

2.3 QA/QC Benthic Sorting and Identification

Benthic samples were sorted and identification of taxa was completed by CZR; however, ten percent of samples were sent to an outside laboratory for re-sorting and re-identification (two control beach samples, two impact beach samples, and two borrow samples). These samples were selected upon completion of the majority of the sorting and identification effort to make best use of the QA/QC process. The selection methodology of which samples to send to the lab for QA/QC ensured that the benthic ecologist had no pre-knowledge of which samples would be selected.

Taxa identified only to genus were not counted when another taxon identified to species shared that genus. Similarly, a taxon identified to a family level or higher was not counted when taxa in that family or group were identified to a lower taxonomic level. Appendix A contains a complete list of taxa identified seasonally from control and impact stations on the beach and offshore.

2.4 Sediment Sampling

Following the same methodology as described above for benthic samples, a fourth core sample was taken at each beach station zone (40 cores) and a second core sample was taken at each offshore location (20 cores) for sediment analysis. These samples were labeled and sealed in plastic bags and analyzed for grain size and calcium carbonate content.

Sediments collected were analyzed in the CSE lab via standard dry-sieving at 0.5 phi intervals and the results provided to CZR Incorporated in a digital format. Appendix B contains graphic depictions of grain size distribution and other data from each sampling event

2.4.1 Percent Calcium Carbonate Substituted for Percent Organic

Subsequent to the April 2010 monitoring plan submittal and after the June 2010 sampling event, additional correspondence among CZR, CSE, and NCDCEM representatives (Anne Deaton of the Wilmington office and Jeff Warren of the Raleigh office) resulted in a decision to analyze the sediment for percent calcium carbonate by acid digestion for all events as opposed to percent organic content by combustion as specified in the draft plan. Analysis followed ASTM Method D2487 for classification of soils where sieve sizes range from 4.75 mm (US Standard sieve No. 4) to 63 μ m (US Standard sieve No. 230) and sediments were categorized by Wentworth's classification (Wentworth 1922).

3.0 RESULTS

For ease of future comparison some graphic depictions of benthic data were modeled after previous sampling efforts performed by Versar for the U.S. Army Corps of Engineers (Versar 2006). The "groups" classification used in the Versar reports is not a formal taxonomic classification; class, orders, subphyla, and other formal classifications are retained under the umbrella of "group" for this report as well as for Appendix A. Taxa richness, abundance, number of groups, and diversity indices were calculated. To evaluate the diversity and evenness of all species found, the Shannon Index of diversity was utilized. Values for this index typically range from 1.5 (low diversity) to 3.5 (high diversity).

Benthic quality control and quality assurance was performed by Cove Corporation (Lusby, MD). For all events combined the taxonomic and sorting error rate was under the widely accepted 10 percent error rate (4.8 and 6.3 percent respectively) followed by others and used by Versar.

3.1 Offshore Summary

During pre-impact sampling of the 20 offshore sample stations 71 taxa were identified from the 10 control stations and 75 taxa were identified from the 10 impact stations. Total taxa identified from the four pre-impact sample events were 99. The most abundant taxon collected offshore was *Ensis directus*, a razor clam, with 1,670 individuals identified from both impact and control stations. This taxon appeared in large numbers only during the spring sample event and was not abundant in any other sampling event. Other offshore taxa common across all sample events include sea squirts belonging to the class Ascidiacea, *Polygordius jouinae*, a polychaete worm, and juvenile bivalves (Figure 2). When all pre-impact sample events are combined the average number of taxa per station for all offshore stations was 18.6 and taxa richness averaged 5.6. Shannon diversity indices ranged from 0.83 at the impact/borrow stations during the spring event to 2.79 at the offshore control stations during the summer event (Table 1).

Grain size ranged from 0.31 mm to 0.76 mm with an average of 0.51 mm (coarse sand). When impact and control stations are combined the spring had the highest average grain size and the fall had the lowest. Percent calcium carbonate for all offshore stations ranged from 3.65 percent recorded from a control station during winter sampling to 0.71 percent from an impact station during spring sampling. The control sample stations during the fall season had the lowest average percent calcium carbonate, with 1.17 percent. The control sites during the winter sampling had the highest average percent calcium carbonate, with 2.3 percent.

