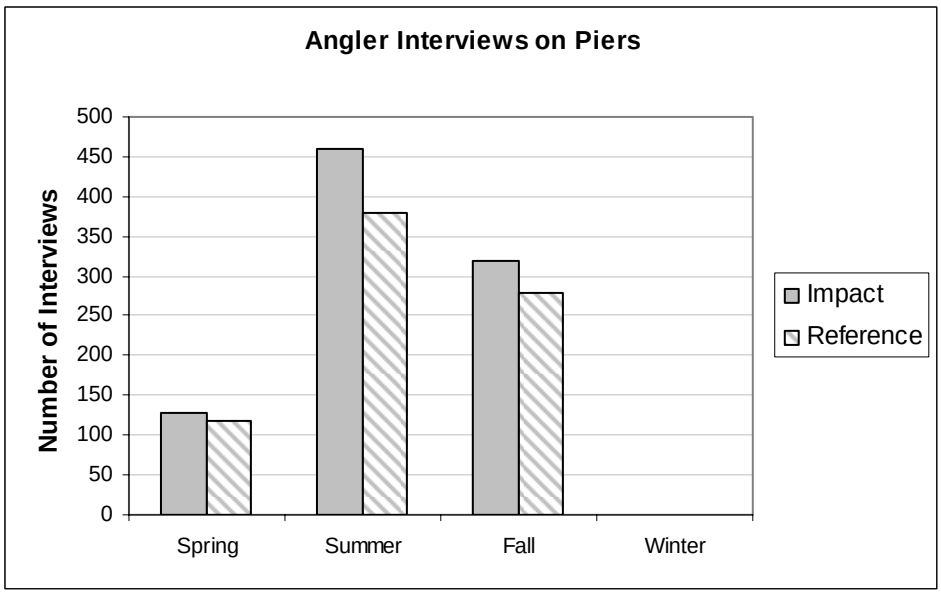


Figure 3-35. Seasonal number of angler interviews conducted for three years on the beaches and piers at the impact and reference creel beaches in Dare County, NC

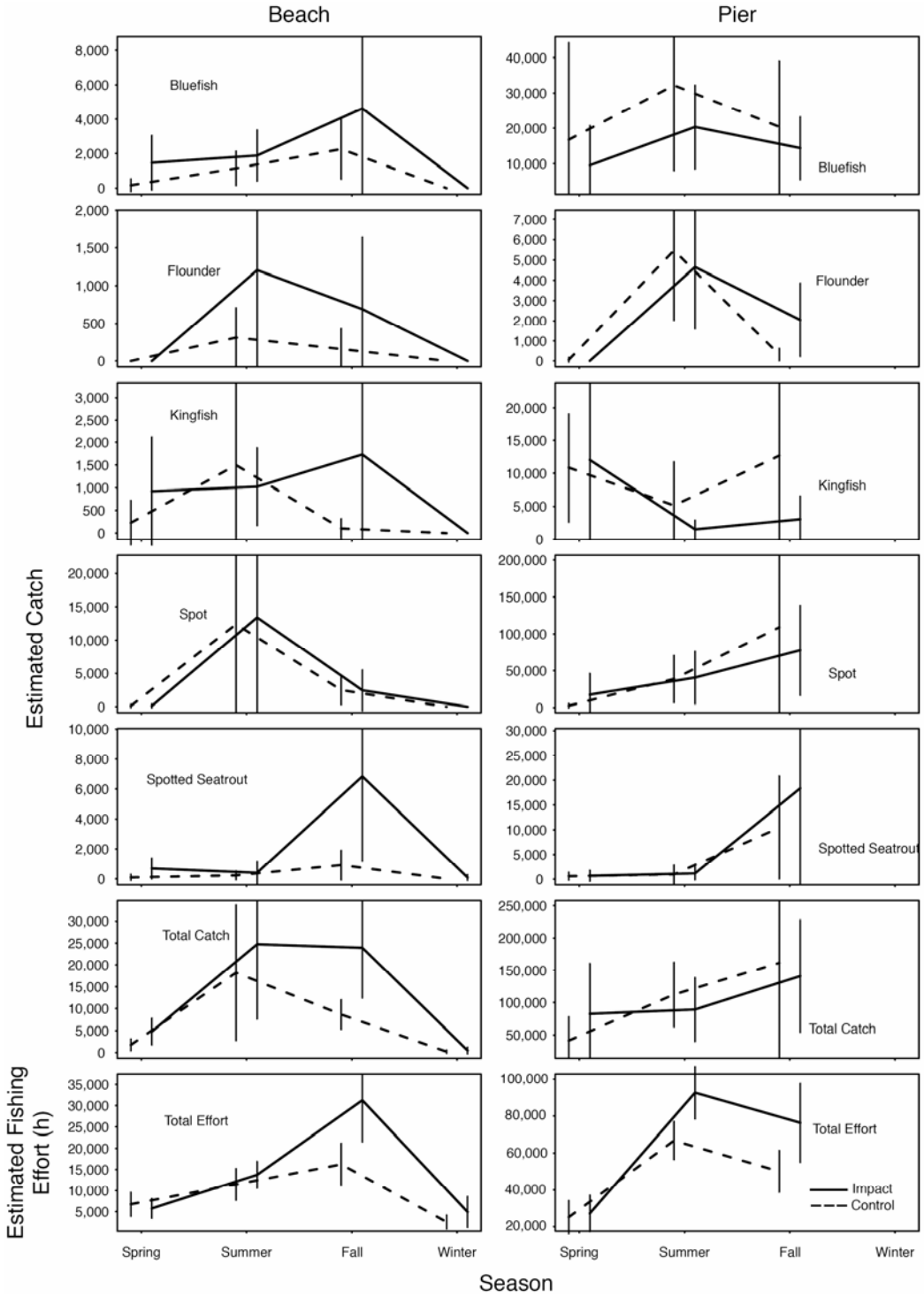
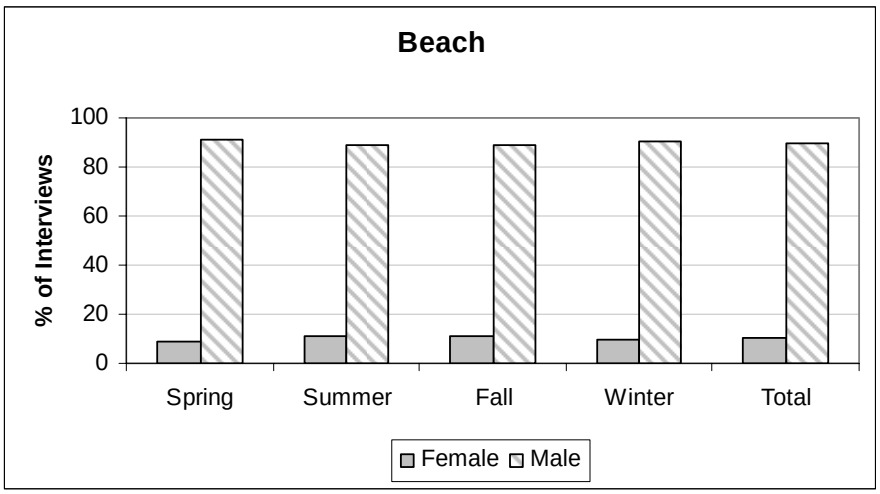
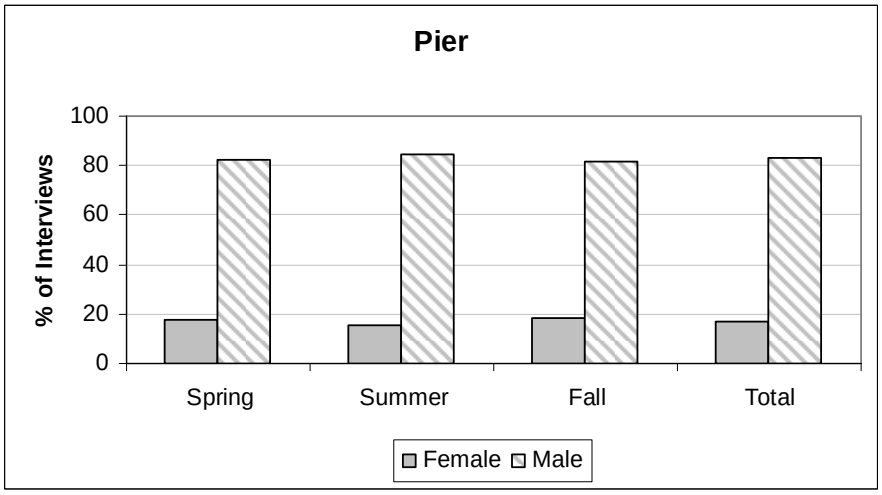


Figure 3-36. Catch of bluefish, flounder, kingfish, spot, and spotted seatrout, total catch, and total fishing effort at the impact and control beaches and piers conducted for three years. Vertical bars indicate approximate 95% confidence intervals. Piers were closed during winter. Note that y-axis scales differ among graphs.





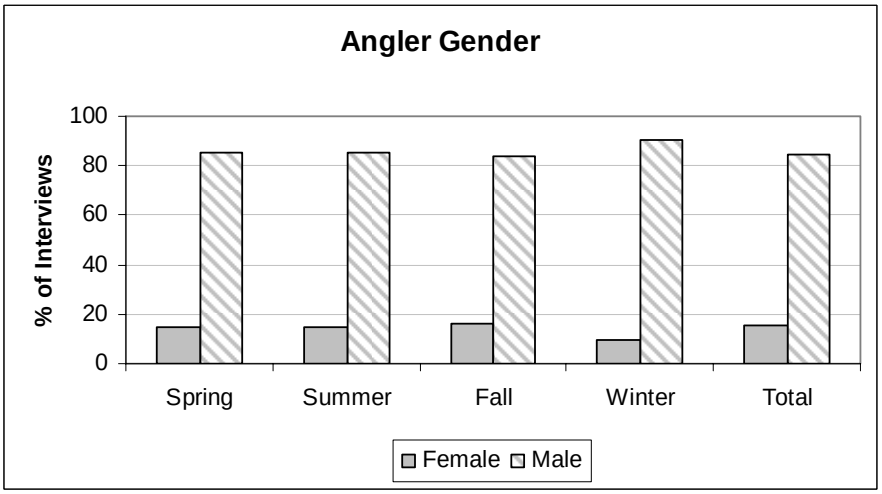


Figure 3-37. Percent of male and female anglers interviewed during three years of angler interviews at the impact and reference beaches and piers in Dare County, NC

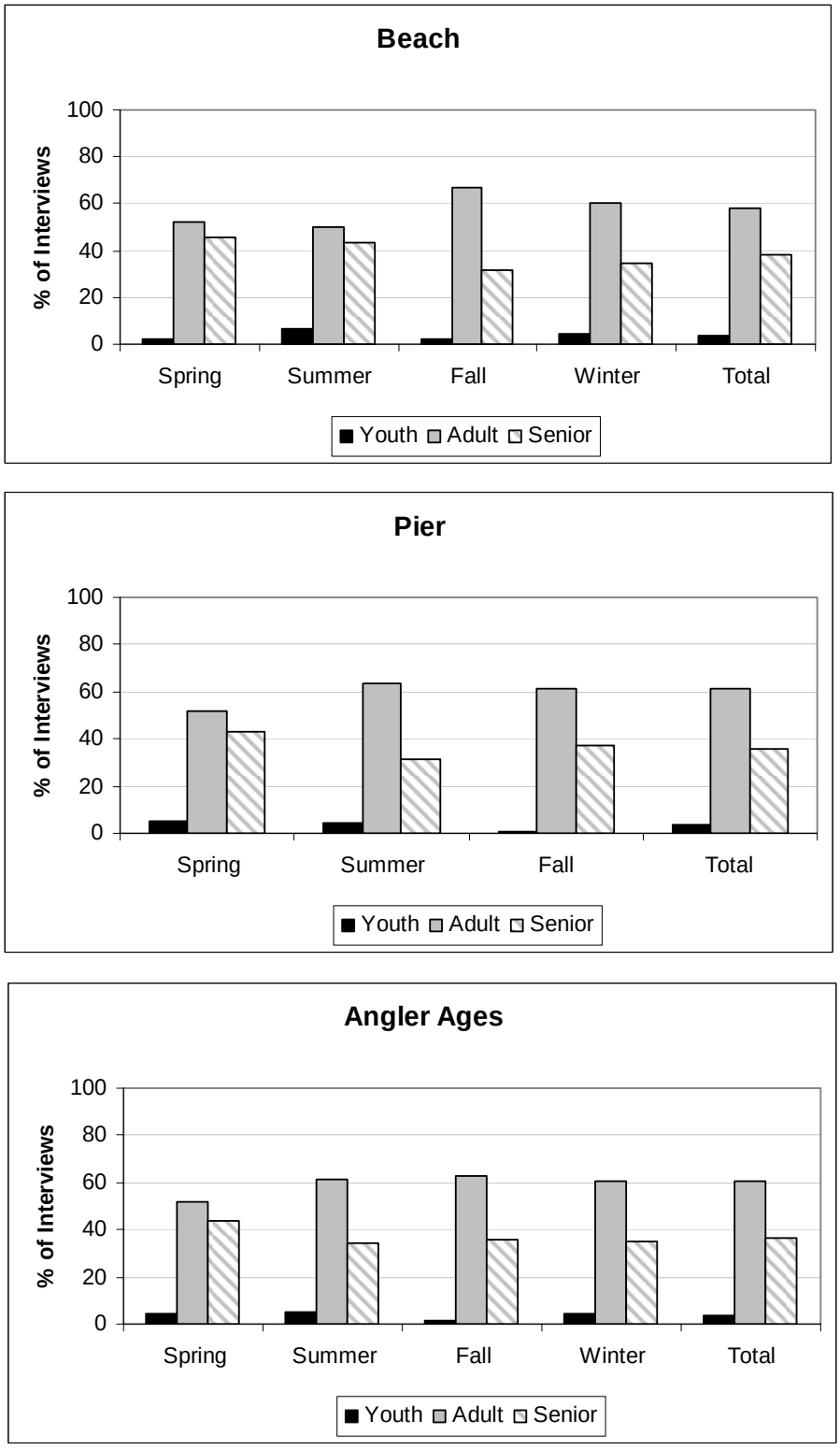


Figure 3-38. Ages of anglers interviewed during three years of angler interviews at the impact and reference beaches and piers in Dare County, NC

