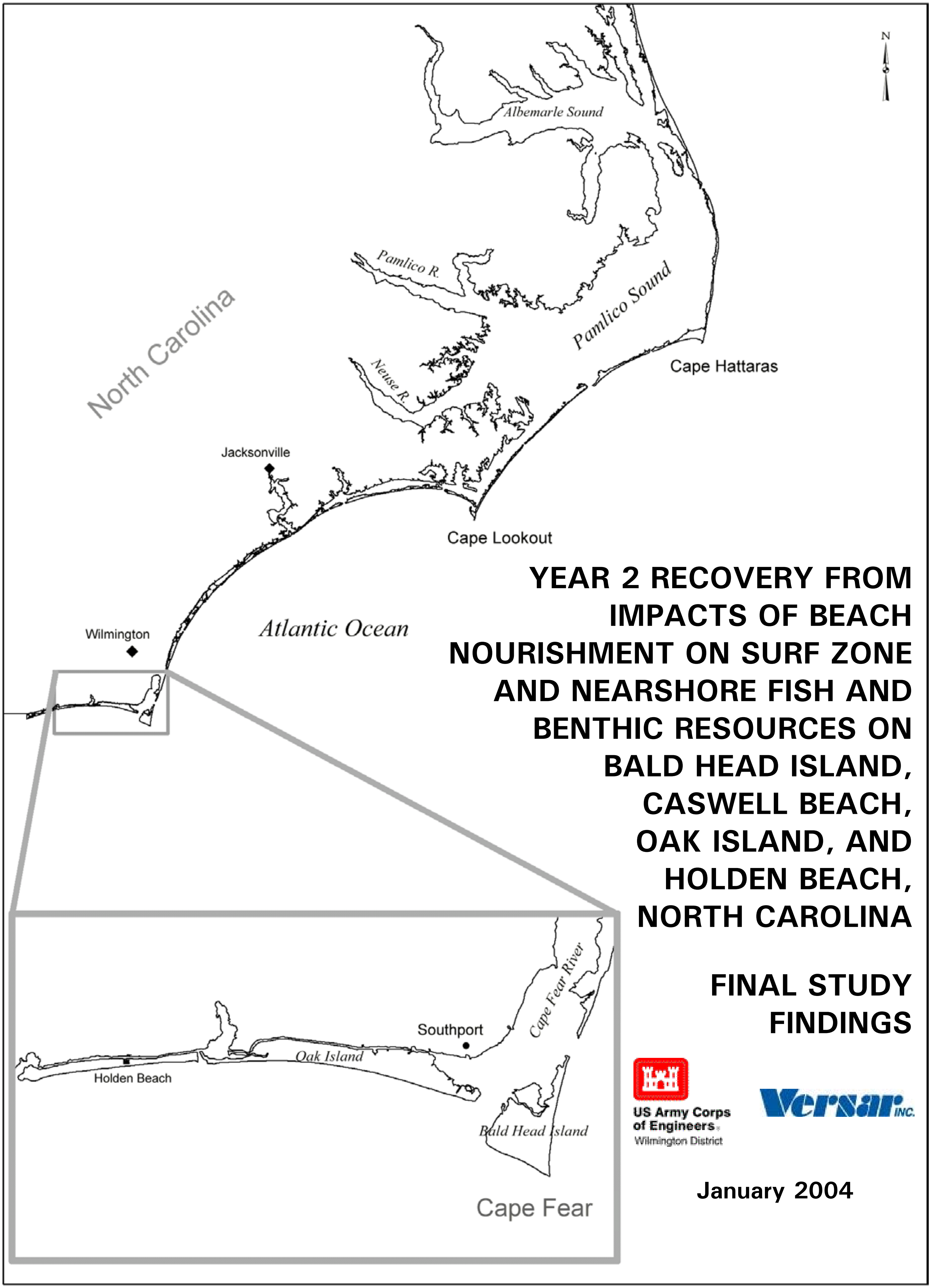


YEAR 2 RECOVERY FROM IMPACTS OF BEACH NOURISHMENT ON SURF ZONE AND NEARSHORE FISH AND BENTHIC RESOURCES ON BALD HEAD ISLAND, CASWELL BEACH, OAK ISLAND, AND HOLDEN BEACH, NORTH CAROLINA

FINAL STUDY FINDINGS

US Army Corps of Engineers
Wilmington District

Versar Inc.

January 2004

YEAR 2 RECOVERY FROM IMPACTS OF BEACH NOURISHMENT ON SURF ZONE AND NEARSHORE FISH AND BENTHIC RESOURCES ON BALD HEAD ISLAND, CASWELL BEACH,OAK ISLAND, AND HOLDEN BEACH, NORTH CAROLINA

FINAL STUDY FINDINGS

Prepared for

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

Prepared by

Versar, Inc.
9200 Rumsey Road
Columbia, Maryland 21045

Contract No. DACW54-00-D-0001
Delivery Order No. 6

Prepared Under the Supervision of

____
William H. Burton
Technical Director

January 2004

ABSTRACT

During 2001-2002 the U.S. Army Corps of Engineers (USACE) Wilmington Harbor Project deepened and realigned the navigational entrance channel to the Cape Fear River located near Wilmington, North Carolina. The work required the removal of about 5.6 million cubic yards of sandy material from the lower portion of the Cape Fear River navigation channel as well as the offshore navigational river entrance channel. The dredged material was used beneficially to replenish the sands of four North Carolina Brunswick County beaches (Bald Head Island, Caswell Beach, Oak Island, and Holden Beach), which had eroded over the past years.

Environmental monitoring was undertaken as part of this beach disposal project to document effects of the beach disposal operations on fish and benthic invertebrate communities inhabiting the surf zone and adjacent offshore areas. A two-year study was designed to assess the immediate impact of beach replenishment on the biological living resources within and adjacent to the project area and to access recovery of the biota up to one-year post replenishment. This report presents results from the second year of sampling and places recovery results in context with the first year study results. Results from this two-year study will add to the growing list of studies examining beach replenishment impacts on the living resources at or near the disturbed beaches. This growing list of studies can be used to interpret future study results and help evaluate cumulative impacts from beach reconstruction activities along the North and South Carolina coastline as more beaches are reconstructed.

For this study, one beach was reconstructed during a season. Sampling of biological resources and water quality followed the progress of the beach reconstruction such that four seasons and beach areas were monitored. The study beach areas were reconstructed in the following sequence: Bald Head Island (Spring 2001), Caswell Beach (Summer 2001), Oak Island (Fall 2001,) and Holden Beach (Winter 2002). Sampling for undisturbed conditions (pre-sand placement) and immediate impacts (up to 8 weeks post-sand placement) were conducted in the season/year that the study beach was reconstructed. All four beaches were sampled one-year later to examine recovery of the living resources. Caswell Beach, Oak Island, and Holden Beach were also sampled quarterly after the initial disturbance to assist in evaluating recovery. A reference beach at Holden Beach West was sampled every time a study beach was sampled.

Living resources examined at the study and reference beaches for this project included ghost crab holes behind the wrack area of the beach. Benthic macroinvertebrates were sampled in the swash zone and shallow and deep subtidal areas of the beach surf zone. Surf zone beach seining and offshore trawling was conducted to sample fish and large macrobenthos. Offshore gillnet sampling and near shore ichthyoplankton tows were also conducted.

During the first year of the study, sand placement impacts on the beach area's benthic communities were evident at all habitats but impacts appeared to be limited in terms of habitat and season of impact. The second year of the study documented recovery of the benthic community at most of the impacted areas.

Immediate impacts in the wrack zone were only found at Bald Head Island reconstructed in the spring. The number of ghost crab holes detected immediately after sand placement at this beach was significantly lower than those detected before the disturbance. The species appeared to have recovered after one-year but since no quarterly sampling was conducted at the beach the speed of recovery is unknown.