3.1.1 Offshore Control

3.1.1.1 Offshore Control Benthos

The offshore pre-impact sampling events identified 71 taxa from the offshore control sample stations. Taxa with the highest abundance included juvenile *Bivalvia* sp. juv. (Mollusca) and *Ascidiacea* (Tunicata), with 398 and 401 individuals respectively (Figure 2). Taxa richness for each of the 10 control stations across events varied between one and 14 with an average of 5.87 taxa. A total of 15 groups and 1,459 individuals were identified over the four pre-impact sample events. When all events are combined the average number of taxa per station for the control offshore stations is 19.3, an indication of the seasonal variation. When taxa richness was evaluated for each sampling event separately the average richness per station was 5.88. When all sampling events were evaluated for diversity the Shannon diversity index value was 1.69.

The summer sampling event had the highest taxa richness with 33 taxa identified and also had the most number of groups present (12). Across all four events, slight fluctuation in group totals was noted. Abundance was highest during the fall event with 576 individuals, although spring contained nearly as many with a count of 568 individuals. The summer sampling event had the highest average number of species with 9.8 taxa.

Table 1. Summary information on seasonal pre-nourishment (baseline) beach invertebrate communities and substrate grain sizes at control and impact beach stations and offshore control and impact/borrow stations associated with the Town of Nags Head Beach Nourishment project.

	Spring*	Summer*	Fall*	Winter*	Combined across events
OFFSHORE CONTROL					
Taxa richness	30	33	27	15	71
Number of taxonomic groups	10	12	10	7	15
Abundance	568	223	576	92	1,459
Shannon index of diversity (<i>H'</i>)	1.09	2.79	1.45	2.39	1.69
Average number of species per station					
All control stations	5.8	9.8	5.5	2.4	19.3
Average grain size (mm)					
All control stations	0.60	0.58	0.48	0.53	0.55
Average percent calcium carbonate					
All control stations	1.8	1.9	1.2	2.3	1.7
OFFSHORE IMPACT/BORROW					
Taxa richness	25	29	23	22	75
Number of taxonomic groups	10	13	11	8	16
Abundance	2,288	219	315	149	2,971
Shannon index of diversity (<i>H'</i>)	0.83	2.69	0.94	2.20	2.44
Average number of species per station					
All borrow stations	5.6	7.9	4.3	3.2	17.3
Average grain size (mm)					
All borrow stations	0.50	0.49	0.47	0.45	0.55
Average percent calcium carbonate					
All control stations	1.2	1.5	1.3	1.9	1.5
BEACH CONTROL^a					
Taxa richness	18	22	10	10	26
Number of taxonomic groups	8	6	7	7	16
Abundance	733	598	80	104	1,515
Shannon index of diversity (<i>H'</i>)**					
Swash Zone A	1.69	1.10	1.36	1.23	1.92
Subtidal Zone B)	1.66	0.93	0.98	1.58	1.74
Average number of species per station					
All control stations	3.4	2.5	1.3	1.5	5.6
Swash Zone A	3.5	2.6	1.9	1.2	5.7
Subtidal Zone B	3.2	2.4	0.6	1.7	5.4
KH swash Zone A	3.5	2.2	1.8	0.6	2.0
KH subtidal Zone B	3.2	3.2	0.4	1.0	1.95
NSS swash Zone A	3.6	3.0	2.0	1.8	2.6
NSS subtidal Zone B	3.2	1.6	0.8	2.4	2.0
Average grain size (mm)					
All control stations	1.17	0.79	1.5	0.81	1.06
Swash Zone A	1.11	0.69	1.04	0.86	0.93
Subtidal Zone B	1.22	0.89	1.96	0.76	1.21
KH swash Zone A	1.76	1.06	1.49	1.16	1.37
KH subtidal Zone B	2.05	1.36	2.95	1.12	1.87
NSS swash Zone A	0.47	0.32	0.59	0.57	0.49
NSS subtidal Zone B	0.38	0.42	0.97	0.39	0.54
Average percent calcium carbonate					
All control stations	3.3	3.2	4.9	3.8	3.8
Swash Zone A	3.5	2.5	4.6	4.5	3.8
Subtidal Zone B	3.1	3.8	5.1	3.1	3.8
KH swash Zone A	3.8	2.8	4.2	3.1	3.5
KH subtidal Zone B	3.9	5.0	2.6	3.2	3.7
NSS swash Zone A	3.3	2.2	5.0	5.9	4.1
NSS subtidal Zone B	2.1	2.7	7.6	3.0	3.9
BEACH IMPACT^b					
Taxa richness	20	20	8	9	27
Number of taxonomic groups	7	6	6	6	11
Abundance	215	255	51	109	630
Shannon index of diversity (<i>H'</i>)					
NHB Swash Zone A	1.93	1.12	1.21	1.22	
NHB Subtidal Zone B	1.93	0.81	0.95	1.00	1.92
Average number of species per station					
All impact stations	4.1	2.5	1.2	1.3	6.1
NHB Swash Zone A	3.8	2.9	1.2	1.2	
NHB Subtidal Zone B	4.4	2.1	1.2	1.3	6.8
Average grain size (mm)					
NHB Swash Zone A	0.84	1.04	0.76	0.70	0.83
NHB Subtidal Zone B	0.62	0.67	1.02	0.66	0.74
Average percent calcium carbonate					
NHB Swash Zone A	3.5	3.6	4.1	3.5	3.7
NHB Subtidal Zone B	2.7	3.1	3.3	4.0	3.3