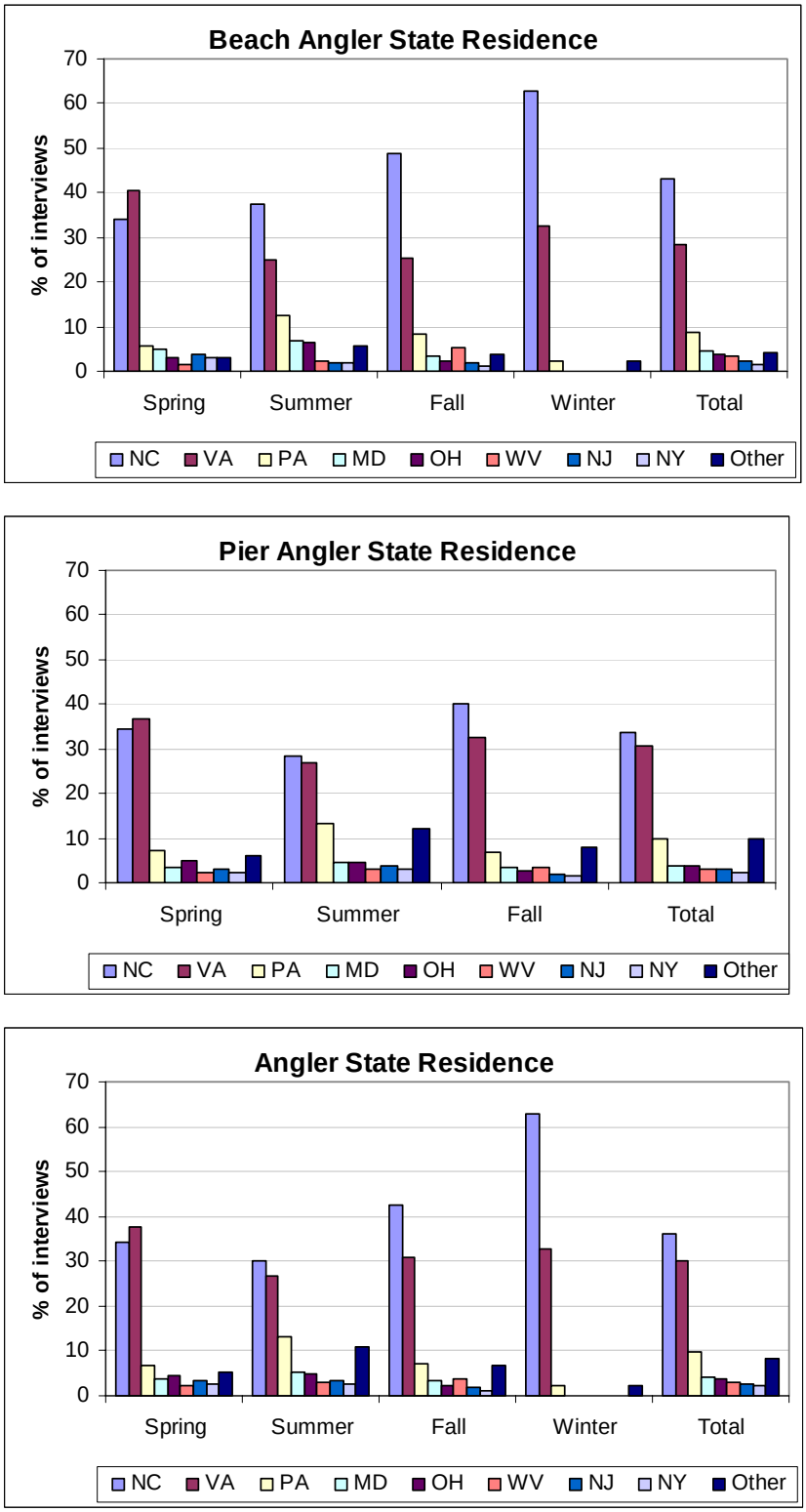


Figure 3-39. State residence of anglers interviewed during three years of angler interviews at the impact and reference beaches and piers in Dare County, NC

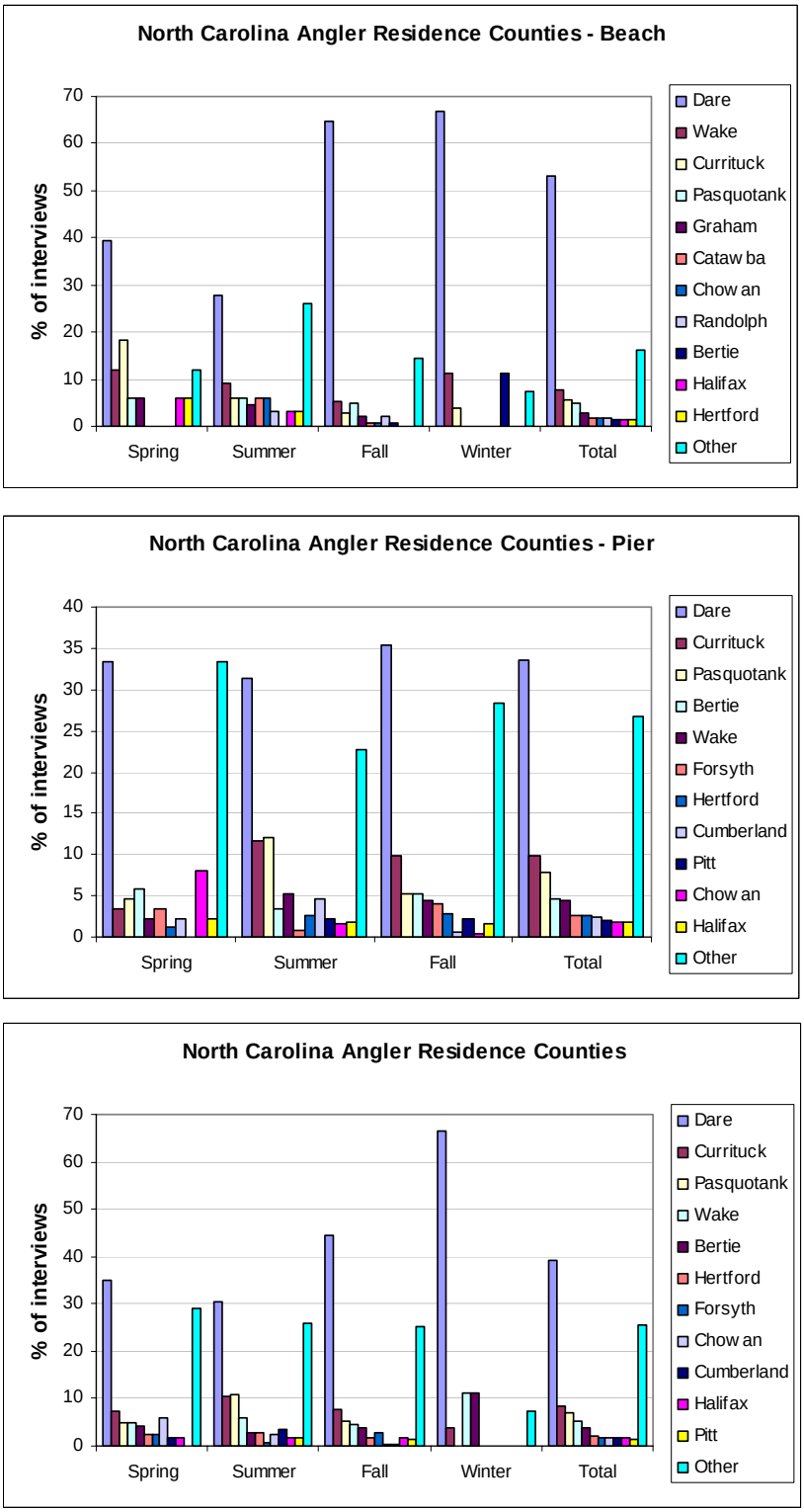


Figure 3-40. County of residence of North Carolina anglers interviewed during three years of angler interviews at the impact and reference beaches and piers in Dare County, NC

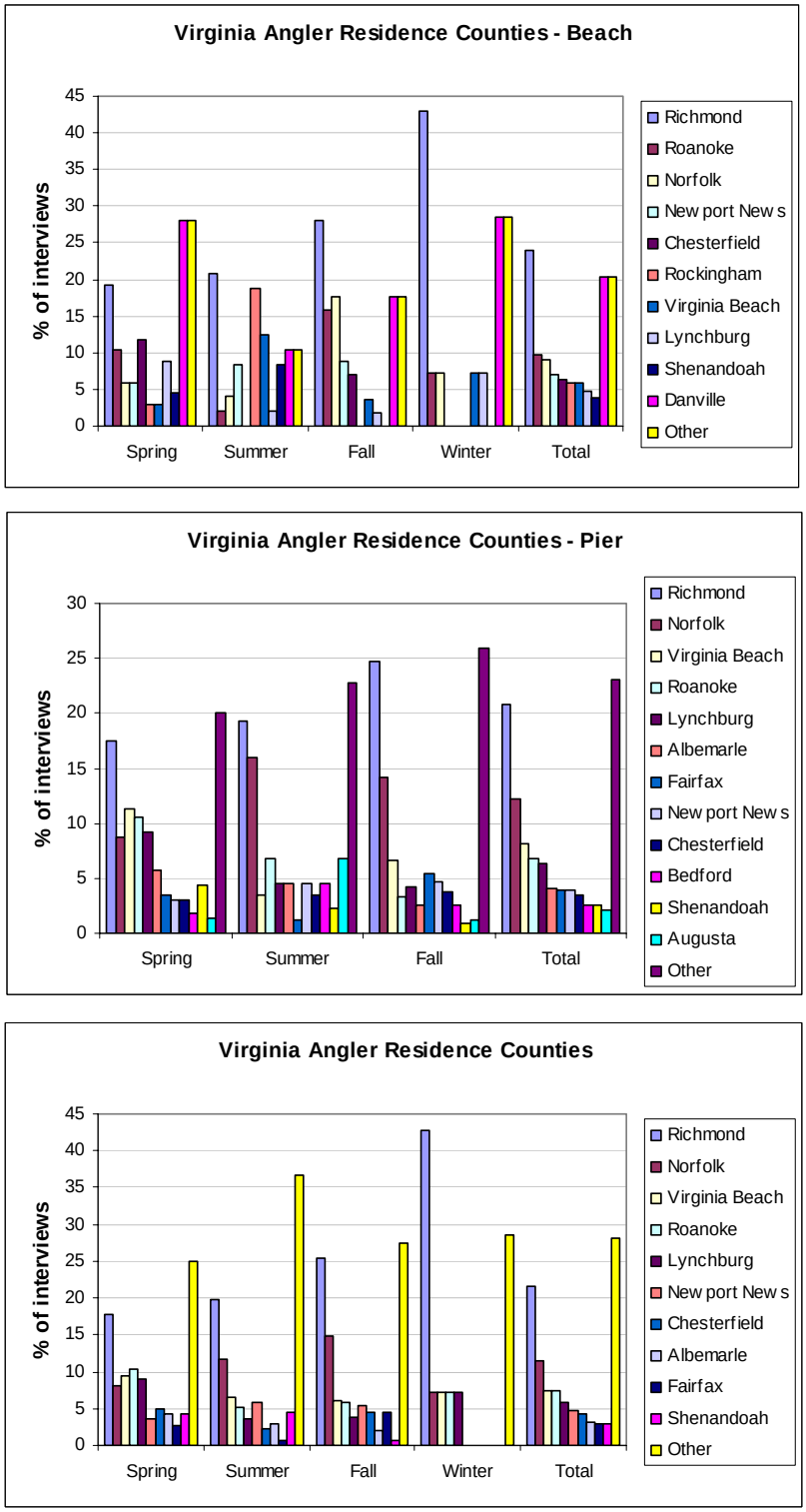


Figure 3-41. County of residence of Virginia anglers interviewed during three years of angler interviews at the impact and reference beaches and piers in Dare County, NC

Table 3-15. Summary of fish species and family groups documented in three years of 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
Serranidae	*Centropristis striata*	Black Seabass
Pomatomidae	*Pomatomus saltatrix*	Bluefish
Rachycentridae	*Rachycentron canadum*	Cobia
Myliobatidae	*Rhinoptera bonasus*	Cow-nosed Ray
Squalidae		Dogfish
Sciaenidae		Drum .
Pleuronectiidae		Flounder
Serranidae		Grouper
Clupiedae	*Alosa mediocris*	Hickory Shad
Scombridae	*Scomberomorus cavalla*	King Mackerel
Sciaenidae	*Menticirrhus*	Kingfish
Tetraodontidae	*Sphoeroides maculatus*	Northern Puffer
Batrachoididae	*Opsanus tau*	Oyster Toadfish
Haemulidae	*Orthopristis chrysoptera*	Pigfish
Sparidae	*Lagodon rhomboides*	Pinfish
Sciaenidae	*Sciaenops*	Pompano
Tetraodontidae	*Tetraodon*	Pufferfish
Rajidae		Rajidae
Sciaenidae	*Sciaenops ocellatus*	Red Drum
Sciaenidae	*Bairdiella chrysura*	Silver Perch
Sciaenidae	*Cynoscion*	Sea Trout
Triglidae	*Prionotus*	Searobin
Clupeidae	*Alosa*	Shad
Elasmobranchii		Shark
Sparidae	*Archosargus probatocephalus*	Sheepshead
Lutjanidae		Snapper
Scombridae	*Scomberomorus maculatus*	Spanish Mackerel
Squalidae	*Squalus acanthias*	Spiny Dogfish
Sciaenidae	*Leiostomus xanthurus*	Spot
Gadidae	*Urophycis regia*	Spotted Hake
Sciaenidae	*Cynoscion nebulosus*	Spotted Seatrout
Moronidae	*Morone saxatilis*	Striped Bass
Balistidae		Triggerfish
Sciaenidae	*Cynoscion regalis*	Weakfish

3.9 UNDERWATER VIDEO SURVEYS

Underwater video surveys were conducted at the ocean sites to document both physical and biological features residing at those sites. Much like the routine seasonal biological monitoring program, the video surveys will be used as a reference snap-shot of conditions to evaluate impacts and visual recovery of the borrow areas if and when dredging occurs. Video is the most comprehensive tool to document physical and related biological changes otherwise unaccounted for using traditional point benthic sampling or trawling methods. Over the course of the monitoring project two video surveys were conducted in different seasons to capture a spectrum of conditions. Because the timing of dredging is unknown, having a census of conditions from different seasons will ensure that recovery can be monitored over time with more than one useful reference point.