The benthic communities of the swash habitat appeared to be the most directly impacted by the sand placement, as effects were apparent across all sampling seasons and when all sampling trips were combined. The timing of beach construction did not appear to influence the immediate impact on the benthic community as all seasons displayed immediate impacts. However, the season when the beach was constructed or the way the beach was constructed (i.e., double impact at Caswell Beach) may have affected the recovery rate of the benthic community. Sampling immediately after sand placement revealed much lower populations of bean clams (*Donax variabilis*) at all four beaches, but the most severe impact was detected in spring (Bald Head Island) and summer (Caswell Beach). In the swash habitat of Bald Head Island, *Donax* abundance decreased by 2 orders of magnitude from undisturbed conditions and remained at this low level one-year later. Additionally, *Emerita* mole crabs decreased by 1 order of magnitude immediately after sand placement and remained that way one-year later. In the swash habitat of Caswell Beach, an immediate impact was detected for *Donax* clam populations. Clam abundance decreased by about 10 fold immediately after sand placement and was still at this low level one-year later. Quarterly sampling at this beach also showed much reduced numbers of clams at the study beach when compared to the reference beach. It is hypothesized that the double impact that occurred at Caswell Beach (this beach was reconstructed twice in the summer of 2001) could have caused a disruption in recruitment of *Donax* clams that persisted in the clam abundances up to a year after the placement effects. If the impact was restricted to one placement event in the summer than it could be expected that the clam population would have been able to recover within a year. Oak Island clam populations (the season with the second highest numbers of clams) also displayed a significant decrease in clam populations immediately after beach reconstruction but abundances had recovered within a year of the impact.

Immediate impacts in the shallow subtidal habitat were mainly limited to Caswell Beach reconstructed in the summer. At this beach, *Donax variabilis* again was the most affected species. The recruitment period for this clam species is thought to occur in the early to mid summer (Hackney et al. 1996). The fact that the clam's abundance was immediately impacted, showed continued reductions during each quarterly sampling, and had not recovered one-year later is most likely due to the double impact conducted at this beach which disrupted the clam's recruitment ability.

Immediate impacts in the deep habitat occurred during the spring sampling period, the major recruitment period for benthic macroinvertebrates based on the first year results. The major contributor to this reduction appeared to have been the polychaete worm, *Scolelepis squamata*. However, these results are confounded by the extremely high abundance of this polychaete collected from Bald Head beach stations sampled before the disturbance. These high numbers of polychaetes were not collected from the reference stations. Abundance of this polychaete one-year after sand placement at the study beach was similar to reference beach numbers both before and after the impact. Therefore the decrease in total abundance that was detected at this beach in the deep habitat was more likely caused by the large natural variation in polychaete abundances rather than sand placement. Since quarterly sampling was not conducted, this hypothesis could not be examined further.

Based on fish sampling with seines and trawls, no immediate impacts in fish abundances and diversities among the disturbed, undisturbed, and reference stations were found at any beach. These results were further supported by the second year study where annual and quarterly seine and trawl sampling exhibited no significant depressions in abundance and diversity one-year after the initial beach construction. When significant differences where observed either an enhancement was indicated or seasonal differences between the subject beach and the reference beach were inconsistent. The schooling nature of a number of dominant species (e.g., bay anchovy) and the highly mobile nature of the fish community constrained the ability to detect impacts and recovery. The fish community's ability to migrate caused a highly variable community in both a temporal and spatial aspect but also indicated that they could move in and out of the beaches impacted by the replenishment operations.

Because of the inherent mobility and migratory behavior exhibited by many adult and transient marine species, the primary goal of the gillnet survey was to document the occurrence and relative abundance of large mobile species utilizing the habitat just outside the surf zone. Additionally, as with the gillnet survey, the premise of ichthyoplankton survey was only to document species occurrence and relative abundance of ichthyoplankton adjacent to the surf zone. Large changes in species composition in both the gillnet and ichthyoplankton surveys were documented in the quarterly and yearly data obtained from the reference data. Since large changes in community composition are displayed naturally within the two community types, the changes displayed within the data collected for these two surveys could not be attributable to beach construction impacts. Other researchers have found the same highly variable results when evaluating beach construction impacts on these fish communities (USACE 2001). They concluded that with the high natural variability in communities, only catastrophic events could be detected in the data. No such catastrophic events were displayed during the current study.

Sediment analyses conducted during both years of the current study found that, with the single exception of spring samples collected immediately after construction at Bald Head Island, the sand being placed on the study beaches did not alter the sediment characteristics of the beaches. At Bald Head Island, a high silt content was present in samples taken immediately after the beach construction activities in the deep habitat. A corresponding decrease in the number of polychaetes was also documented in the deep habitat at this beach immediately after sand placement. However, with the addition of a second year of data, we hypothesize that the decrease in polychaetes displayed immediately after sand placement is more attributable to a natural decline expected after such a large peak displayed in the pre-construction data than by a beach construction impact. The sediment composition did not display the high silt content one-year after beach construction seen in the prior year's data and the number of polychaetes were not much different than those collected from the reference beach.

Continuous water quality monitoring at the two Oak Island fishing piers conducted before, immediately after, and one-year after beach reconstruction revealed that beach replenishment operations did not create large increases in turbidity over background conditions. While turbidity spikes where observed when the pipeline was near both piers, similarly high turbidity values were recorded during periods when the beach replenishment operations were miles from the monitoring sites or when dredging operations where temporarily shut down. Observed increases in turbidity detected during the second year of sampling were attributed to storm events and high surf conditions. Turbidity plume mapping based on the first year's data revealed that the turbidity created by the pipeline discharge hugged the shoreline following the long-shore currents. On-shore wind events contributed to keeping turbidity plume close to shore and in most cases the plumes were not discernable from turbidity created by the breaking waves in the surf zone a few 100 meters away from the end of the pipeline. Elevated suspended sediment loads outside of the surf zone were rarely observed. These data suggest that turbidity plumes caused by the de-watering operations on the beach face were small and short-lived.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (CONTINUED)

I:\DEPT.74\Wil 2\Year 2\Year 2 Draft Report\TABLE OF CONTENTS.doc

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

Figure No. **Page No.**

LIST OF FIGURES (CONTINUED)

Figure No. **Page No.**

LIST OF FIGURES (CONTINUED)

Figure No. **Page No.**

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

Figure No. **Page No.**

1.0 INTRODUCTION

During 2001-2002 the U.S. Army Corps of Engineers (USACE) Wilmington Harbor Project deepened and realigned the navigational entrance channel to the Cape Fear River located near Wilmington, North Carolina. The work required the removal of about 5.6 million cubic yards of sandy material from the lower portion of the Cape Fear River navigation channel as well as the offshore navigational river entrance channel. The dredged material was used beneficially to replenish the sands of four North Carolina Brunswick County beaches (Bald Head Island, Caswell Beach, Oak Island, and Holden Beach), which had eroded over the past years. Erosion of these beaches had reduced the protective, recreational, and economic value of the beaches as a result of the significant reduction in beach width. A total of 14 miles of beach received sands between March 2001 and May 2002.

Environmental monitoring was undertaken as part of this beach disposal project to document effects of the beach disposal operations on fish and benthic invertebrate communities inhabiting the surf zone and adjacent offshore areas. A two-year study was designed to assess the impact of beach replenishment on the biota within and adjacent to the project area and to access recovery of the biota up to one-year post replenishment. Results from this two-year study can be used to optimize the design and scheduling of future disposal efforts undertaken by the USACE. If such effects can be demonstrated, modifications to future beach disposal programs may need to be considered (e.g., dredging windows to protect resources).

A report produced after the first sampling year provided details of short-term impacts (i.e., those observable within two months after sand placement) on the beach benthic fauna and surf zone fish communities (Versar 2002). The study was designed so that seasonal sampling followed the progress of the beach reconstruction. As a result, four seasons were monitored at four separate beaches. The beach areas monitored included Bald Head Island (Spring 2001), Caswell Beach (Summer 2001), Oak Island (Fall 2001) and Holden Beach (Winter 2002). Three habitats were examined for impacts: a swash intertidal zone, a shallow subtidal zone, and a deep subtidal zone.

Results from the short-term impact study indicated that sand placement impacts on benthic communities were evident at all beaches examined but were limited at some habitats by season. The benthic communities of the swash habitat were most directly impacted, as effects were apparent across all sampling seasons. Impacts in the shallow subtidal habitat were evident during the spring and summer sampling periods. Impacts in the deep habitat occurred during the spring sampling period, the major recruitment period for benthic macroinvertebrates. Short-term impacts on fish communities were less clear. Based on fish sampling with seines and trawls, no consistent significant differences in nekton abundances and diversities were apparent during any season. There was a trend of fewer gulf kingfish occurring at the disturbed stations relative to the undisturbed stations. However the schooling nature of some dominant species (e.g., bay anchovy), the highly mobile nature of the nekton community, and the fish community's ability to migrate caused a highly variable community in both a temporal and spatial aspect and constrained the ability to detect differences.