^a Control beaches: KH=Kitty Hawk

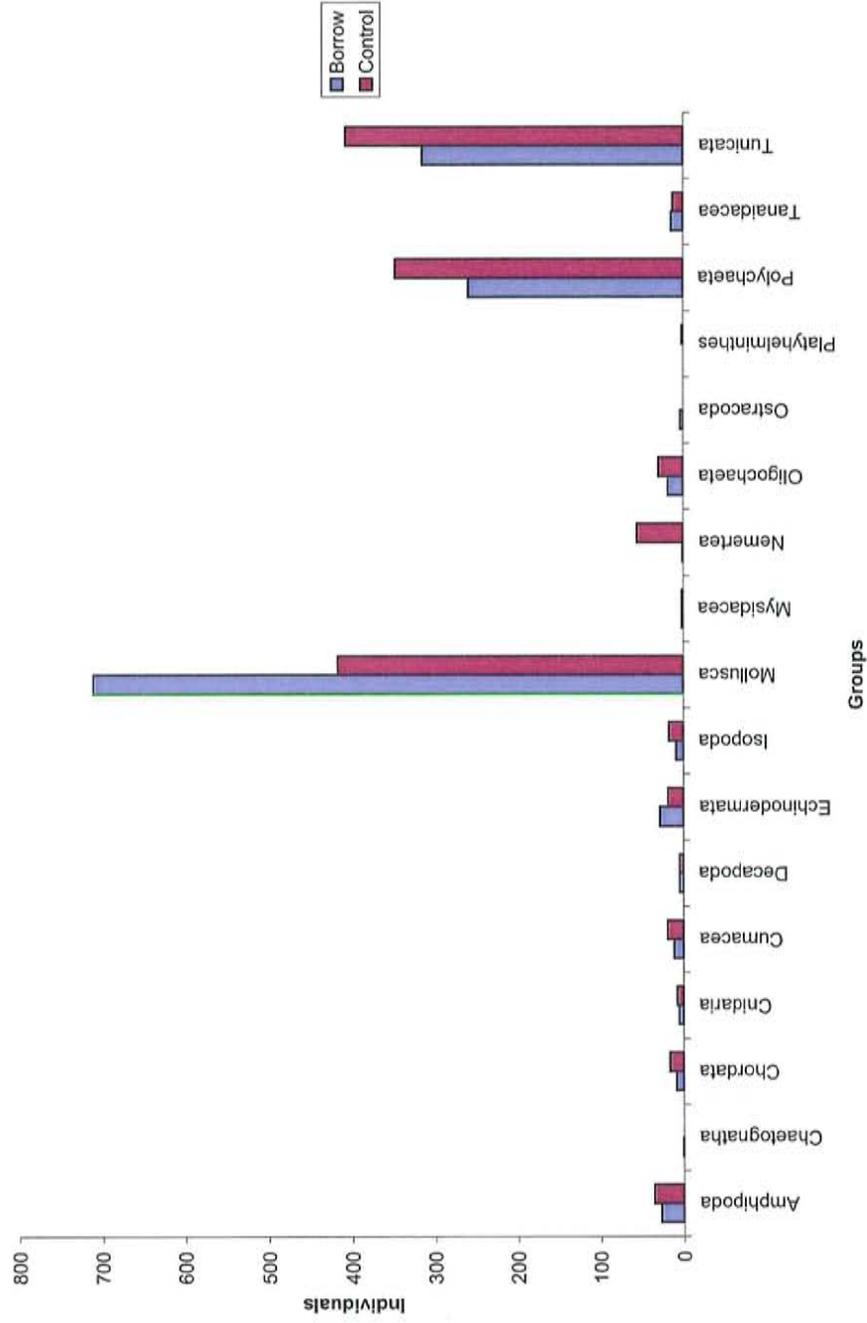
NSS=National Seashore

^b Impact beach:Nags Head

*Sample event dates: spring=8-9 June 2010, summer= on 19-20 August 2010, fall=17-18 November 2010, and winter=14-15 April 2011.

**Shannon diversity index *H'*=index commonly used to characterize species diversity in a community. Shannon's index accounts for both abundance and evenness of the species present. Values for this index typically range from 1.5 (low diversity) to 3.5 (high diversity).

Figure 2. Offshore macroinvertebrate abundance by group at control and impact/borrow stations, minus the most abundant taxa, *Ensis directus* with 123 individuals in the control stations and 1,547 individuals in the impact/borrow stations.



3.1.1.2 Offshore Control Sediment

The offshore control sediment sample means ranged in grain size from 0.49 mm to 0.69 mm with an average of 0.55 mm (coarse sand). No significant seasonal variation was determined for offshore control stations; however, the fall sediment samples had the lowest average grain size compared to the other sampling seasons. Percent calcium carbonate per station ranged from 3.7 percent during the winter to 0.8 percent during the fall. The fall season had the lowest average percent calcium carbonate (1.2 percent), while the highest average percent calcium carbonate was found in the winter (2.3 percent), with an average for all offshore control stations of 1.7 percent.

3.1.2 Offshore Impact/borrow

3.1.2.1 Offshore Impact/borrow Benthos

Within the offshore impact stations 75 taxa were identified during the pre-impact sampling events. The most abundant taxa were *Ensis directus* with 1,547 individuals and *Bivalvia* sp. juv (Mollusca) with 679 individuals (Figure 2). Similar to offshore control samples, taxa richness ranged from one to 14 taxa at each station with an average richness of 5.25 taxa. Evaluating all sample events together the offshore borrow sites averaged 17.3 species per station. Shannon's index of diversity during all pre-impact events combined was 2.44.