Each video survey is presented here as a stand-alone interpretation and no comparisons are done between surveys. This is primarily because each survey was conducted during different seasons and many of the biological features are expected to be different. However, it is should be pointed out that some of the differences in physical features documented between the surveys is likely attributed to variation in interpretation by the personnel analyzing the video clips. The 2004 survey was conducted using the VIMS benthic video sled and the video clips were analyzed by VIMS. The 2006 survey was conducted and analyzed at Versar without having any video reference information from the prior survey. Therefore, subtle differences, such as the difference between fine and Fine-medium sand, and the percent shell values were interpreted differently. This does not pose a significant problem; however, because each of the misinterpreted values between surveys remained consistent, i.e.,the values for each feature had the same percentage of occurrence within the site although its description was slightly different. To account for this in future surveys a reference catalog of feature values will be created. Another difference between surveys was that when biological organisms or biogenic structure was present in the video, but not quantifiable because of poor visibility, presence of the organism was still noted and presented (see Figs. 3-49 - 3-59).

2004 Video Survey

Features documented in the video footage show differences in the physical habitat and only slight differences in the biological counts between the N1/N2 borrow site 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 (Figs. 3-42 and 3-43). 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 (Fig. 3-44). Although there were differences between each of the 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 3-16).

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 (Figs. 3-46 and 3-47). Biogenic features (burrows, mounds and biological traces) were documented in nearly equal numbers at both sites (Fig. 3-45) and were distributed evenly throughout both sites (Fig. 3-47). Burrows were the most dominant biogenic feature (Fig. 3-45). Worm tubes and hermit crabs were also found in equal numbers at both sites and were the most dominant biological feature documented from video (Figs. 3-45 and 3-46). Other biology documented in the video were starfish, squid, sand dollar and sea anemone (Fig. 3-45).

Six fish species and one skate were also documented in equal numbers between the sites (Fig. 3-45). Fish were rare and patchy throughout both sites (Fig. 3-48). 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.

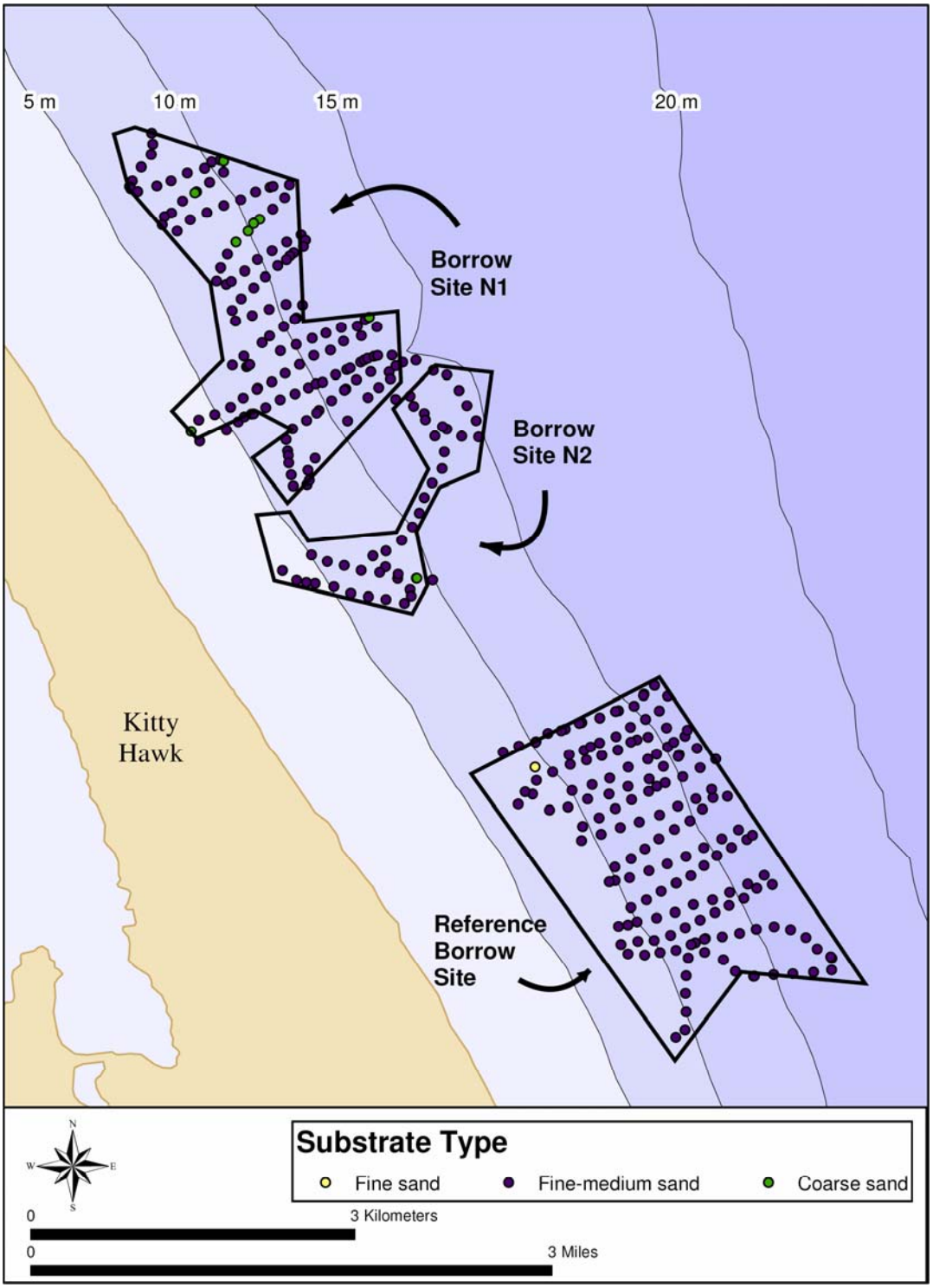


Figure 3-42. Distribution of substrate types observed in video images from the December 2004 underwater video survey conducted within the N1 and N2 borrow sites and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

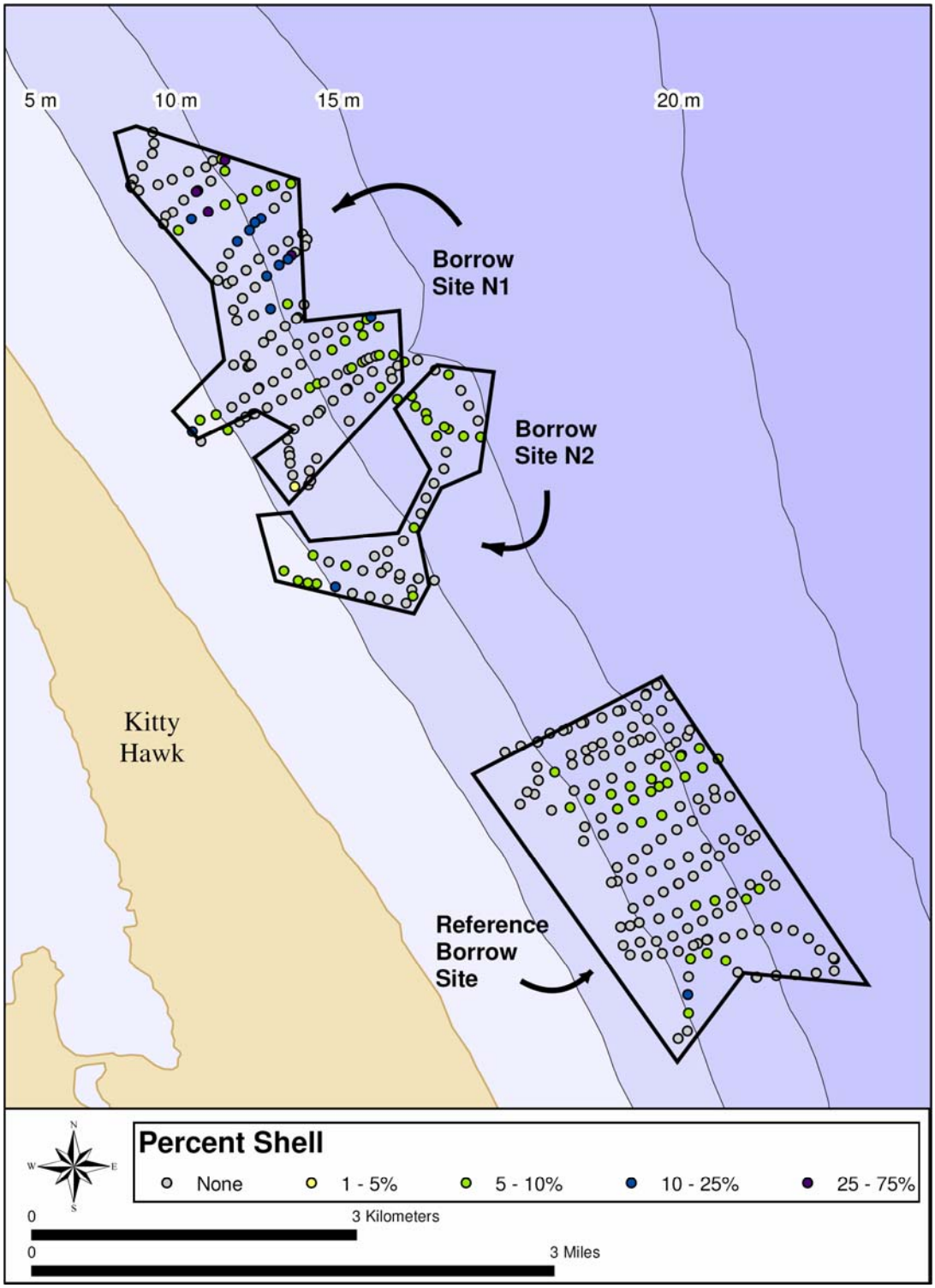


Figure 3-43. Distribution and coverage of shell observed in video images from the December 2004 underwater video survey conducted within the N1 and N2 borrow sites and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

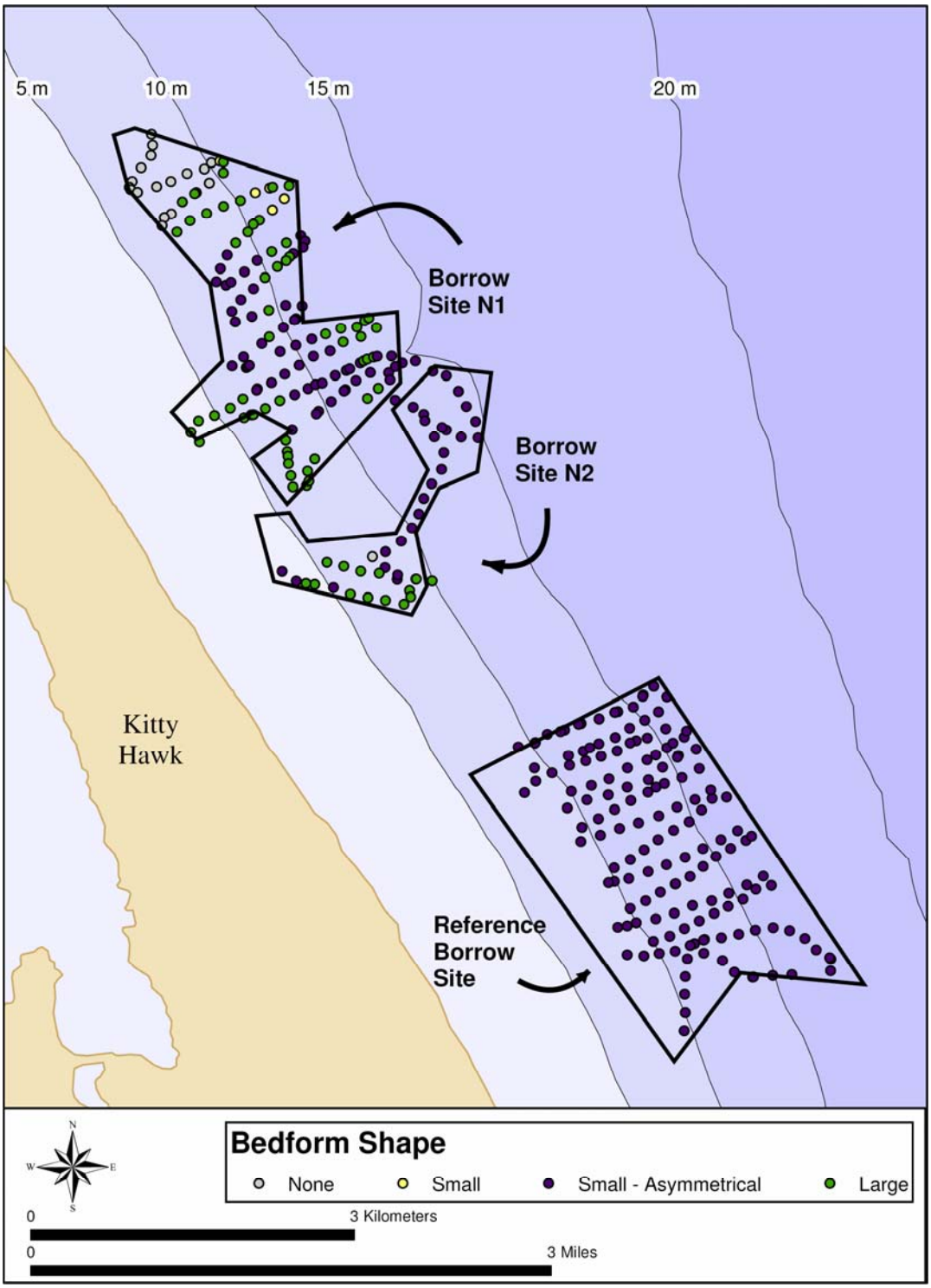


Figure 3-44. Distribution and shape of bedforms observed in video images from the December 2004 underwater video survey conducted within the N1 and N2 borrow sites and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

Table 3-16. Occurrence 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

Bed Form Size	Bed Form Shape	Grain Size	Shell Cover	Biogenic	Borrow		Reference	
					Total Occurrence	%	Total Occurrence	%
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**