The current study was designed to continue to examine the effects of sand placement on the nearshore benthic and fish community and follow the living resources recovery up to a year after sand placement. At each of the four replenished beaches, fixed stations sampled before sand placement and immediately after placement were sampled one year after beach replenishment activities to examine potential long-term adverse impacts. Three of the four beaches were also sampled quarterly to provide seasonal information.

This report presents the results and analyses of data collected during the second year of a 2-year study. Results and data from the 1st year study were used in the assessment of long-term impacts for the current study but are not presented in detail in this report. For details on the first year's findings see Versar 2002.

2.0 METHODS

The study design included sample collection at eight fixed sites systematically distributed along each of the four study beaches (Bald Head Island, Caswell Beach, Oak Island, and Holden Beach, Figure ME-1) and at four sites along a beach selected as a reference (western end of Holden Beach). At the onset of the study, stations were positioned at the study beaches such that they were expected to be impacted by beach reconstruction within a time span of about 56 days. Because the beach disposal work would be conducted over about a one-year period, this design resulted in the four different study beaches each being sampled in a different season of the year. Only the single reference beach was sampled in all seasons.

Based on the dredging operations the beaches were replenished and sampled in the first year of the monitoring program and an undisturbed reference beach was sampled in the following sequence:

- Spring 2001 - Bald Head Island (Figure ME-2)
- Summer 2001 – Caswell Beach (Figure ME-3)
- Fall 2001 - Oak Island (Figure ME-4)
- Winter 2002 - Holden Beach (Figure ME-5)
- Spring 2001 – Winter 2002 - Undisturbed Reference Beach (Figure ME-6)

For the first year of study, the sampling plan was developed under the assumption that stations would be sequentially impacted over the course of four sampling trips. Thus, Trip 1 was intended to sample all stations as undisturbed (representing pre-construction conditions). During Trip 2, 14 days later, several or all eight stations along the respective beach would be disturbed or in the recovery phase (depending on the speed of beach replenishment). Subsequent sampling during Trips 3 and 4 would provide data on various stages of recovery. As with most field sampling studies, deviations from the initial design due to unforeseen circumstances led to a somewhat varied design (see Versar 2002 for details).

For the current study, three beaches (Caswell, Oak Island, and Holden) were sampled during all four seasons (Table ME-1). Bald Head Island was not sampled quarterly but was sampled in the same season as the impact one-year later (i.e., Spring 2002). Due to the study design, sampling for undisturbed conditions only occurred in the season of sand placement; undisturbed conditions were not available for each season sampled at a study beach.

2.1 SAMPLING PROTOCOL

At each study beach, eight stations were positioned 800 feet apart at equal distance along the respective beach ahead of the pipeline. At the reference beach four stations were positioned 800 feet apart. The distance was chosen based on prior information provided by the USACE dredging contractor about expected progress of the deposition along the beach. Sampling stations on Bald Head Island were originally assigned numbers 1 to 8 but due to deviations in the sand placement operations, Stations 1-4 were dropped before the second trip and four new stations (11, 12, 13, and 14) were added to the east (Figure ME-2). For the remaining beaches, Caswell Beach stations were numbered from 21 to 28 (Figure ME-3), Oak Island stations were numbered from 41 to 48 (Figure ME-4), Holden Beach stations were numbered from 61 to 68 (Figure ME-5), and the reference stations were numbered form 81 to 84 (Figure ME-6). Series numbering was assigned to provide maximum numeric separation between beach areas in the database and does not correspond to beach miles or distance markers used by the dredging company.

2.1.1 Second Year Sampling Plan

Except for Bald Head Island, each beach was sampled quarterly to examine the benthic community condition at each beach during each season. Table ME-1 provides a summary of the sampling time frame for each beach. Note that some seasonal sampling occurred in different years.

2.1.2 Benthic Macroinvertebrates

For each sampling trip, samples were collected at eight fixed stations at a study beach and four fixed stations at the reference/control beach. Sampling was conducted along one landward to seaward transect at each station, covering four beach zone habitats: (1) wrack zone, (2) swash zone, (3) shallow subtidal and (4) deep subtidal. Sampling procedures employed were selected based on general knowledge of the types of organisms expected to be found in these four zones. In the swash zone of sandy beaches in the southeastern U.S., bean clams (*Donax*), mole crabs (*Emerita talpoida*) and several polychaete species are typically found (Nelson 1993). Diversity generally increases in the shallow sublittoral, with a mixture of haustorid amphipods, bivalves such as *Donax*, and a few polychaete species. Diversity in the deeper sublittoral zone, just beyond the wave breakers, increases sharply to include multiple taxa within the amphipod, bivalve, polychaete, and other miscellaneous taxonomic groups. The benthic sampling procedures employed at each habitat were as follows:

Wrack Zone Sampling – Transects parallel to shore covering 15 m back to the toe of the sand dune examined for number of ghost crab burrow holes.

Swash Zone Sampling – Two replicate petite ponar grab samples (225 cm^2) were collected at each swash zone station. The samples were sieved through a 1 mm screen. Only two species of benthos were quantified in the swash zone samples:

the bivalve species *Donax variabilis* and the mole crab *Emerita talpoida*, and only *Donax* and *Emerita* retained by the screen were counted. A 1 mm sieve size was used for the swash zone to reduce retention of coarser sediment.

Shallow and Deep Subtidal-sampling – Two replicate grab samples were taken at each station in the shallow and deep subtidal zones. Shallow stations were sampled with the petite ponar grab (225 cm^2) while deep stations collected from a vessel were taken with a Young grab (440 cm^2). Each sample was sieved through a 0.5 mm screen and all organisms were enumerated and identified to lowest practical taxon (species in most cases). The use of a 0.5 mm sieve in the subtidal zones ensured adequate sampling of the smaller macrofaunal species in the subtidal zone (Nelson 1993).

For the subtidal benthic samples (i.e., shallow and deep habitats), 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. Counts of benthic invertebrates collected by the ponar and Young grab samples were expressed in numbers per square meter of bottom area for all subsequent data analyses.

2.1.3 Juvenile Fish

The distribution and abundance of juvenile surf-zone fishes was monitored using a haul seine in the surf zone and otter trawl beyond the breakers. The baseline survey of juvenile fish involved beach seine and trawl sampling at 4 of the 8 fixed stations at each study beach and at one of the four fixed stations at the reference beach during each quarterly and annual sampling trip (i.e., every other benthic station was sampled for fish). Two replicates hauls were made with seine and trawl at each sampling station.

2.1.3.1 Haul Seines

Surf zone juvenile fish communities were sampled with a 150 ft X 6 ft seine with ½ inch square mesh and 6 ft X 6 ft bag, except during the first seasonal sampling (spring 2001) and the annual sampling (spring 2002) at Bald Head Island when a ¼ mesh net was employed. The switch to a larger mesh net in subsequent sampling was done in order to target larger fish and also to reduce haul-back pressure and make sampling more feasible. The net was deployed in a semicircle and pulled to shore by hand during daylight hours at or near low tide. Sampling at or near low tide was intended to limit changes in fish abundance that occur during various tidal stages and to provide a reasonable working area for seine hauling. Fishes and macroinvertebrates (e.g., crabs and shrimps) were identified to species or lowest practical taxonomic level, enumerated, and a random sample of 50 specimens for each species was measured for total length. Beach seine collections of nekton are expressed in catch per haul.

2.1.3.2 Otter Trawls

Subtidal juvenile fish sampling was conducted using a 25 ft. semiballoon trawl equipped with two 3 ft X 1½ ft wooden doors. The net had a 2-inch mesh body and 1½-inch stretched mesh cod-end fitted with a 1/8-inch cod liner. Replicate tows were made at each sampling station at or near low tide. Trawls were towed parallel to shore for 10 minutes outside of the breakers in waters considered safe for navigation. Distance covered was estimated from DGPS coordinates recorded at the beginning and end of each trawl. Collected fishes and macroinvertebrates (crabs and shrimps) were identified to species, enumerated, and a random sample of 50 specimens for each species was measured for total length. Trawl collections were standardized to numbers per 500 meters of tow length.