When comparing between sample events taxa richness was highest during the summer with 29 taxa, abundance was highest in the spring with 2,288 individuals identified, the majority of which were *Ensis directus* (1,541 individuals) and an unidentified bivalve (668 individuals). While the highest number of groups identified (13) occurred during the summer sampling, the other three events showed little seasonal variation with 10 in the spring, 11 in the fall, and 8 in the winter.

3.1.2.2 Offshore Borrow Sediment Samples

The offshore borrow sediment sample means ranged in size from 0.34 mm to 0.60 mm with an average of 0.44 mm (medium sand). Grain sizes were lowest on average during winter sampling and highest during the spring although seasonal differences were small. The percent calcium carbonate ranged from 2.4 percent noted during winter sampling and 0.7 percent sampled during the spring. The lowest average percent calcium carbonate was found during the spring (1.2 percent), the highest was found in the winter (1.9 percent), with an average for all impact sampling events of 1.5 percent.

3.2 Beach Summary

A total of 34 taxa were recorded from all beach stations during pre-impact sampling. On the Nags Head impact beach 28 taxa were identified during pre-impact events. A total of 26 taxa were identified on the control beach. The most common taxon collected from beach sampling locations was *Scolecopsis squamata*; a polychaete worm, with an abundance of 150 individuals from the impact beach and 507 individuals from the control beach. Other taxa abundant in the beach sampling sites during pre-impact include, *Amphiporeia virginiana* with 416 individuals, and *Donax variabilis* with 280 individuals. Figure 3 depicts beach taxa abundance for the impact and control stations. Shannon diversity ranged from 0.81 during the summer on the subtidal impact beach to 1.93 for both beach zones in the spring impact beach stations (Table 1).