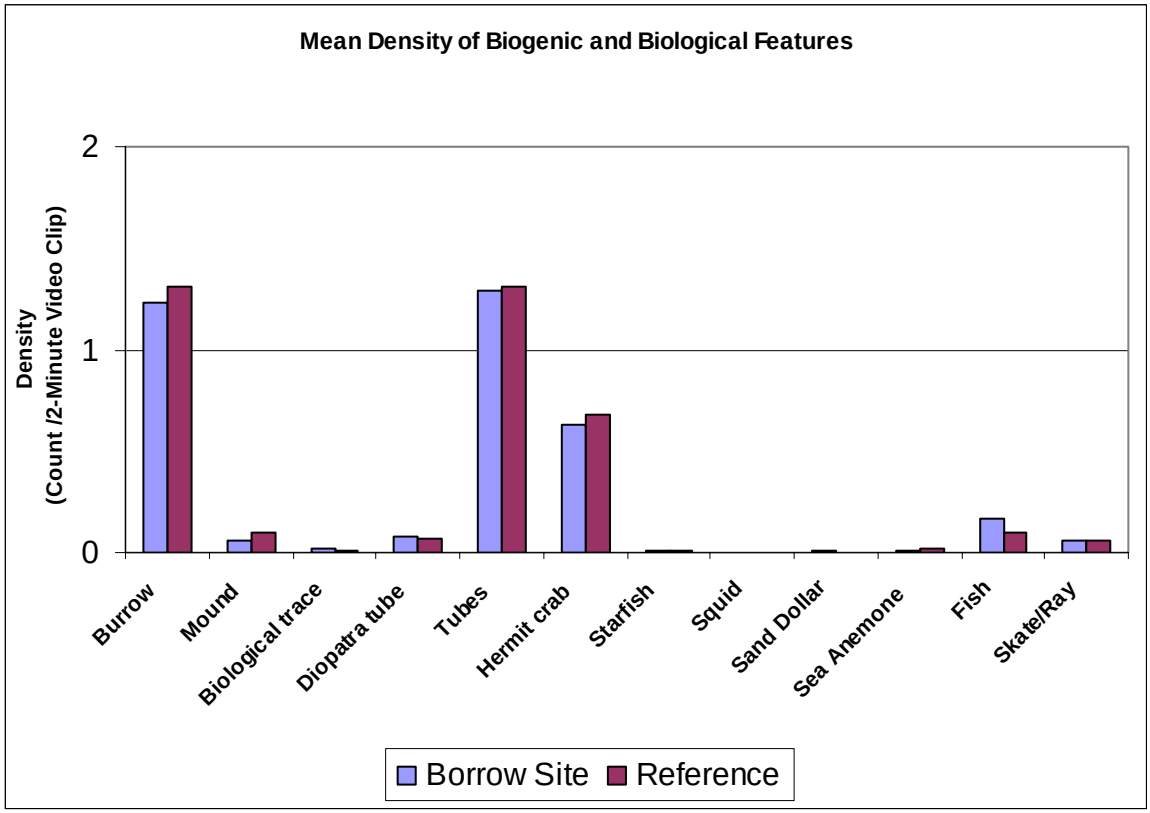


Figure 3-45. Mean count of biological features observed in video sled images taken within the Dare County borrow site and a nearby reference site in December 2004

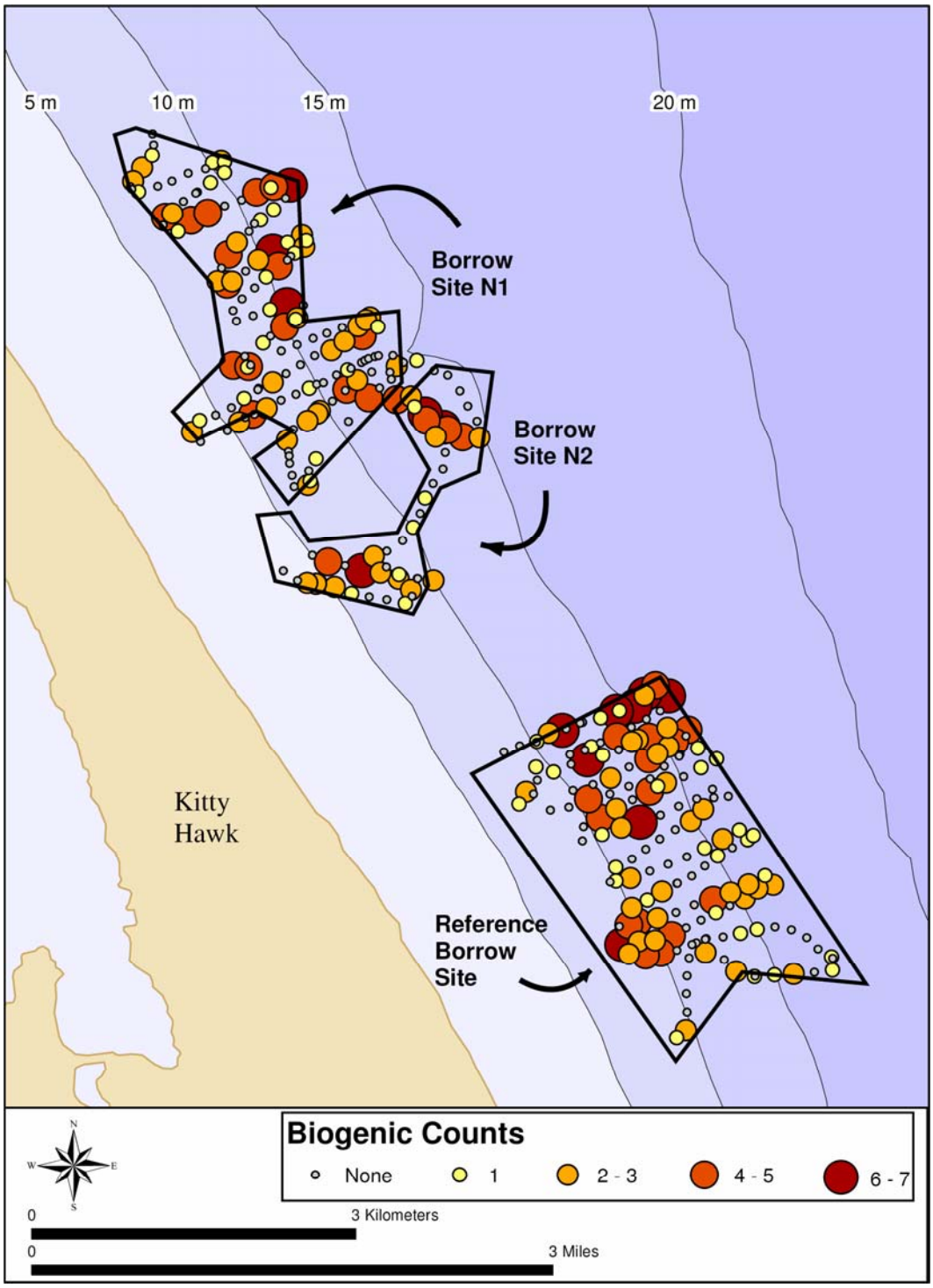


Figure 3-46. Distribution and quantity of all biogenic structure observed in video images from the December 2004 underwater video survey conducted within the N1 and N2 borrow sites and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

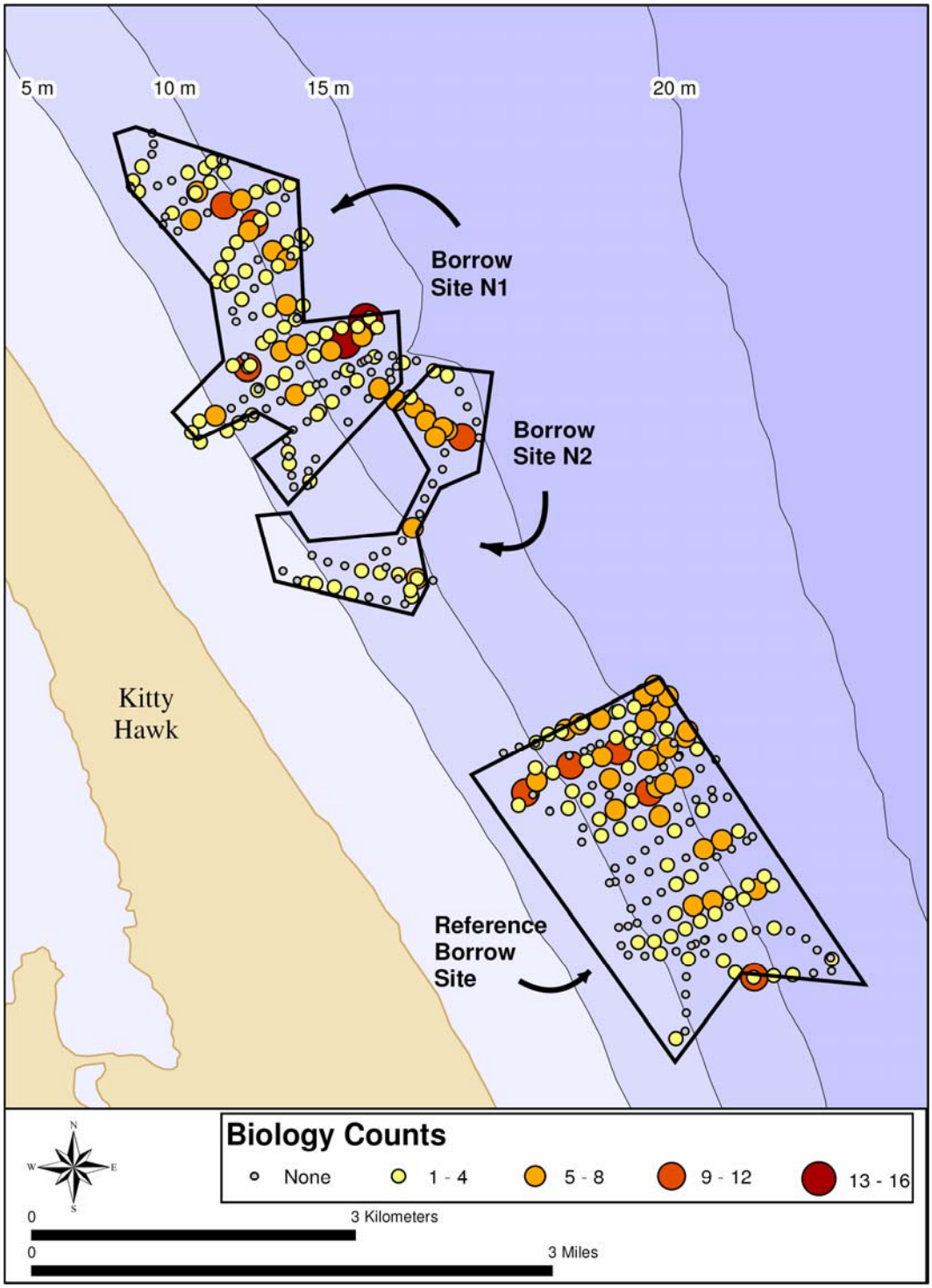


Figure 3-47. Distribution and quantity of surface biology observed in video images from the December 2004 underwater video survey conducted within the N1 and N2 borrow sites and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

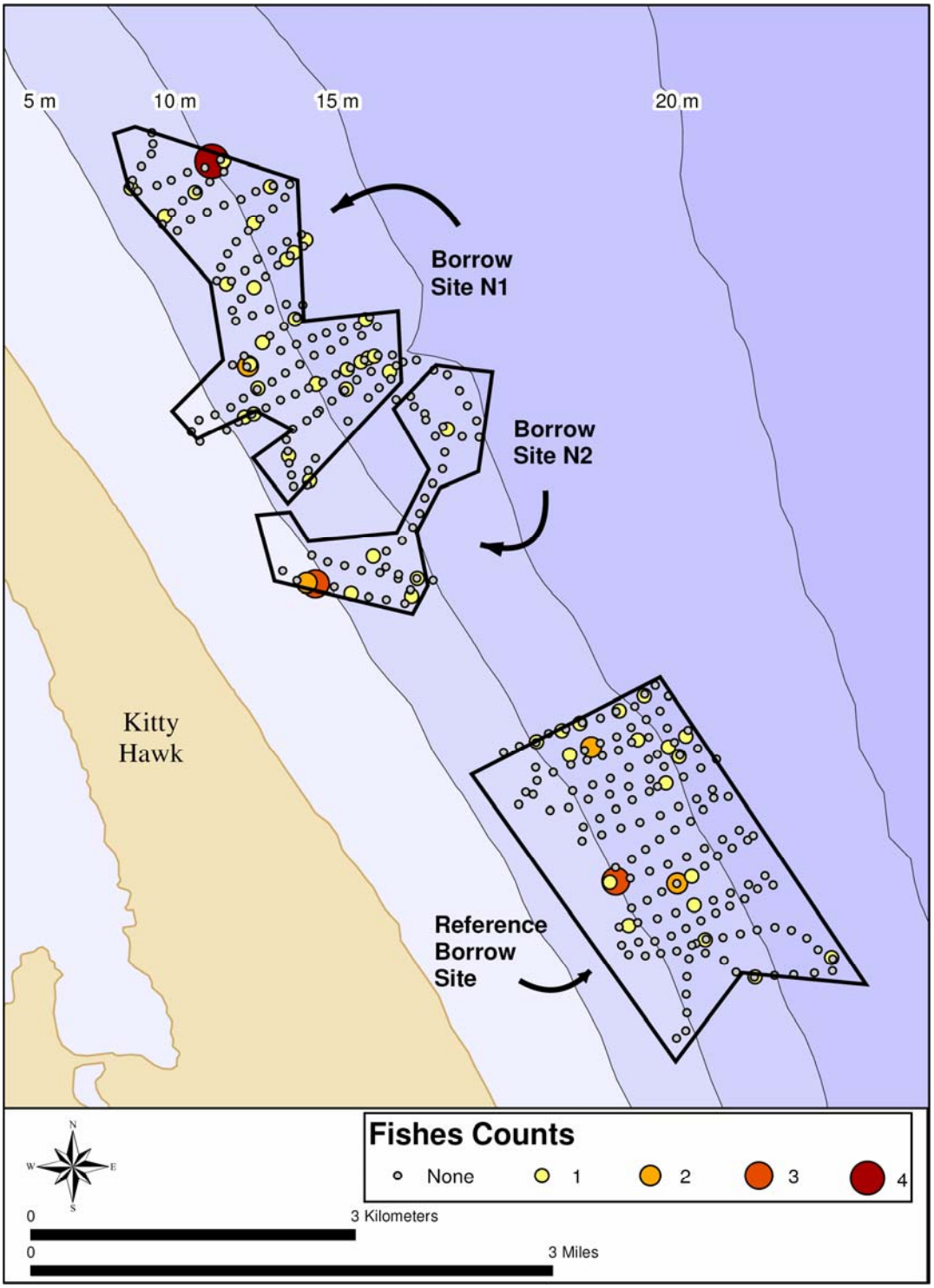


Figure 3-48. Distribution and quantity of fishes observed in video images from the December 2004 underwater video survey conducted within the N1 and N2 borrow sites and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

2006 Video Survey

In the 2006 survey, the N1/N2 borrow site and the reference site were composed of fine to medium sand substrate (Fig. 3- 49). The S1 site was composed of nearly all fine sands (Fig. 3-50). Small amounts of shell (1-5%) were also found at all the sites, but between 5 and 25% shell cover was documented in some areas at the N1 and N2 borrow (Fig. 3-51). Bottom shape at the reference site consisted of either no bedforms or small bedforms (Fig. 3-53). The N1 and N2 borrow site was more heterogeneous with portions of large and small bedforms generally corresponding to areas of shell throughout the site (Figs. 3-51 and 3-53). The S1 borrow site was nearly flat with very few areas of small bedforms (Fig. 3-54). 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 3-17).