2.1.4 Gillnet Sampling

A variety of large, transient fish utilize the surf zone and/or adjacent subtidal areas seasonally as foraging habitat and migratory corridors. Many of these species support recreational and/or commercial fisheries along the North Carolina coastline. A general characterization of the distribution and abundance of the pelagic species inhabiting the project area was developed through gillnet sampling.

The monitoring and assessment of adult predators was conducted using gillnet sampling at four of the eight fixed stations at each study beach and at one of the four fixed stations at the reference beach. Sampling was conducted in the area where the subtidal trawls were conducted using 300 ft X 10 ft experimental gillnets constructed of six 50 ft panels consisting of duplicate panels of 2, 4, and 6 inch stretch mesh. Gillnets were anchored perpendicular to shore and soak times were altered based on the catch rates anticipated by the commercial gill-netter hired to conduct this work. Sampled fishes were identified to species, measured for length, and enumerated. Gill net collections were standardized to catch per 1 hour of soak time.

2.1.5 Ichthyoplankton Tows

The distribution and abundance of ichthyoplankton was monitored by sampling at four of the eight fixed sites at each study beach and at one of the four fixed sites at the reference beach during each quarterly and annual sampling event. Data acquired in this sampling was intended to provide a general characterization of the timing, species composition, and magnitude of early life stages of larval fish in the project area. At each sampling location, bongo nets (50 cm plankton net, 0.5 mm Nitex mesh) were towed for 5 minutes parallel to shore, targeting the subtidal zone outside of breaking waves that can safely be covered from a boat. Two surface tows were taken at each site. The bongo nets were equipped with a mechanical flow meter to estimate the volume of water sampled. Ichthyoplankton samples were preserved in the field in 5% formalin. In the laboratory, larvae were removed from the sample, identified to species using appropriate taxonomic keys, and enumerated. Ichthyoplankton densities were expressed in numbers per 100 cubic meters of water filtered by the plankton nets.

2.2 WATER QUALITY MONITORING AND SEDIMENT GRAIN SIZE METHODS

Water quality parameters were measured and recorded electronically at two piers, Ocean Crest and Long Beach Pier, located in Oak Island, NC. YSI 6600 sondes were deployed to monitor dissolved oxygen, turbidity, water temperature, salinity, and pH at fifteen-minute intervals continuously for the duration of the study. Sensors were calibrated and deployed in accordance with the manufacturers guidelines. Sondes were initially switched out and calibrated once a month by field crews; however, heavy fouling of probes required the deployment period to be shortened to approximately two weeks.

2.2.1 Deployment System

Weights were anchored into the sand with two guide wires attached to the pier. Sondes were suspended between both guide wires with 5 lbs of weight to maintain a constant depth. Periodic maintenance of the anchoring system was required due to a natural shifting of sand beneath the piers.

2.2.2 Filtering Electronic Data

Electronic data for turbidity, temperature, salinity, dissolved oxygen, and pH were examined and filtered for each parameter. The filtering of the data was necessary because of biological fouling that caused sensor degradation over time, failure of probes, or readings out of sensor range. Due to range accuracy limitations on the turbidity probe, all readings above 1000 were assigned a value of 1000. In similar manner, all readings that were below the 0 NTU threshold were assigned a value of 0. The turbidity data were also filtered to remove excessive spikes in the data between successive readings. If the turbidity changed more that 100 NTUs between readings, the data were eliminated. Errant pH readings were obtained due to sensor malfunctions caused by biological fouling which often broke the probes. Data collected over the entire study period showed that salinity and conductivity readings declined over deployment periods of several weeks, most likely as a result of biological fouling of the sensors. Fouling resulted in readings that were well beyond values typical for the study location. For example, salinity readings ranged from lows near 10 ppt to highs of 47 ppt during extended sonde deployments. Based on independent grab samples and general knowledge of the area, salinities from 30 ppt to 38 ppt were typical for the local conditions. Thus, salinity data falling outside that range were deleted from the data sets. Observed levels of dissolved oxygen generally were inconsistent between the two stations, another problem associated with biological fouling of sensors. Dissolved oxygen data were deleted from the data set when readings showed sudden drops or increases (2-3 ppt over a 15 minute period) that departed from the data obtained by the other unit. In many cases sensors on units when these aberrant readings were recorded were found to have perforated membranes.

2.2.3 Sediment Grain Size Methods

Sediment samplings for grain size analysis were collected concurrent with the benthic samples. A surface sediment sample was collected from the eight study beach stations and four reference beach stations during each sampling event at each of the four habitats (i.e., wrack, swash, shallow, and deep). Each sediment sample from the study beach was composited and a subsample removed for laboratory processing. The same was done for the reference beach samples for each sampling trip.

Grain size analysis was completed in accordance with ASTM method D2487. Sediments were sieved and categorized by Wentworth's classifications for use in benthic studies. The ASTM method states that the smallest sieve to be used is 75-Fm, but the standard division between sand and silt/clay for benthic macroinvertebrate studies is 63-Fm (Buchanan 1984) so this sieve size was used for analysis.

2.3 STATISTICAL METHODS

The statistical analysis for this second year report focuses on the detection of long-term impact for each of the four study beaches, based on samples collected before the impact and one-year after the impact. The before impact (undisturbed) data for the beaches were sampled in a different season (spring, summer, fall, and winter), but the reference beach was sampled in all four seasons before and after impact, thus providing control data for all beaches.

The "reference" category includes all samples taken at the reference portion of Holden Beach. The "undisturbed" category includes all samples taken at any of the study beaches prior to the station experiencing sand placement. The "disturbed" category includes all samples collected during the first year of study, which were collected within 0 to 8 weeks after sand placement. Samples collected one-year after sand placement were combined into the "one-year later" category. Additionally, seasonal sampling was conducted quarterly at Caswell Beach, Oak Island, Holden Beach, and the reference beach.

Quarterly data were primarily used as a means for interpreting the one-year recovery results.

Before the analyses we had to treat the replicate data collected from each station for both fish and benthos. For the fish trawl and seine sampling, to maintain consistency with the first year analysis (Versar 2002), we summed the two replicates taken at each station/habitat to represent the parameter of interest at any given station. For the benthic data, the replicates were averaged to produce a mean per station. This was a deviation from the first year analysis where the replicate benthic data for each station was summed (Versar 2002). The mean for each station/benthic parameter was determined this time for ease of converting the data to the standard m^2 designation typically used for benthic studies. The effective sample size for testing differences among disturbance categories for both fish and benthic parameters was thus determined by the number of stations in each category rather than by the number of replicate samples.

The analyses we present here consist of tests of differences among various attributes (abundance, biomass, and species richness) of each biological community sampled (e.g., benthic macroinvertebrates in the shallow zone, fish seine data) at the study and reference beach before impact and one-year after impact. We used a two-way analysis of variance (ANOVA) model to evaluate long-term effects of beach replenishment on the benthic and fish communities:

$$y_{ijk} = \mu + B_j + T_k + B_j T_k + \varepsilon_{ijk}$$

where

B_j = the main effect of beach location (disturbed beach versus reference beach),

T_k = the main effect of time (before disturbance and one-year later),

$B_j T_k$ = the interaction of location and time.

ε_{ijk} = random error terms assumed to be normally distributed with mean zero and constant variance σ^2.

Figure ME-7 provides a key to interpreting the statistical analysis and the data plots presented in this report.

Abundance and biomass data were log-transformed for each station, with a constant of 1 being added to all observations in cases where zero-observations occurred. The main interest in this analysis was to test if the interaction terms are significant, and if so, to test whether the mean values were depressed one-year later at the study beach, as compared to the before disturbance. The main effect was introduced to account for overall differences among years, and for differences between the reference and study beaches.

Community diversity for both macroinvertebrates and fish was assessed using number of species and the Shannon Wiener Diversity Index (H′). H′ includes measures of both taxa richness and evenness (the higher the number the greater the diversity) (Shannon and Weaver 1949; Krebs 1978).

The formula for the calculation of the Shannon Wiener Index is:

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

where

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

Table ME-1. Initial impact seasons, and quarterly and annual sampling schedule for the second year of monitoring at Brunswick County beaches.