3.2.1 Control Beach

3.2.1.1 Control Beach Benthos

Pre-impact sampling events identified 26 taxa from the control beaches. The most abundant taxa included *Donax variabilis* (Mollusca) and *S. squamata* (Polychaeta) with 238 and 507 individuals respectively (Figure 3). On the Kitty Hawk control beach 16 taxa were identified; the most abundant taxa were Nemertea sp. and Platyhelminthes with 180 and 169 individuals, respectively. On the National Seashore control beach 18 taxa were identified, seven of which were common to both the Kitty Hawk and National Seashore control beaches. The most abundant taxa identified from the National Seashore samples were *Scolecopsis squamata* and *Amphiporeia virginiana*, with 334 and 204 individuals respectively.

When evaluated over the course of the pre-impact sampling effort, taxa richness was highest for the control sites during the summer (22 taxa) and lowest in the fall and winter with 10 taxa. Abundance was highest in the spring with 733 individuals and lowest in the fall with 80 individuals. While number of taxa and abundance fluctuated with season the number of groups present was more consistent; 8 groups were found in the spring and 7 were identified in the fall and winter, with only 6 groups in the summer. The average number of taxa per station for all events was 5.55. The Shannon diversity index for all sampling events on the control beach was 1.92.

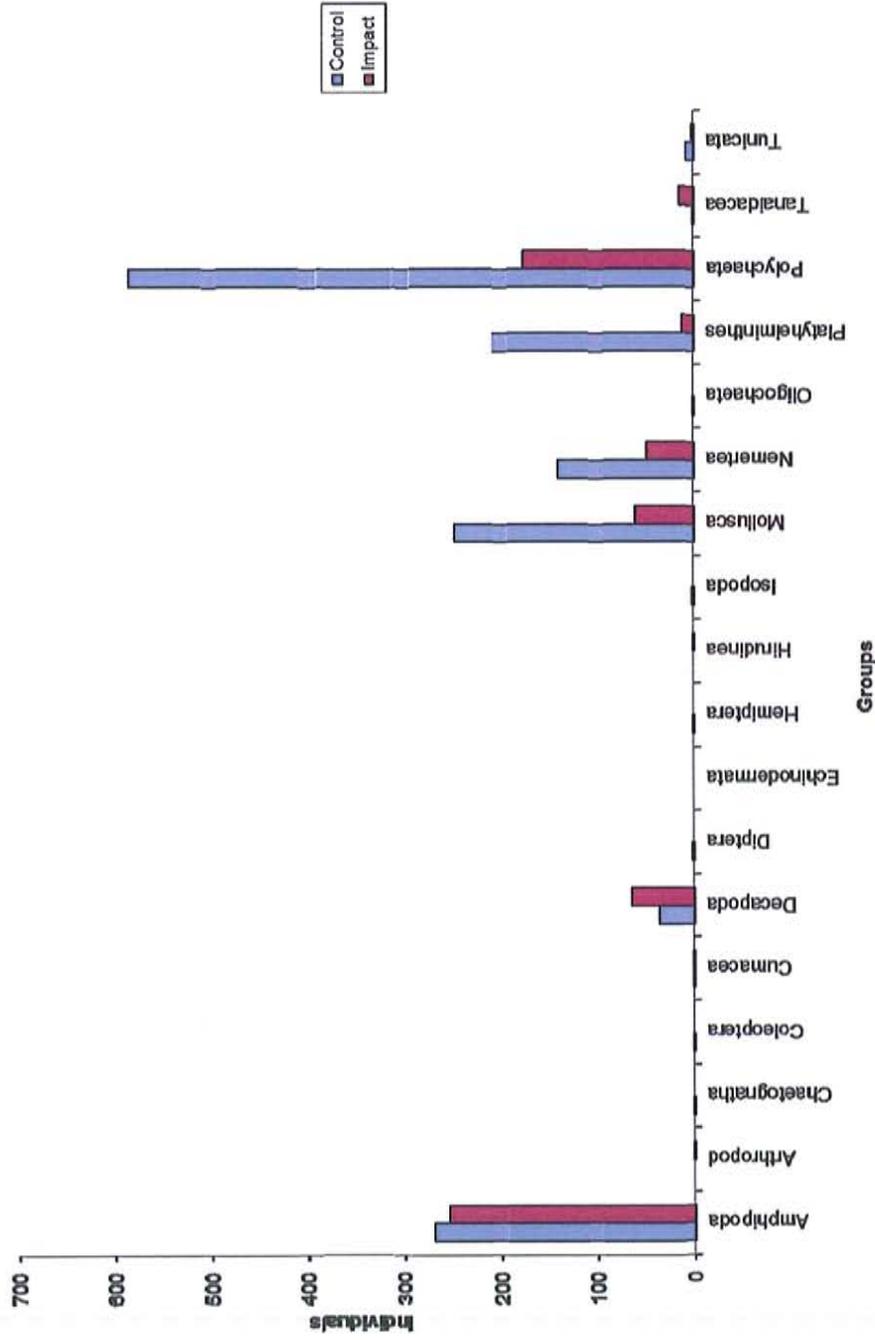
3.2.1.2 Control Beach Sediment

The control beach swash Zone A sediment sample means ranged in size from 0.27 mm to 2.56 mm (average of 0.93 mm) and the control subtidal beach Zone B sediment sample means ranged in size from 0.27 mm to 4.39 mm (average of 1.21 mm) with an overall control beach average of 1.07 mm. The grain sizes vary significantly between the Kitty Hawk and National Seashore beaches and each beach and zone are analyzed separately below. The percentage of calcium carbonate in the sediment ranged from 19.1 to 1.0 percent with the average across both zones of 3.8 percent. The National Seashore control beach averaged 4.0 percent and the Kitty Hawk control averaged 3.6 percent calcium carbonate.

3.2.1.3 Control Beach Swash (Zone A) Benthos and Sediments