Average counts of biogenic and biological features recorded on the video images at the N1/N2 borrow site and reference area were very similar suggesting nearly identical biological activity occurs within both areas (Fig. 3-55). Biogenic features (burrows, mounds and biological traces) were documented in nearly equal numbers at both the N1/N2 borrow site and the reference site (Fig. 3-55) and were present and evenly distributed throughout both sites (Fig. 3-56). The S1 site had lower biological traces compared to the other sites, but burrows were found in much higher numbers (Fig. 3-55). As with the other three sites biogenic features were distributed evenly throughout S1 (Fig. 3-57). Worm tubes were the most dominant biological feature documented from video at all sites (Fig. 3-55). Hermit crabs and starfish were also documented in limited numbers at all sites and moon snail eggs and tunicates dominated the biology at the S1 site (3-55). Biological features were found throughout all of the sites and were evenly distributed in similar densities (Fig. 3-58 and 3-59). Other biology documented in the video were horseshoe crabs and shrimp (Fig. 3-55).

Four fish species and one skate and several rays were also documented in equal numbers between the sites (Fig. 3-55). Fish were rare and patchy throughout both sites (Figs. 3-60 and 3-61). Northern sea robin, clearnose skate, and summer flounder were the most frequently encountered species at all sites, with spotted hake occurring in limited numbers.

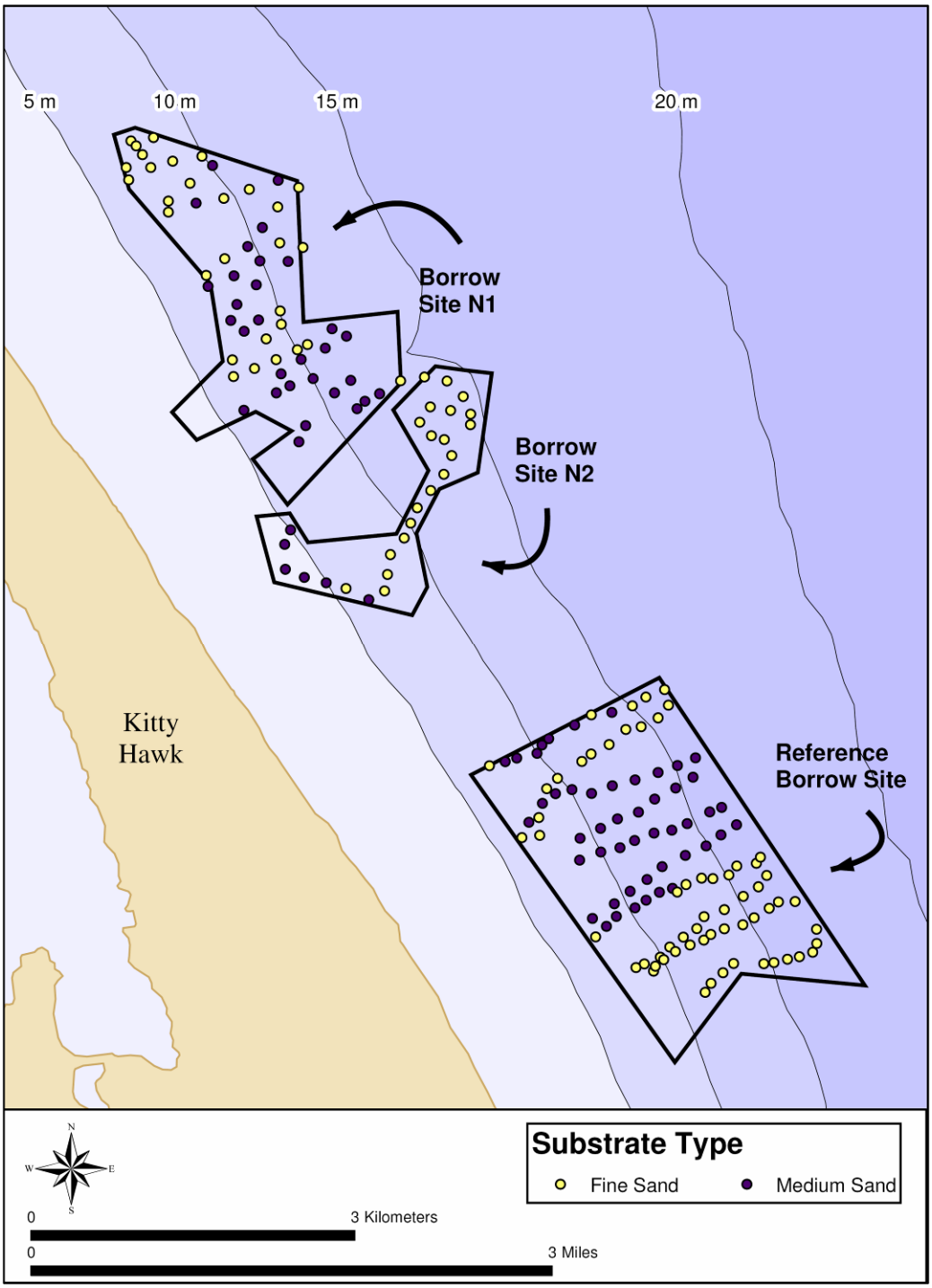


Figure 3-49. Distribution of substrate types observed in video images from the June 2006 underwater video survey conducted within the N1 and N2 borrow sites and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

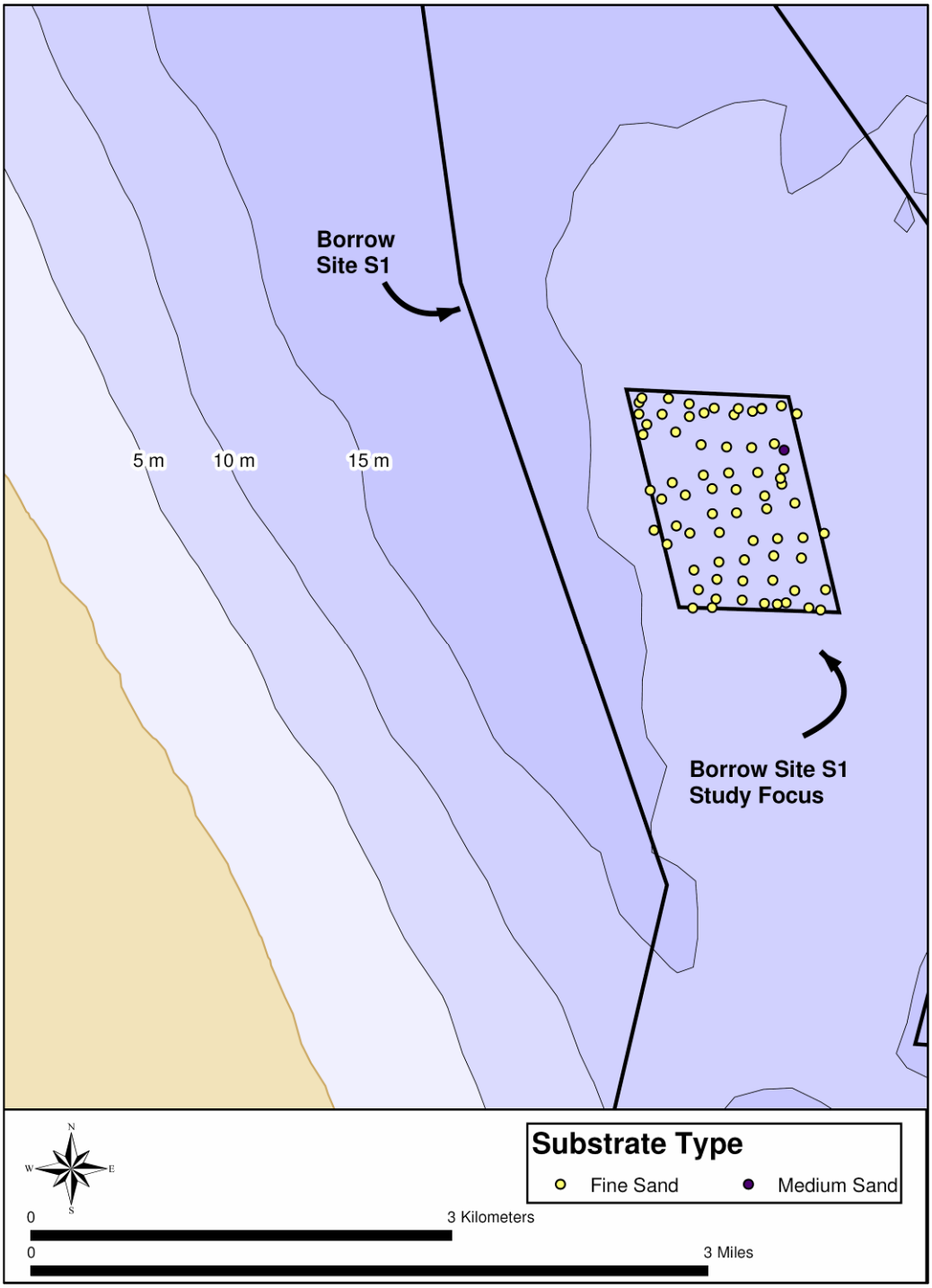


Figure 3-50. Distribution of substrate types observed in video images from the June 2006 underwater video survey conducted within the S1 borrow site located offshore of Nags Head in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

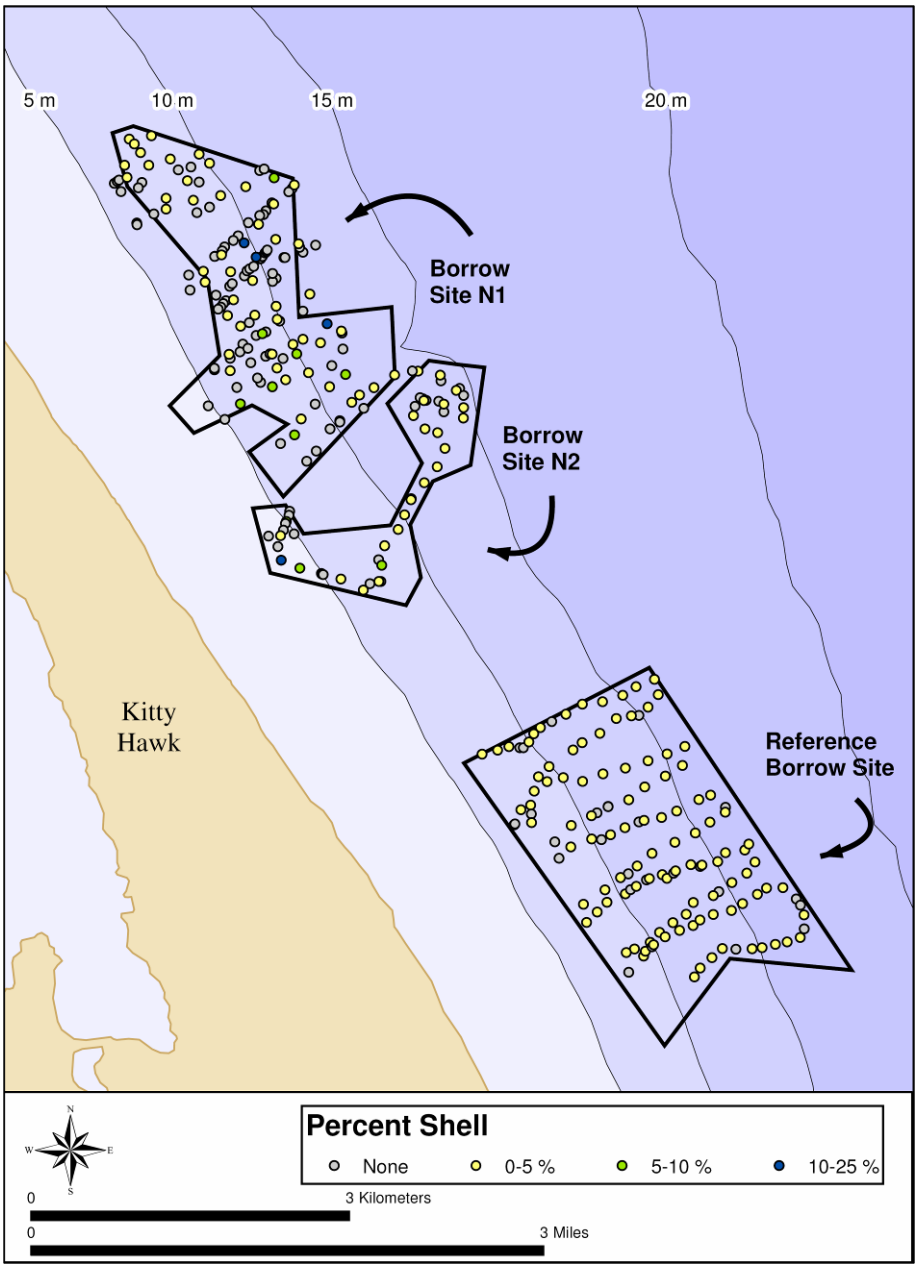


Figure 3-51. Distribution and coverage of shell observed in video images from the June 2006 underwater video survey conducted within the N1 and N2 borrow sites and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