Subject Beach	Initial Impact	Recovery			
		Quarterly			One-Year After Construction
		First	Second	Third	
Bald Head Island	Spring 2001	--	--	--	Spring 2002
Caswell Beach	Summer 2001	Fall 2001	Winter 2002	Spring 2002	Summer 2002
Oak Island	Fall 2001	Winter 2002	Spring 2002	Summer 2002	Fall 2002
Holden Beach	Winter 2002	Spring 2002	Summer 2002	Fall 2002	Winter 2003

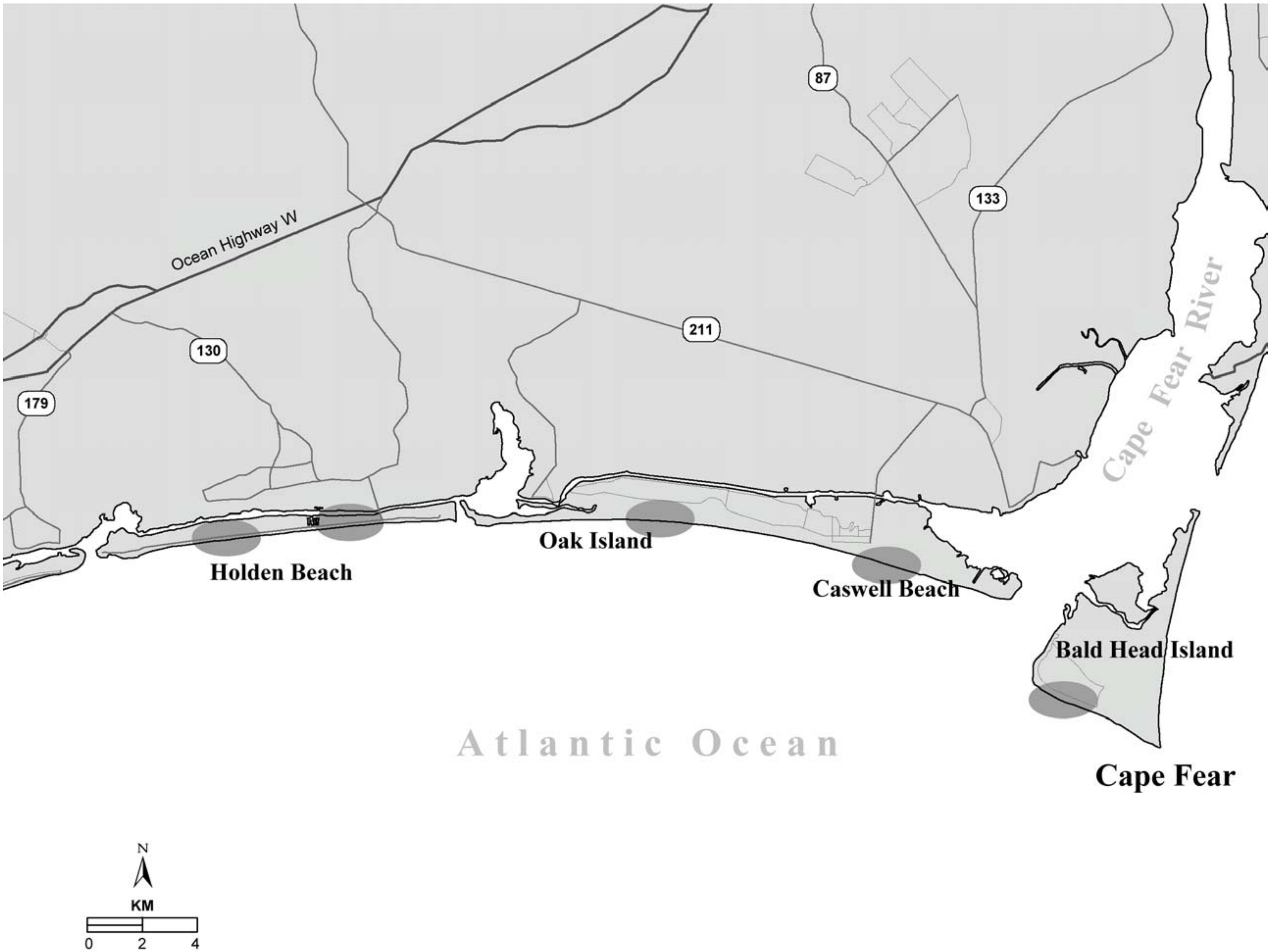


Figure ME-1. Overview of beach monitoring study area

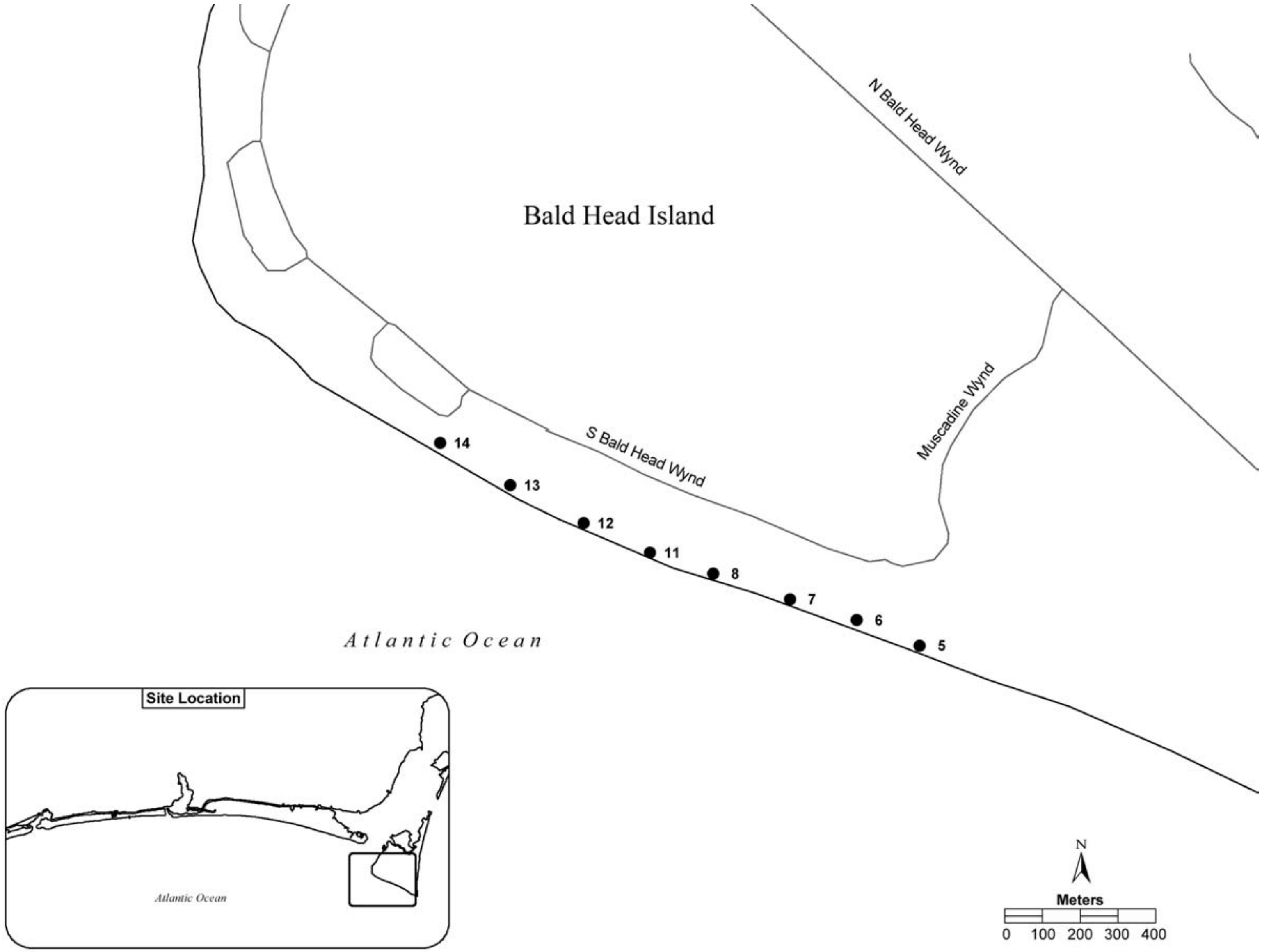


Figure ME-2. Swash station locations at Bald Head Island sampled during the two-year study. Shallow and deep samples were taken along a transect leading out from the shoreline.