Samples taken from the swash zone of the control beaches contained a total of 18 taxa and 910 individuals. The most abundant taxa in Zone A include *S. squamata* and *A. virginiana* with 280 and 194 individuals respectively. The number of taxa per station in Zone A was highest in the spring with an average of 3.5 and lowest in the winter at 1.20. The National Seashore had a higher average number of taxa per swash station for all events compared to the Kitty Hawk beach swash stations. When all events are combined the control swash Zone A average was 5.7 taxa per station; the average Kitty Hawk control beach was 6.2, and the average National Seashore was 5.2. The Shannon diversity index for the swash Zone A on the control beach was 1.86.

Figure 3. Total combined individuals identified per group for all pre-impact events at control beach stations compared to combined impact beach stations.



The sediment grain size in the swash Zone A of the Kitty Hawk beach ranged from 0.37 mm to 2.56 mm with an average of 1.37 mm (very coarse sand). An average of 2.0 taxa was identified per swash control station on the Kitty Hawk beach for all pre-impact events. The sediment grain size in the swash Zone A of the National Seashore beach ranged from 0.27 mm to 0.77 mm with an average of 0.49 mm (medium sand). Average taxa per station on the National Seashore beach Zone A for all pre-impact events was 2.6. Average percent calcium carbonate was higher on the National Seashore beach (4.1 percent) when compared to the Kitty Hawk beach (3.5 percent). No significant seasonal variation occurred in the swash Zone A of the Kitty Hawk or National Seashore beaches; however, the National Seashore beach did show a wide range of grain sizes in the fall event compared to the other events on this beach, an indication of poor sorting. While not statistically significant, the Kitty Hawk beach has some seasonal variation and shows a similar trend as the National Seashore beach with higher grain sizes in the spring and fall and lower grain size in the summer and winter.

3.2.1.4 Control Beach Subtidal (Zone B) Benthos and Sediments

In the subtidal Zone B of the control beaches 605 individuals were counted from 19 taxa. Abundance in this zone was dominated by *S. squamata* and *Nemertea* with 227 and 139 individuals respectively. The taxa per station in the subtidal Zone B were highest in the spring with an average of 3.2 individuals and lowest in the fall at 0.60. When all events are combined Zone B had an average of 5.4 taxa per station. The Shannon diversity index in Zone B of the control beaches was 1.74.