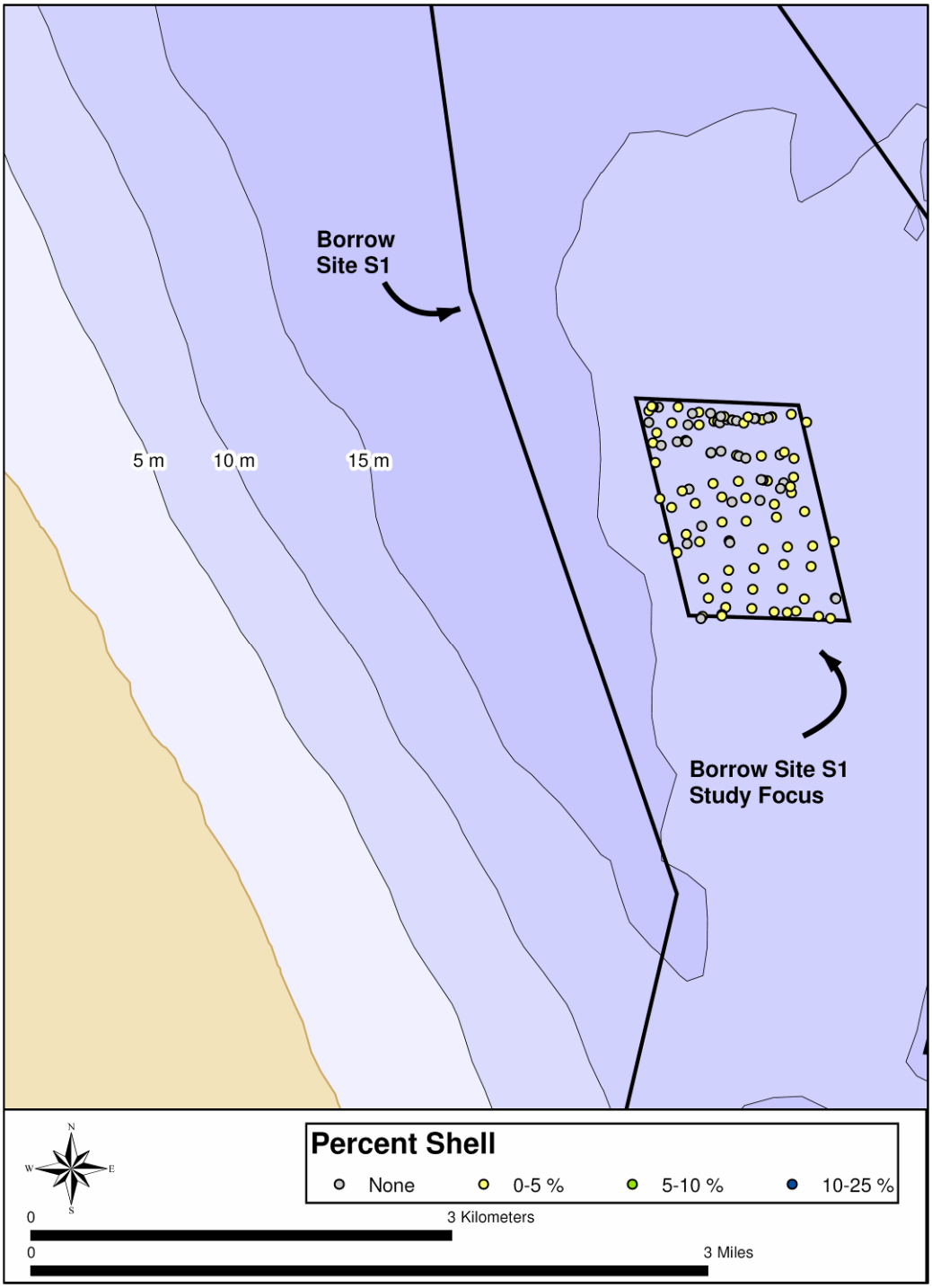


Figure 3-52. Distribution and coverage of shell observed in video images from the June 2006 underwater video survey conducted within the S1 borrow site located offshore of Nags Head in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

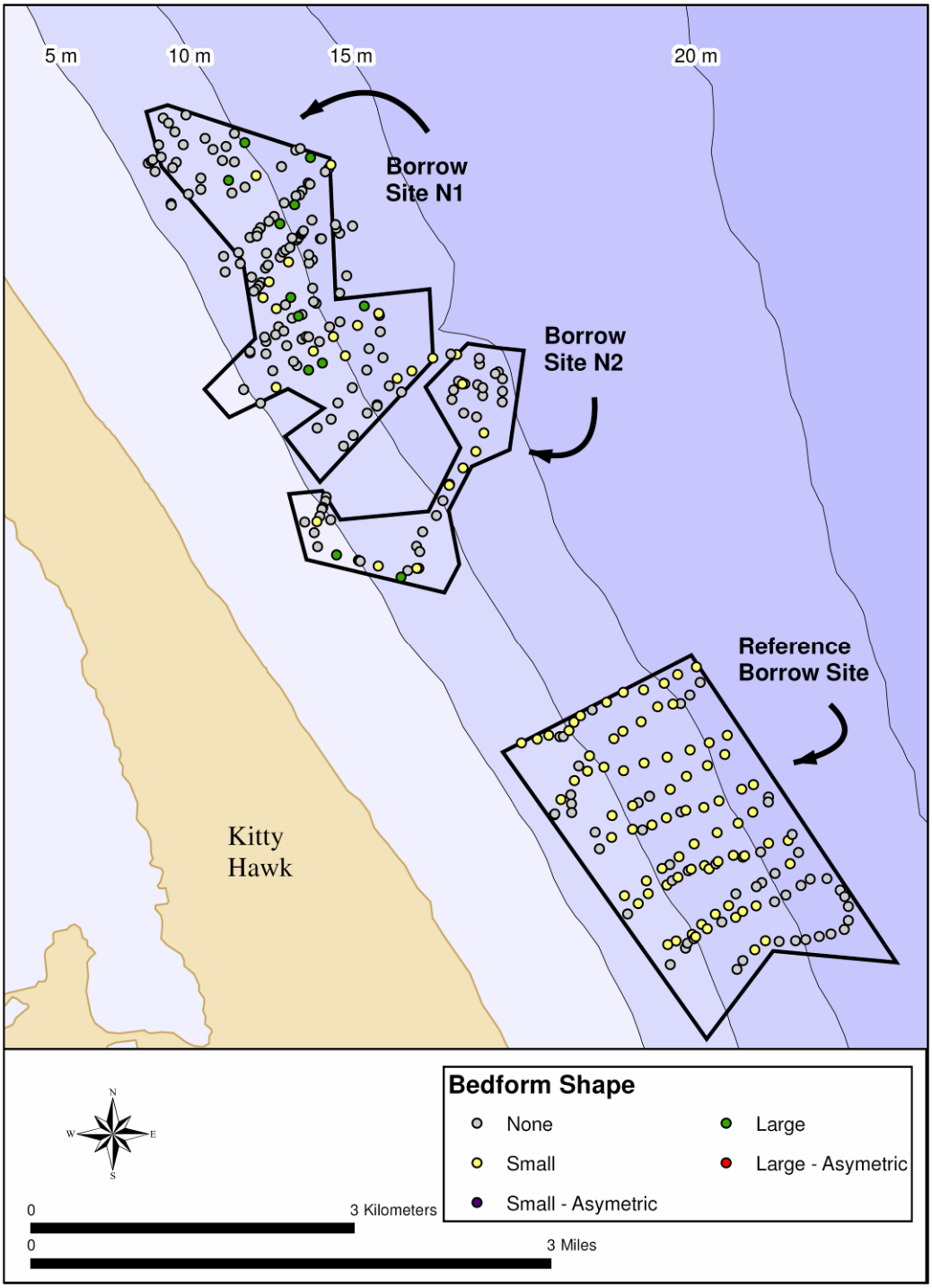


Figure 3-53. Distribution and shape of bedforms observed in video images from the June 2006 underwater video survey conducted within the N1 and N2 borrow sites and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

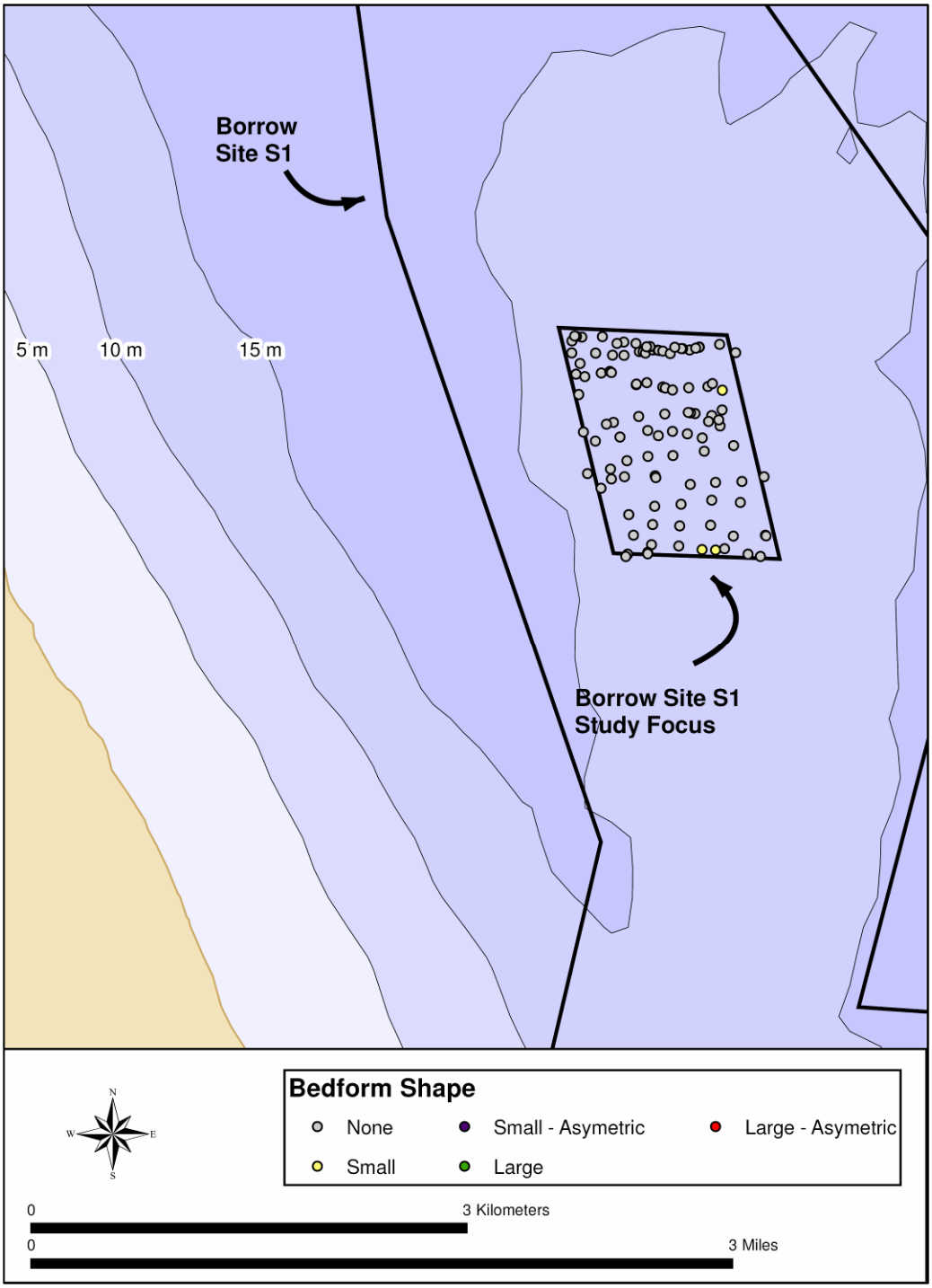


Figure 3-54. Distribution and shape of bedforms observed in video images from the June 2006 underwater video survey conducted within the S1 borrow site located offshore of Nags Head in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

Table 3-17. Occurrence of final habitat classifications observed between the Dare County borrow areas and the adjacent reference site observed during the June 2006 benthic video sled survey

					N Borrow Site		Reference		S Borrow Site	
Bed Form Size	**Bed Form Shape**	**Grain Size**	**Shell Cover**	**Biogenic**	**Total Occurrence**	**%**	**Total Occurrence**	**%**	**Total Occurrence**	**%**
Large-Asymetric	Sharp	Medium Sand	5-10 %	Biogenic	3	3.41	0	0.00	0	0.00
Large-Asymetric	Sharp	Medium Sand	0-5 %	Biogenic	1	1.14	0	0.00	0	0.00
Large-Asymetric	Smooth	Medium Sand	0-5 %	Biogenic	1	1.14	0	0.00	0	0.00
Large	Smooth	Medium Sand	0-5 %	Biogenic	4	4.55	0	0.00	0	0.00
Large	Smooth	Medium Sand	5-10 %	Biogenic	2	2.27	0	0.00	0	0.00
Large	Smooth	Fine Sand	5-10 %	Biogenic	1	1.14	0	0.00	0	0.00
Large	Smooth	Medium Sand	10-25 %	Biogenic	1	1.14	0	0.00	0	0.00
Large	Smooth	Medium Sand	10-25 %	Not Biogenic	1	1.14	0	0.00	0	0.00
Small-Asymetric	Sharp	Fine Sand	0-5 %	Biogenic	11	12.50	31	28.44	2	2.82
Small-Asymetric	Sharp	Medium Sand	0-5 %	Biogenic	11	12.50	45	41.28	0	0.00
Small-Asymetric	Sharp	Medium Sand	5-10 %	Biogenic	2	2.27	0	0.00	0	0.00
Small-Asymetric	Smooth	Medium Sand	0-5 %	Biogenic	0	0.00	0	0.00	1	1.41
Small-Asymetric	Sharp	Medium Sand	0-5 %	Not Biogenic	0	0.00	1	0.92	0	0.00
Small	Sharp	Medium Sand	0-5 %	Biogenic	0	0.00	1	0.92	0	0.00
None	None	Fine Sand	0-5 %	Biogenic	35	39.77	29	26.61	65	91.55
None	None	Medium Sand	0-5 %	Biogenic	5	5.68	1	0.92	0	0.00
None	None	Medium Sand	10-25 %	Biogenic	2	2.27	0	0.00	0	0.00
None	None	Medium Sand	5-10 %	Biogenic	2	2.27	0	0.00	0	0.00
None	None	Fine Sand	5-10 %	Biogenic	1	1.14	0	0.00	0	0.00
None	None	Fine Sand	None	Not Biogenic	1	1.14	1	0.92	0	0.00
None	None	Fine Sand	0-5 %	Not Biogenic	1	1.14	0	0.00	2	2.82
None	None	Medium Sand	0-5 %	Not Biogenic	1	1.14	0	0.00	0	0.00
None	None	None	None	Biogenic	1	1.14	0	0.00	0	0.00
None	None	None	0-5 %	Not Biogenic	1	1.14	0	0.00	0	0.00
None	None	None	0-5 %	Biogenic	0	0.00	0	0.00	1	1.41
Totals					**88**	**100**	**109**	**100**	**71**	**100**