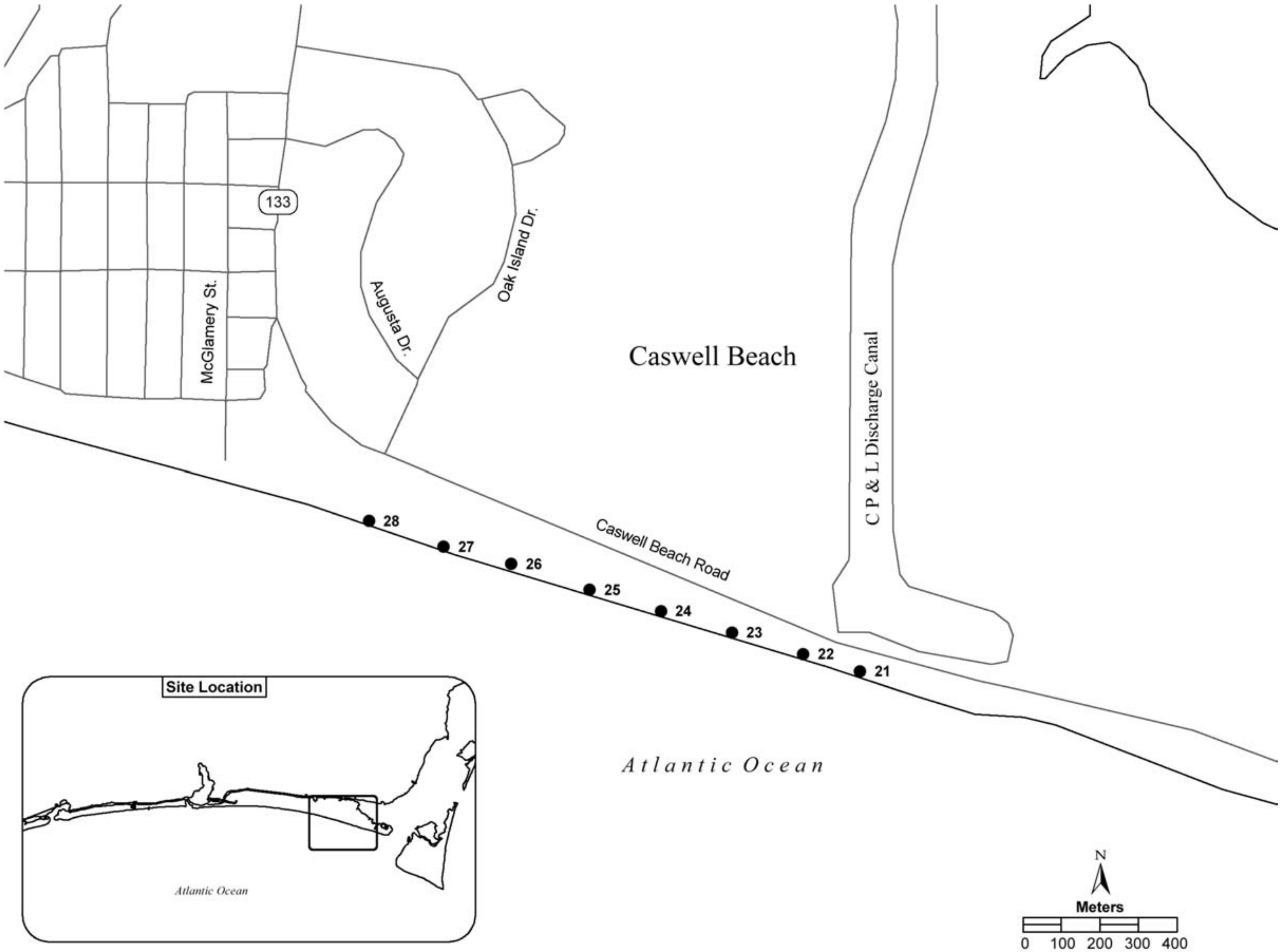


Figure ME-3. Swash sampling locations at Caswell Beach during the two-year study. Shallow and deep samples were taken along a transect leading out from the shoreline.

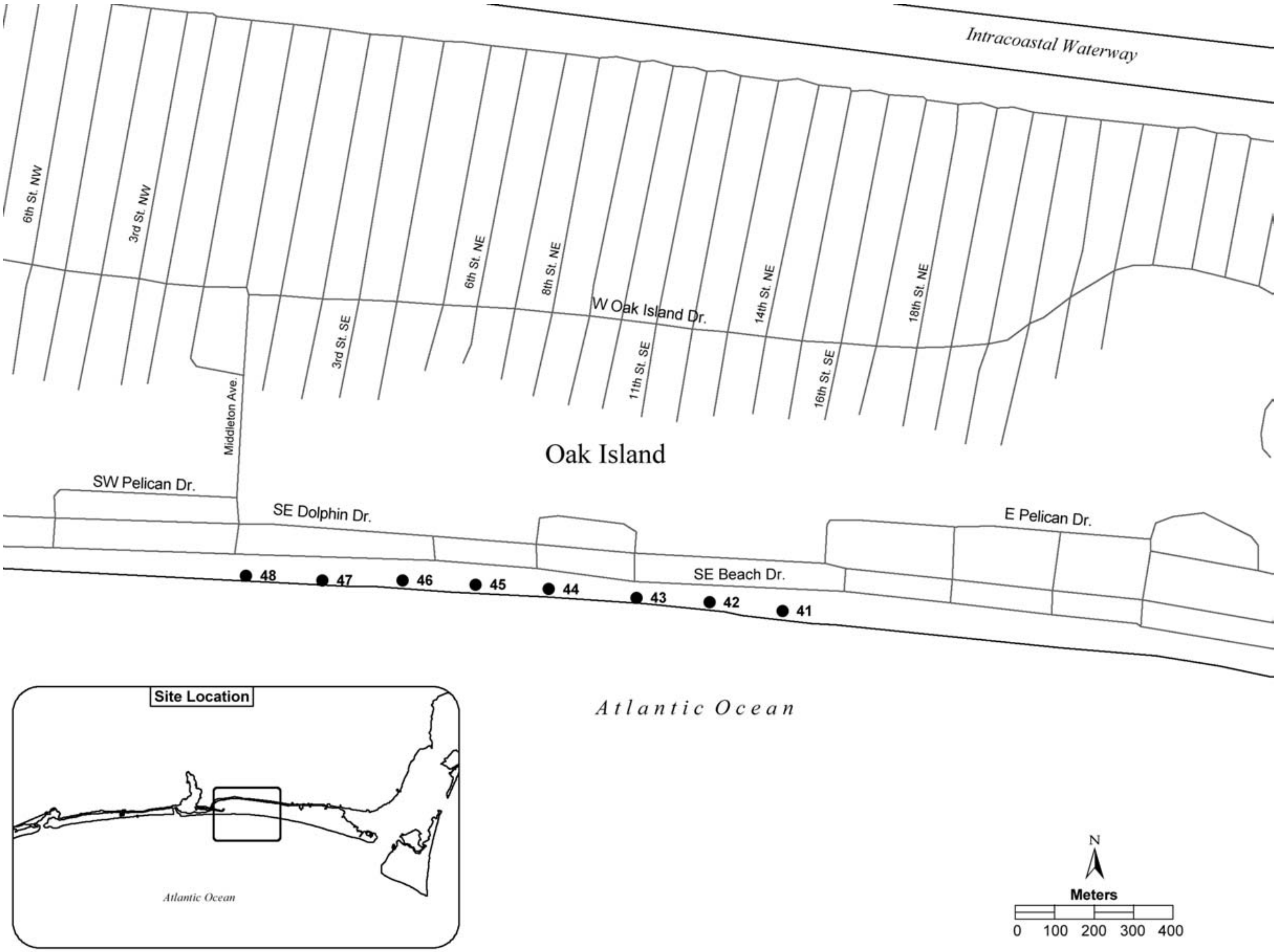


Figure ME-4. Swash station locations at Oak Island sampled during the two-year study. Shallow and deep samples were taken along a transect leading out from the shoreline.