Grain size in the subtidal Zone B varied significantly between the Kitty Hawk and National Seashore control beaches ($p=0.003$). Grain size in Zone B of the Kitty Hawk beach ranged from 0.32 mm to 4.39 mm with an average of 1.87 mm (very coarse sand). An average of 1.95 taxa was identified per subtidal station during pre-impact sampling events. In the subtidal Zone B of the National Seashore beach grain size ranged from 0.27 mm to 2.37 mm with an average of 0.54 mm (coarse sand). An average of 2.0 taxa was identified per sampling station in the National Seashore Zone B.

3.2.2 Impact Beach

3.2.2.1 Impact Beach Benthos

A total of 28 taxa and 630 individuals were identified from the impact beach during the pre-impact sampling events. The most abundant taxa included *A. virginiana* and *S. squamata* with 195 and 150 individuals identified, respectively (Figure 3).

When compared by sampling event or season, taxa richness on the impact beach was highest during the spring and summer (20 taxa each) and lowest in the fall (8 taxa). Abundance was highest during the summer with 255 individuals and lowest in the fall with 51 individuals. Similar to the control beach, the number of groups identified on the impact beach showed little seasonal variation. Taxa richness per station for all pre-impact events averaged 2.3 taxa. Combining all events the average number of taxa per station was 6.1 and the Shannon diversity index was 2.06 (Table 1).

3.2.2.2 Impact Beach Sediment

Grain sizes on the impact beach (swash and subtidal zones combined) ranged from 0.26 mm to 3.13 mm with an average of 0.79 mm (coarse sand). Percent calcium carbonate found

when both zones are evaluated together was lowest in the spring (3.1 percent) and highest in winter (4.1 percent) with an average of 3.5 percent.

3.2.2.3 Impact Beach Swash (Zone A) Benthos and Sediments

The swash Zone A on the impact beach contained 17 taxa and 368 individuals during the four pre-impact sample events. Two taxa, *A. virginiana* and *S. squamata*, comprised the majority of the individuals, with 177 and 44 individuals respectively. When all four pre-impact events are combined the average taxa per station was 5.5.

Grain sizes in the swash Zone A of the impact beach ranged from 0.28 mm to 2.86 mm with an average of 0.83 mm (coarse sand). In the swash Zone A, an average taxa richness of 2.3 per station was determined for the impact beach. Seasonal variation in grain sizes was minimal, with the summer having the widest range of grain sizes and the highest average grain size. Percent calcium carbonate was lowest in winter (3.5 percent) and highest in fall (4.1 percent) with an average of 3.7 percent

3.2.2.4 Impact Beach Subtidal (Zone B) Benthos and Sediments

Pre-impact sampling of subtidal Zone B on the impact beach identified 21 taxa and 263 individuals, with *S. squamata* and *Nemertea* as the most abundant taxa with 106 and 39 individuals respectively. The highest average taxa per station was 4.4 during the spring sampling and the lowest was 1.2 during the fall. The combined average taxa per station for all pre-impact events was 6.8. The Shannon diversity index value for Zone B was 1.92.

In the subtidal Zone B grain size ranged from 0.26 mm to 3.13 mm with an average of 0.74 mm (coarse sand). Average taxa richness for Zone B was 2.3 taxa per station. The subtidal zone had some slight seasonal variation in sediment, predominantly in the fall with a higher average grain size than other sampling events as well as a wider range of grain sizes. Percent calcium carbonate found in Zone B was lowest in spring (2.7 percent) and highest in winter (4.1 percent) with an average of 3.3 percent.

4.0 Discussion and Comparative Analysis

Both abundance and number of taxa identified varied with season. This trend was seen in both the beach and offshore stations; however, this trend was more evident at beach stations. There was little seasonal variation in number of groups identified, particularly from the beach stations. While the number of groups identified were similar between offshore impact/borrow and offshore control stations and between seasons, there was some variation in particular groups.

4.1 Comparative Analysis of Offshore Benthos and Sediment

Seasonal variation was prevalent among taxa richness, total individuals, and the dominant macroinvertebrate groups across pre-impact sampling events (Figure 4). Taxa richness was highest during the summer sampling for both the control and impact/borrow stations. The number of individuals was highest during the spring sampling at both the control and impact/borrow stations; high numbers of *Ensis directus* (razor clam) were identified from the impact/borrow stations and not the control sites. The large numbers of razor clam found in the spring from the impact/borrow sites may be anomalous or may indicate the patchy recruitment of this taxon. The number of individuals between