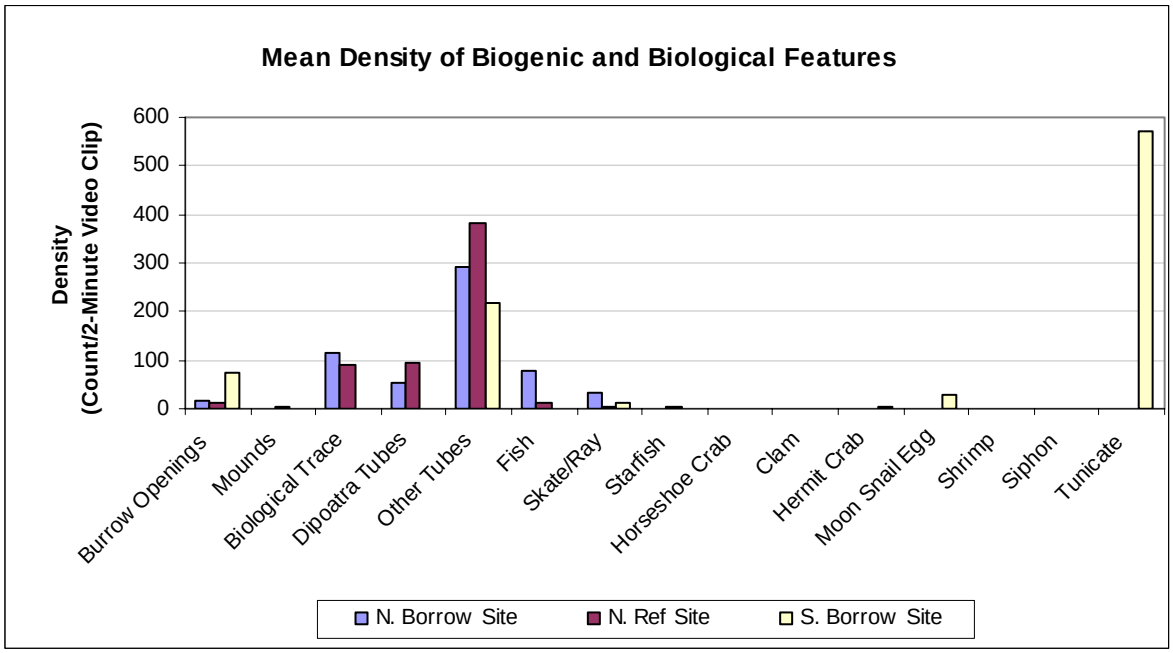


Figure 3-55. Mean count of biological features observed in video sled images taken within the Dare County borrow sites and the reference site during a survey in June 2006

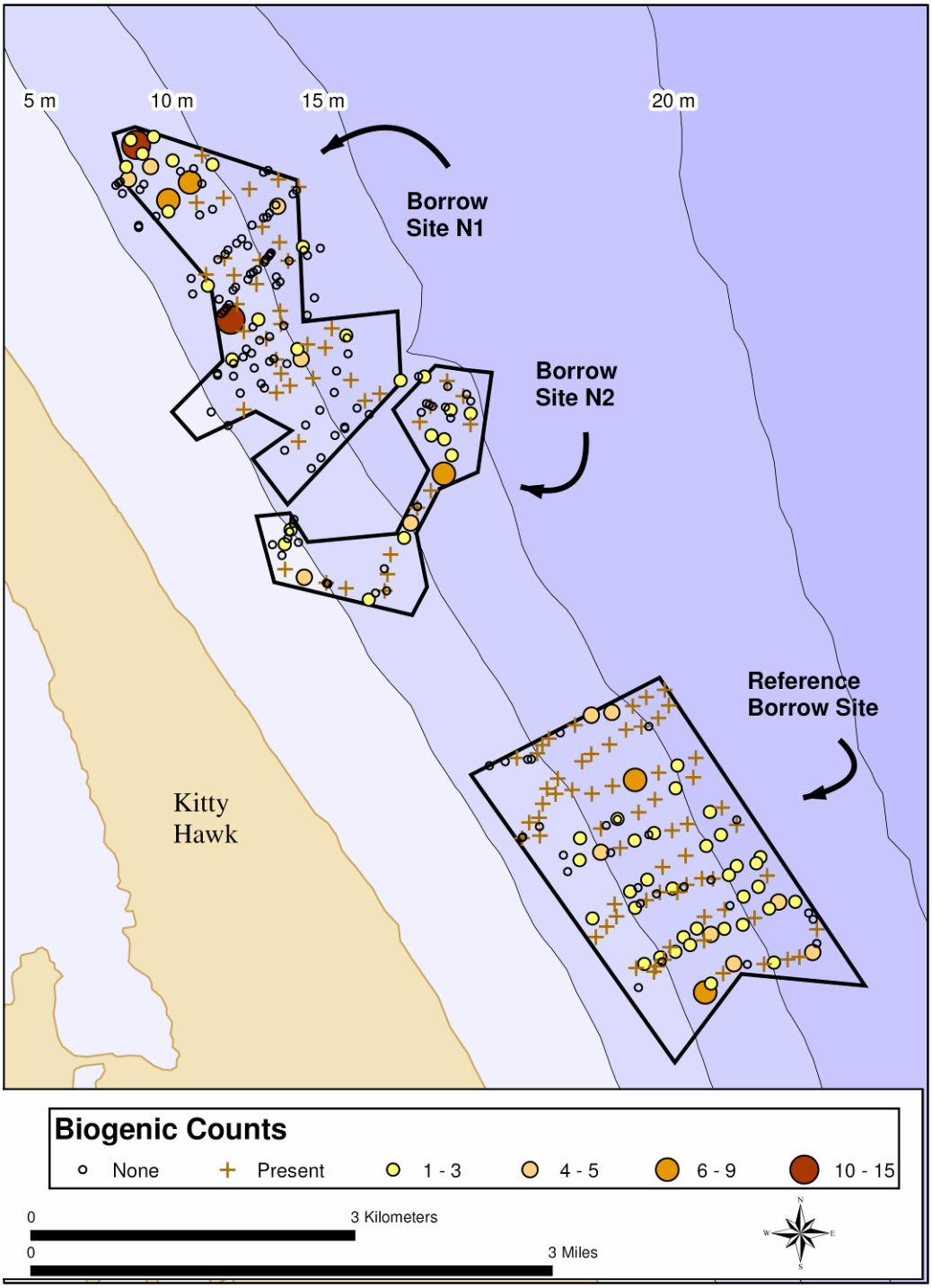


Figure 3-56. Distribution and quantity of all biogenic structure observed in video images from the June 2006 underwater video survey conducted within the N1 and N2 borrow sites and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

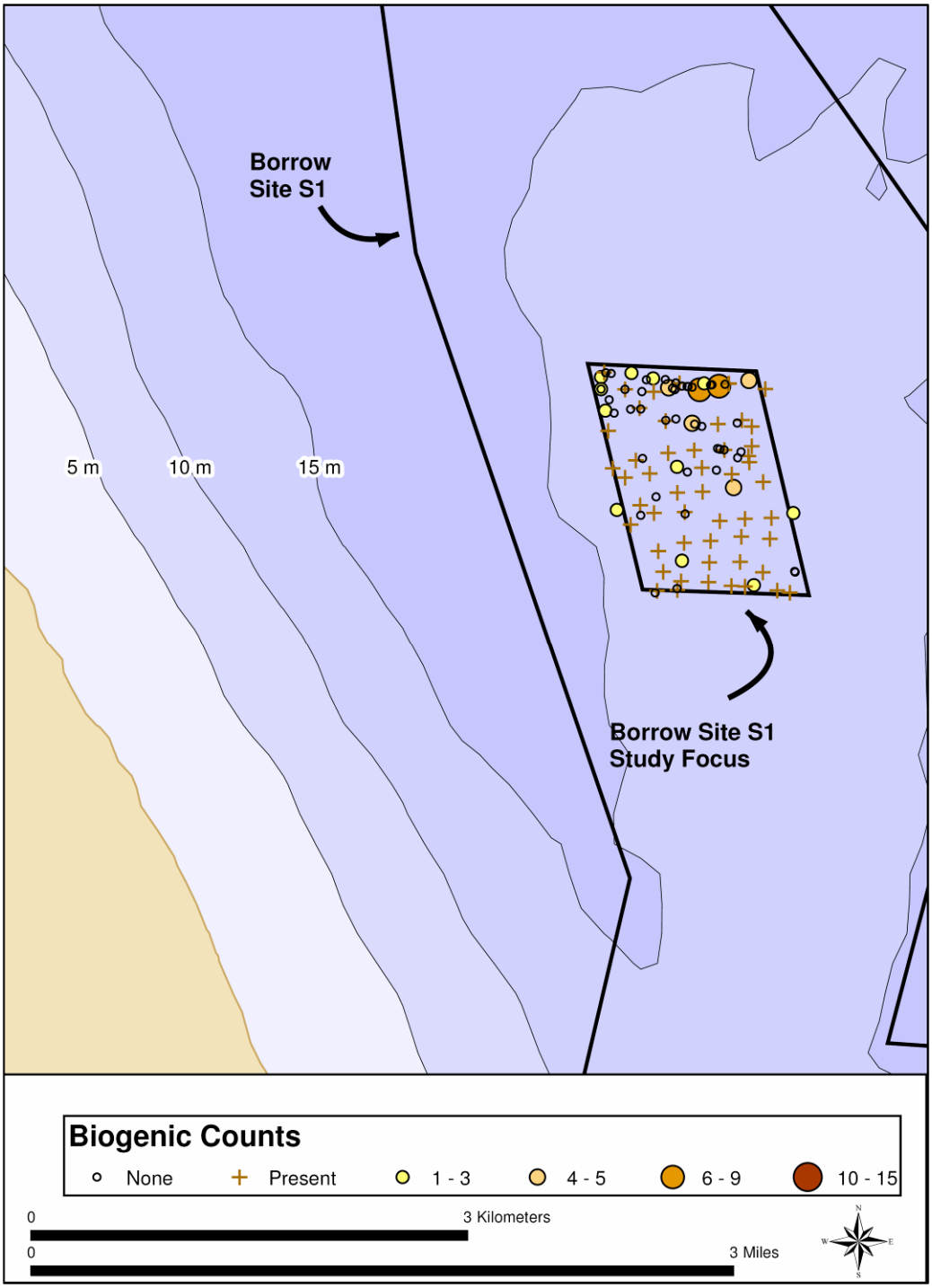


Figure 3-57. Distribution and quantity of all biogenic structure observed in video images from the June 2006 underwater video survey conducted within the S1 borrow site located offshore of Nags Head in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

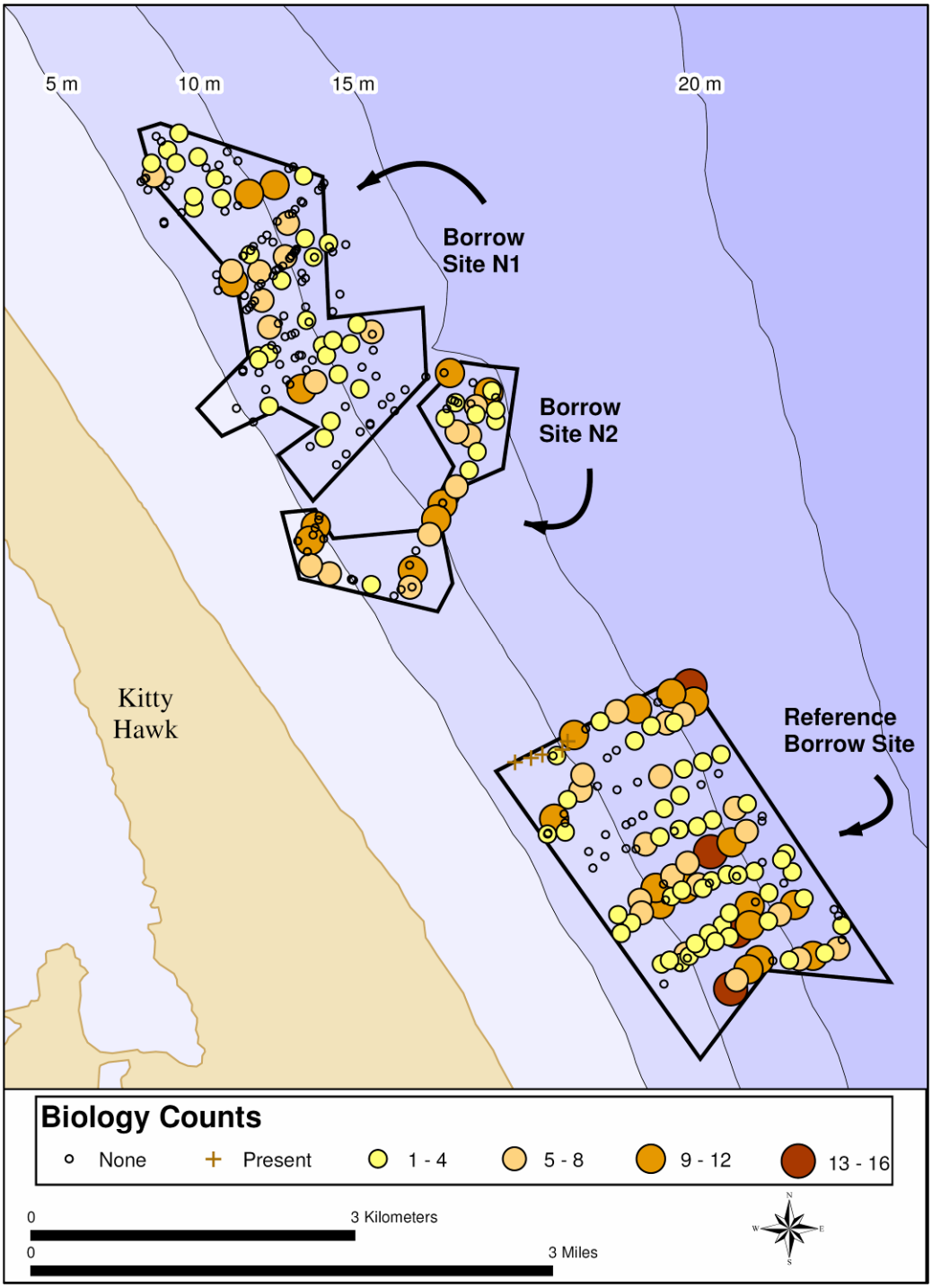


Figure 3-58. Distribution and quantity of surface biology observed in video images from the June 2006 underwater video survey conducted within the N1 and N2 borrow sites and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