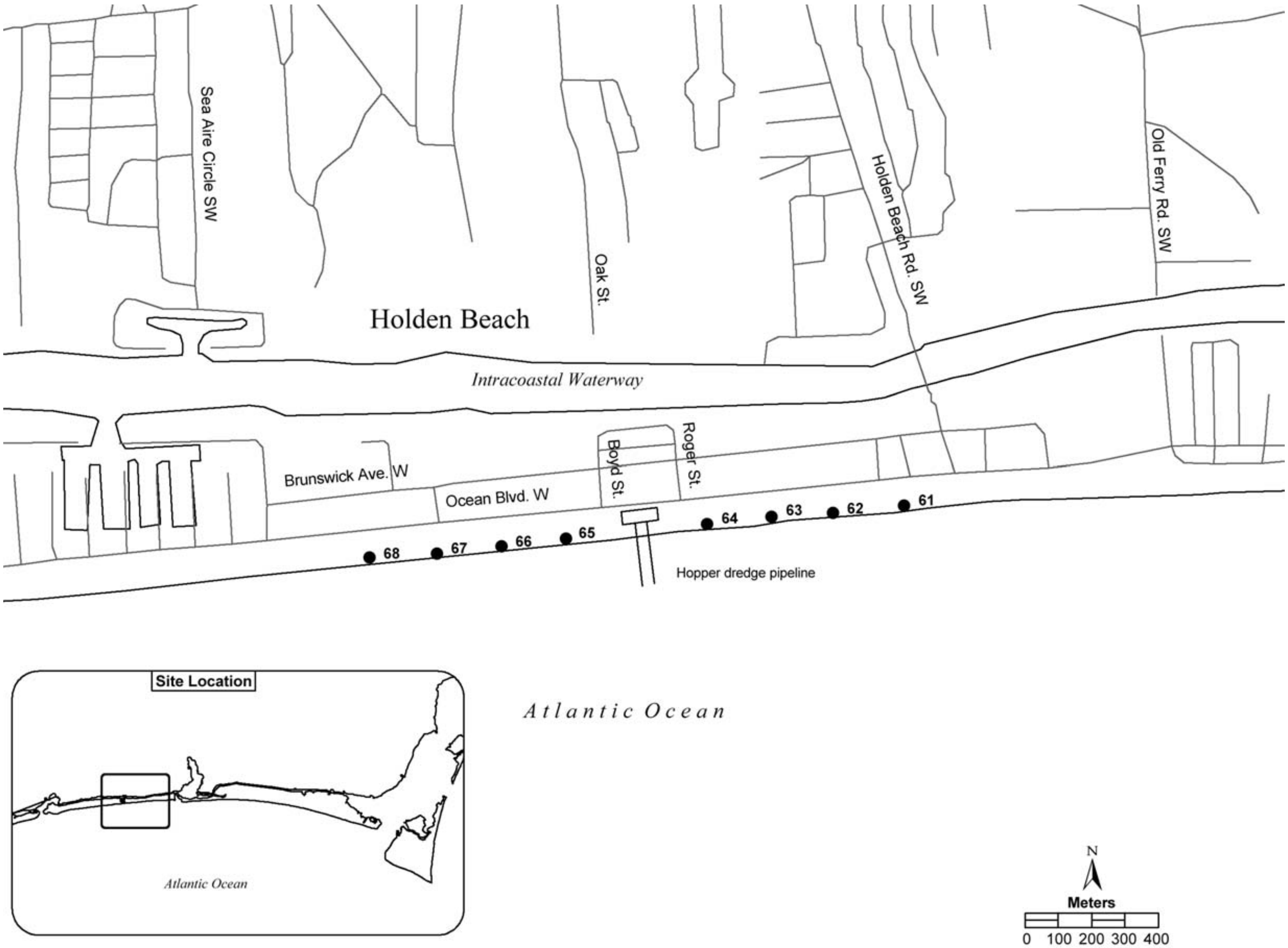


Figure ME-5. Swash station locations at Holden Beach sampled during the two-year study. Shallow and deep samples were taken along a transect leading out from the shoreline.

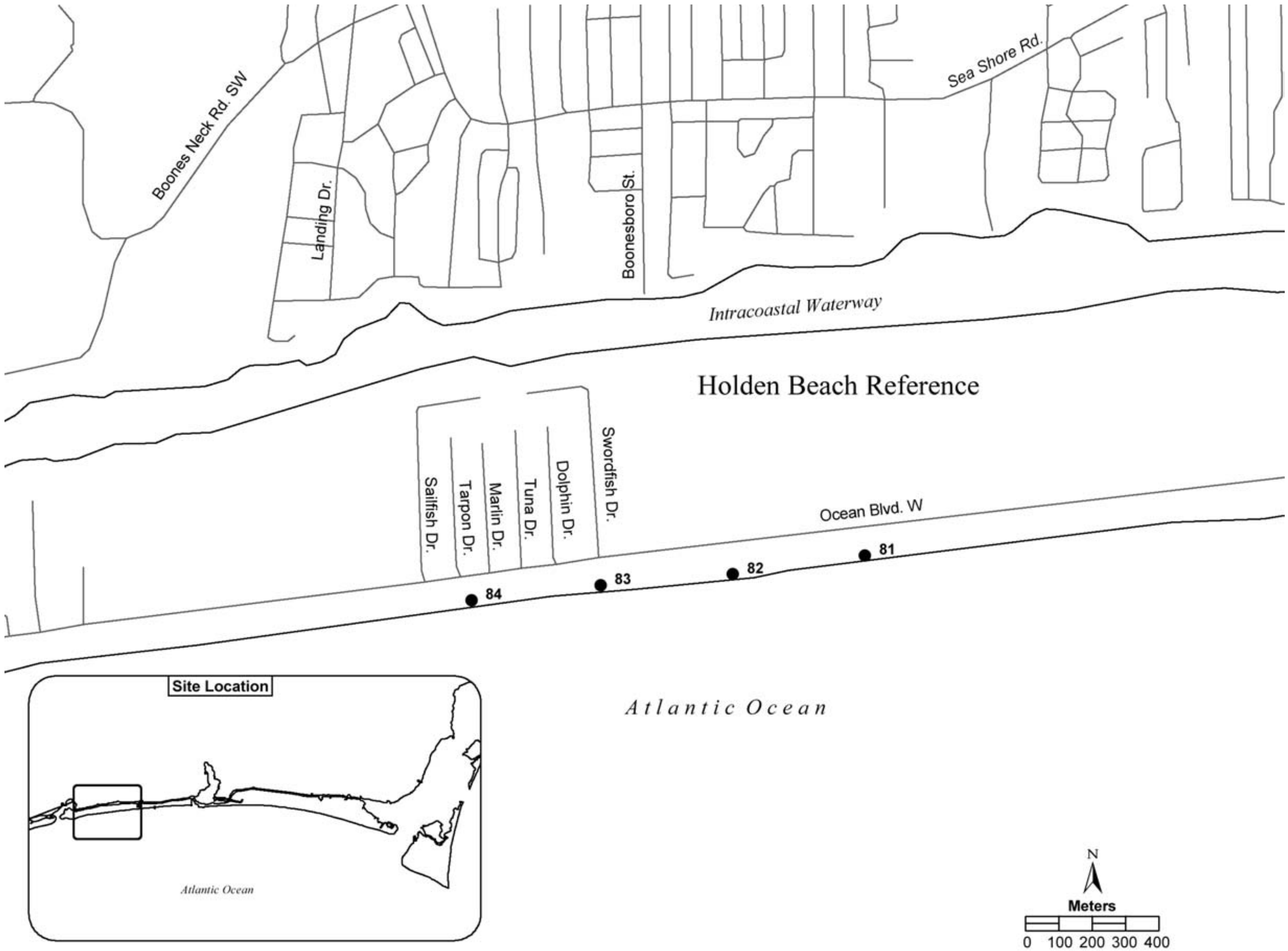
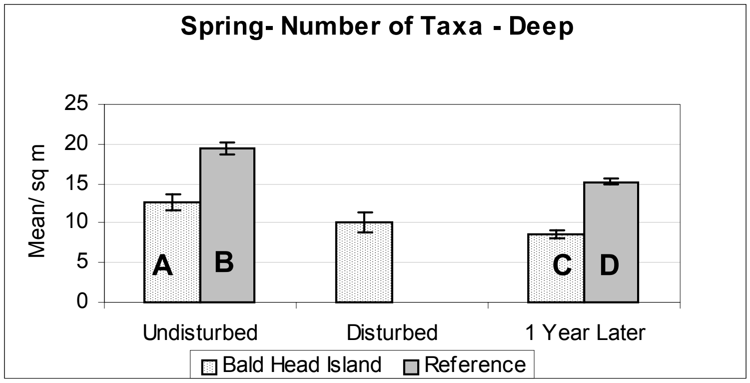


Figure ME-6. Swash station locations at the reference beach located at Holden Beach West. Shallow and deep samples were taken along a transect leading out from the shoreline.