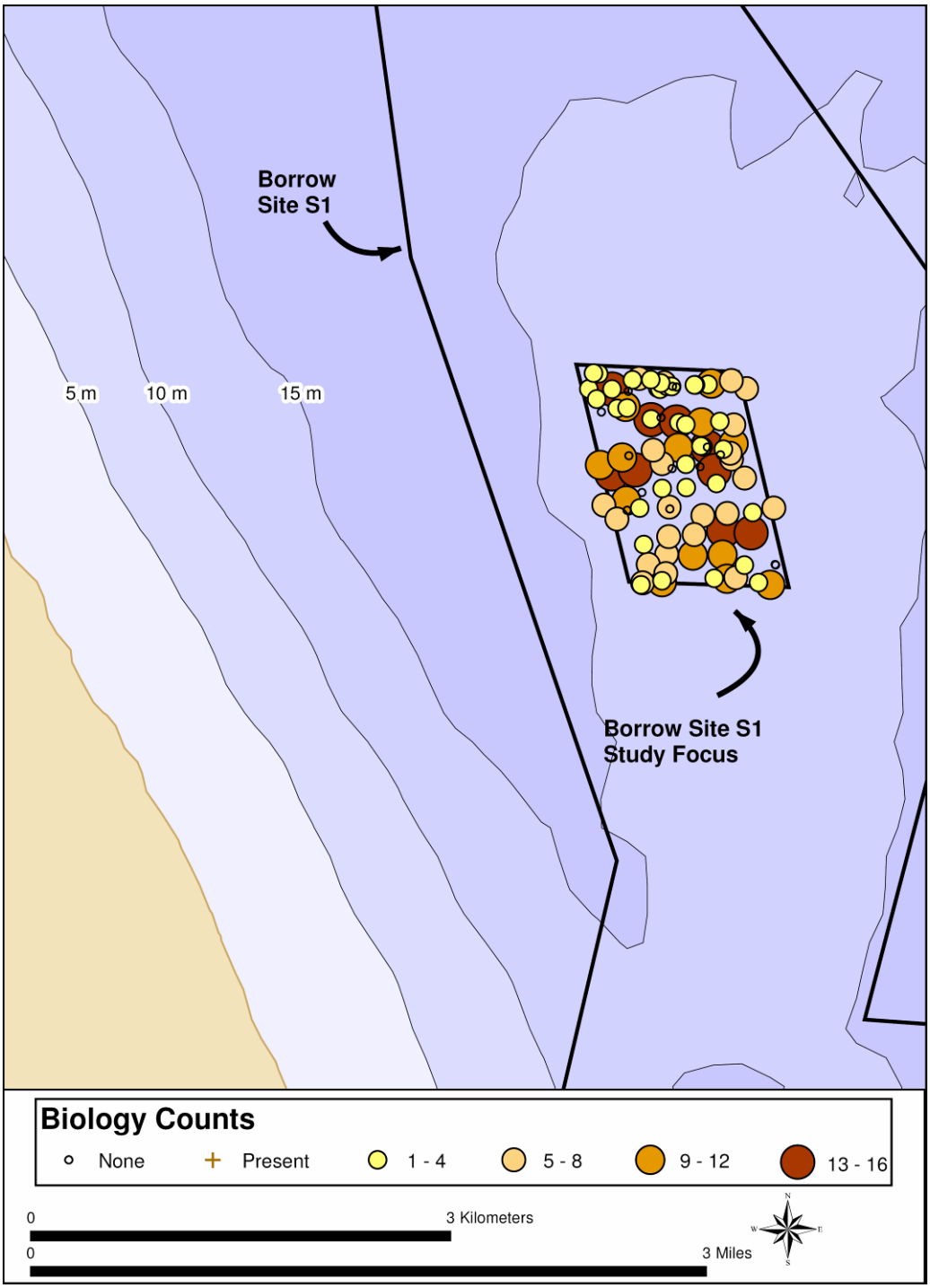


Figure 3-59. Distribution and quantity of surface biology observed in video images from the June 2006 underwater video survey conducted within the S1 borrow site located offshore of Nags Head in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

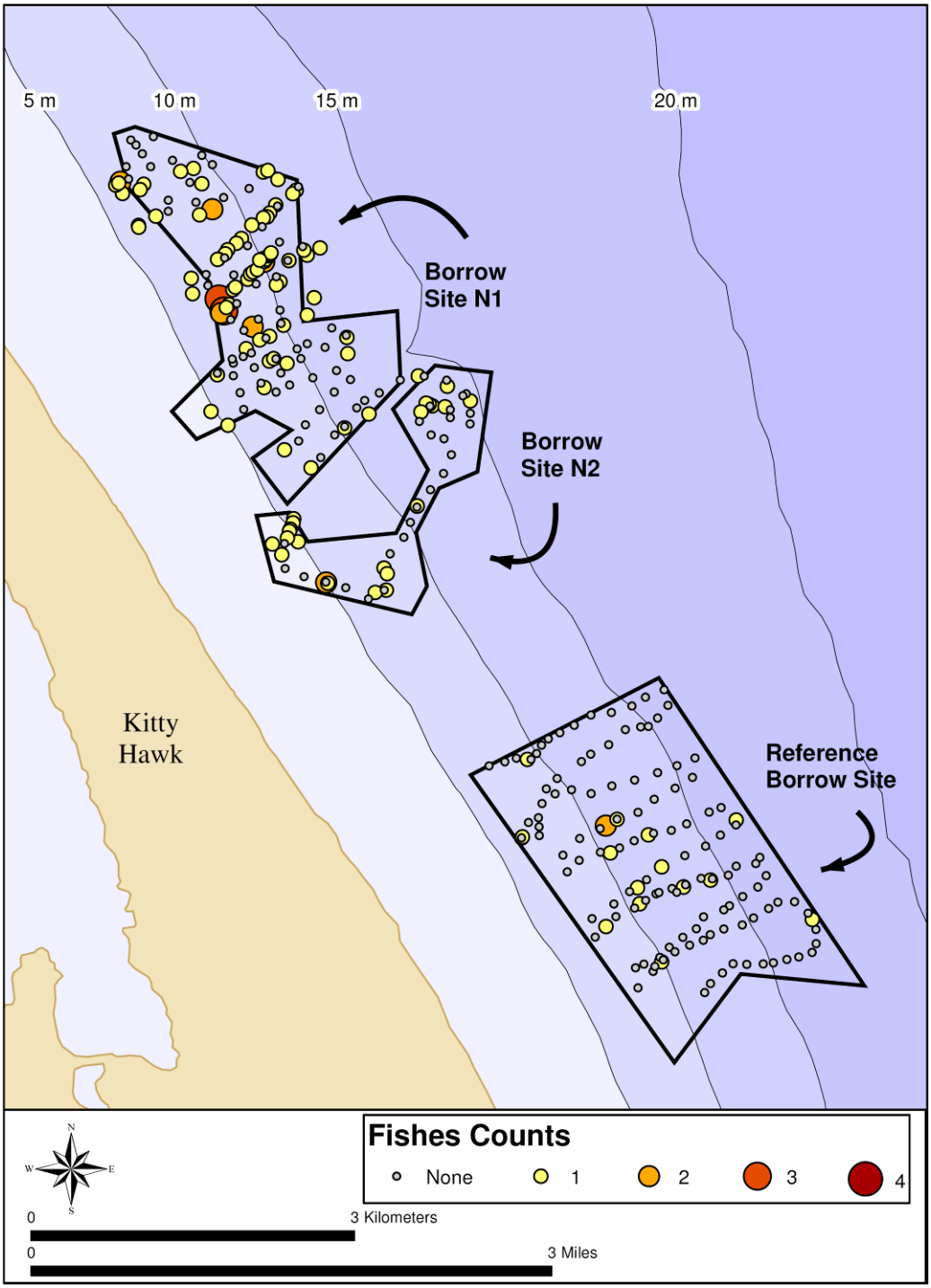


Figure 3-60. Distribution and quantity of fishes observed in video images from the June 2006 underwater video survey conducted within the N1 and N2 borrow sites and reference borrow site located offshore of Kitty Hawk in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

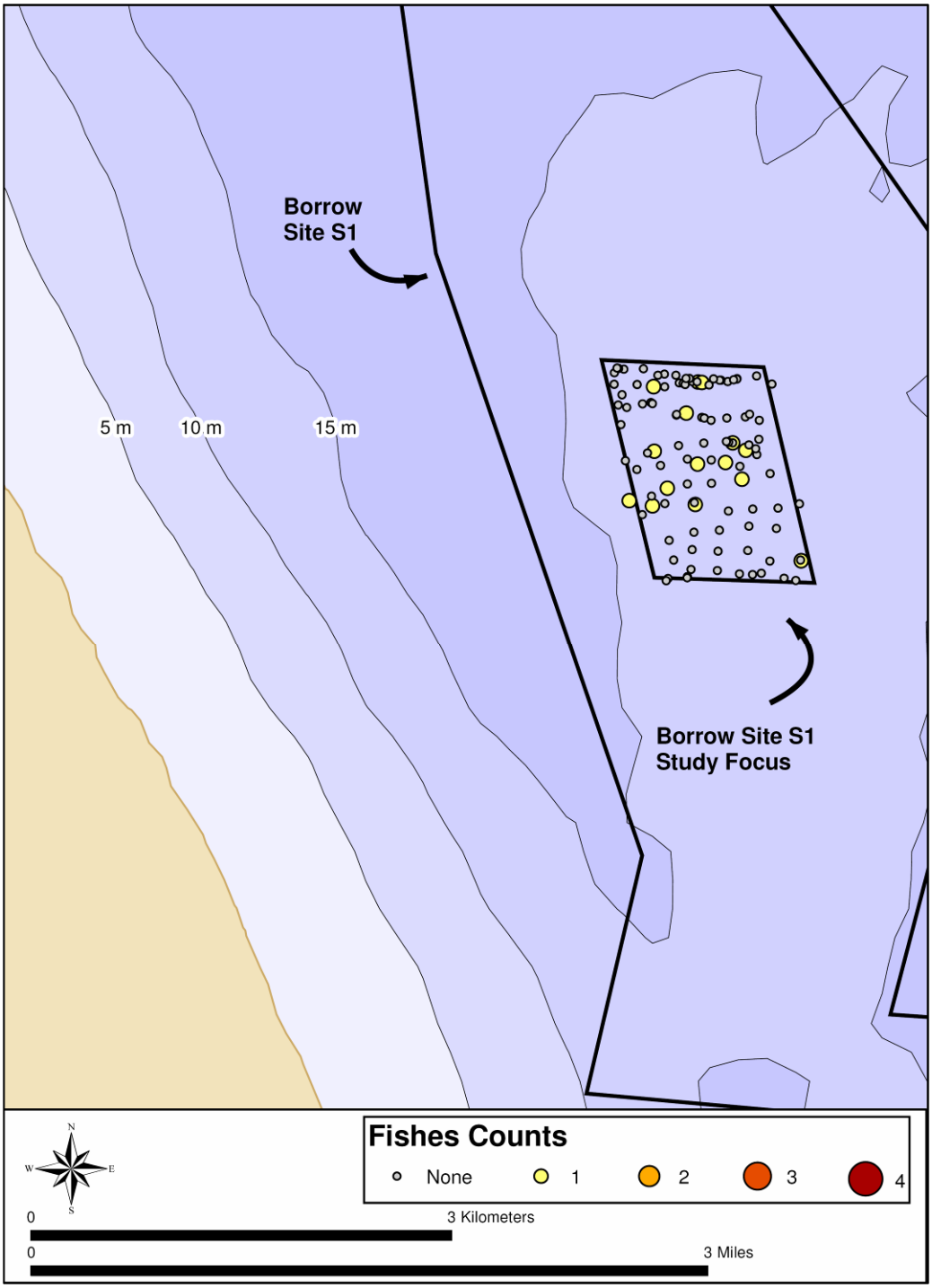


Figure 3-61. Distribution and quantity of fishes observed in video images from the June 2006 underwater video survey conducted within the S1 borrow site located offshore of Nags Head in Dare County, NC. Points represent locations of 2-minute video clips analyzed from the video.

4.0 DISCUSSION

This report has summarized the average seasonal baseline ecological conditions of several beach and ocean borrow sites scheduled for beach nourishment in the Northern Project area of Dare County, North Carolina. The data collected during the three years of monitoring (April 2004 - February 2007) included the abundance of fish, benthic, bird, and ghost crab communities at two beaches, and the fish and benthic communities at three offshore ocean sites. A roving creel survey was also conducted to monitor recreational fisherman activity at the beaches. Three years of data was collected to document seasonal and annual fluctuations occurring within the study sites, and these data will be used as baseline information to evaluate and monitor the potential physical and biological changes that may occur as a consequence of the beach nourishment process.

Three years of monitoring data indicates significant temporal and spatial scale fluctuations in many of the biological resources monitored on the beaches and at the ocean sites. The trends and variation of these resources monitored and presented as three year averages are similar to those documented in the first year report of the project (Slacum et al. 2006). However, some of the general trends presented in the first year report are slightly different than what is reported here. This is due to the extreme seasonality of many of the species collected in the study area. For example, at some of the sites, the overall three year average fish distribution and abundance is different between what was reported in Slacum et al. 2006 (see section 3.3) and what is reported here. In contrast, however, many of the seasonal trends identified from the first year report, such as benthic organisms, remained consistent throughout the three year monitoring project (see Section 3.2 Slacum et al. 2006 and section 3.2 this report). In addition to differences between years, there were also differences between many of the sites. 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 (Fig. 3-14), fish data (Figs. 3-19 and 3-21), and ghost crab data (Fig. 3-24). There were also differences in creel survey data between the beaches and piers (Fig. 3-36).

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 USACE Research Pier in Duck, NC. 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). Over the three years of monitoring, a total of 181 taxa were documented from both the N1/N2 and S1 borrow sites and the reference borrow site. 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 trends, densities of species, and species numbers were 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 (Figs. 3-14 and 3-17).

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 3-9). 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).

As reported in the first year report (Slacum et al. 2006), fish collections at the borrow sites indicate depauperate conditions. Aside from the spring surveys, very few fish or invertebrate species were collected over the three years of surveying at the borrow sites and borrow reference site (Fig. 3-21). Between the sites, the S1 borrow site exhibited the least amount of species (Table 3-10). The lack of catch at these sites could be attributed to the fact that we are using a large mesh trawl and that few large fish inhabit the sites. 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, Versar, Inc. 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 (Tables 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 throughout the monitoring project were representative of species commonly found on the Outer Banks (Fussell 1994). A total of 46 species of shore (N=10), waterbird (N=26), and other birds (N=10) were documented in this study (Table 3-13). This is similar to the results from a two year survey conducted by CZR (2003) on the beaches of Brunswick County, NC. In that study of shore and waterbird distribution, over 60 species were documented using the beaches. Many of the species that were common and abundant along the Brunswick County beaches 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 (Fig. 3-35). 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 (Fig. 3-39). Most of the fish species documented in the angler catches were also species collected in the seines (Figure 3-36 and Table 3-9). 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).

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