Mean of AB versus CD = Undisturbed vs. One-Year Later
Mean of AC versus BD = Beach vs Reference

The table below provides an example of the statistical summaries included in this report. Significant main effects (i.e., Undisturbed vs. One-Year Later or Beach vs. Reference) are indicated with an asterisk. A down arrow indicates that the second mean in the significant main effects is lower than the first. An up arrow indicates that the second mean in the significant main effects is higher than the first. Highlighted cells indicate that the significant interaction was interpreted as a depression of the parameter one-year later.

Test	Bald Head Island	Caswell Beach	Oak Island	Holden Beach
Mean Total Abundance				
Undisturbed vs. One-Year Later	*▼	NS	*▼	*▼
Beach vs. Reference	*▲	NS	*▲	NS
Year/Beach Interaction	*	NS	NS	NS
Mean Total Biomass				
Undisturbed vs. One-Year Later	*▼	NS	*▼	*▼
Beach vs. Reference	NS	*▲	NS	NS
Year/Beach Interaction	*	NS	NS	NS
Mean Number of Species				
Undisturbed vs. One-Year Later	*▼	NS	*▼	*▼
Undisturbed vs. One	*▲	NS	NS	*▼
Year/Beach Interaction	*	NS	NS	*
Mean Shannon Wiener				
Undisturbed vs. One-Year Later	*▲	NS	NS	*▼
Beach vs. Reference	*▲	*▲	NS	NS
Year/Beach Interaction	*	NS	NS	NS

Treatment Definitions

Undisturbed: Includes all undisturbed study beach and references samples from year 1.
One-Year Later: Includes all study beach and reference beach samples from year 2.
Beach: Includes all undisturbed study beach samples from year 1 plus all study beach samples from year 2
Reference: All reference samples from both year 1 and year 2.
Year/Beach Interaction: The interaction term in the ANOVA model that removes the Year/ Beach effects, leaving effects that can be attributed to beach replenishment.

Figure ME-7. Key to interpreting the statistical analysis and the data plots.

3.0 RESULTS

3.1 BENTHIC SAMPLING

3.1.1 Overall Summary by Habitat

Prior to the start of the study it was determined from previous studies that the dominant taxa in the swash habitat were the clam, *Donax variabilis,* and the mole crab, *Emerita talpoida*. As a result, these two species were the only species examined in the swash habitat. Based on reference beach data collected over a two-year period, the clam *Donax variabilis* was most abundant during the summer and fall sampling periods and lowest during the winter sampling period at the swash habitat (Appendix A). On average, mole crabs, *Emerita talpoida*, were also most abundant during the summer and fall sampling periods and were present in low numbers in the winter and spring (Appendix A).

In the shallow habitat based on the reference stations sampled over a two-year period, total benthic abundance, in general, was highest in the spring and decreased seasonally to a low in winter (Appendix B). The total number of taxa collected from the reference stations during the two-year data record ranged from a low of 21 in the winter to a high of 35 in the spring. At the study beaches, the number of taxa ranged from a low of 20 at Oak Island and Holden Beach (sampled in the fall and winter respectively) to a high of 36 at Bald Head Island sampled in the spring (Appendix B). This pattern of decreasing number of taxa from a high in the spring to a low in the winter was the same pattern displayed by the benthic community in both total abundance and biomass.

The shallow habitat was dominated by the polychaete worm, *Scolelepis squamata*, the bean clam, *Donax variabilis*, and amphipods of the Haustoriidae family. Other researchers have documented the same fauna characteristics for this beach habitat along North Carolina (Diaz and DeAlteris 1982, Hackney et al. 1996, Jutte et al. 1999a and 1999b). *Scolelepis squamata* displayed a peak abundance in the spring and declined to a low abundance during the winter sampling period. *Donax variabilis* had a peak abundance in the shallow habitat in the summer and declined to a low during the spring sampling period. Haustoriid amphipods as a group were present in high numbers during the fall sampling period and declined to low numbers in the summer.

Many more organisms and taxa were collected from the deep habitat than the shallow habitat, which is expected since the shallow area is a more physically harsh environment for benthic organisms. In general, the benthic community was most abundant during the spring, the recruitment period for most benthic species. Benthic abundance at the reference beach declined throughout the summer and fell to a low during the winter period (Appendix C). Total number of taxa collected from both the study and reference beaches were also highest during the spring sampling period (Appendix C).

3.2 ASSESSMENT OF LONG-TERM IMPACT OF BEACH REPLENISHMENT

3.2.1 Bald Head Island

Bald Head Island was reconstructed in the spring of 2001. Sampling at this beach was limited to before sand placement (referred to as undisturbed in the graphics), immediately after beach reconstruction (referred to as disturbed in the graphics), and one year later. No quarterly sampling was conducted.

At the wrack habitat, an immediate significant decrease in number of ghost crab holes was seen at Bald Head Island (Figure BN-1). One-year after sand placement the number of ghost crab holes counted at Bald Head Island was similar to the number counted immediately after sand placement but the ANOVA examining for year/beach Interactions was not significant (Table BN-1). Since quarterly sampling was not conducted at this beach, it is impossible to determine whether the number of ghost crabs inhabiting the beach at Bald Head Island had recovered or whether the ANOVA test result was due to high variability in the data set.

In the swash habitat, no *Donax* clams were collected immediately after sand placement (Figure BN-2). This reduction of clam abundance was also evident, one-year after sand placement, as no clams were collected from the eight stations sampled at the beach (Figure BN-2). The ANOVA testing for differences between the undisturbed and the one-year later stations was significant indicating a continued depression of clams at Bald Head Island (Table BN-2).

Beach construction appeared to have impacted mole crab abundance in the swash habitat as well. No *Emerita* crabs were collected immediately after sand placement or one-year after construction (Figure BN-2). However, overall the number of mole crabs collected from both the reference and study beaches was low ($<$ 15 crabs/m^2) during all the sampling trips. As a result, the standard error between the means of the beaches was high, and the ANOVA results were not significant (Table BN-2). Since quarterly sampling was not conducted at this beach, it is impossible to determine whether the lack of crabs at Bald Head Island one-year later was due to naturally low abundances or whether the population had not yet recovered from sand placement.

Immediate and long-term impacts in the shallow habitat at Bald Head Island were not evident. Based on the year/beach interaction term no significant differences were detected for mean total abundance, mean number of taxa and Shannon Wiener at Bald Head Island either immediately after beach construction or one-year later when compared to the undisturbed stations or the reference stations (Figure BN-3, Table BN-3). Mean total biomass at Bald Head Island did not exhibit a significant impact immediately after sand placement but a significant year/beach interaction was detected one-year later (Figure

BN-3, Table BN-3). High biomass exhibited in the reference area in the spring one-year later was most likely the driving factor in the significant ANOVA result for this parameter.

In the deep habitat at Bald Head Island, significant depressions in both total abundance and total biomass were detected (Figure BN-4). These depressions were sustained one-year later as significant year/beach interactions were detected (Table BN-4). Mean total abundance was an order of magnitude lower one-year after sand placement. The significant decreases in total abundance and biomass in the deep habitat at Bald Head Island were due to a decrease in polychaete abundance and biomass. Mean polychaete abundance was over 8200/m^2 at Bald Head Island before sand placement and was less than 300/m^2 one-year later (Figure BN-5). Mean polychaete biomass was just less than 1.0 g/m^2 before sand placement and decreased to about 0.07 g/m^2 one-year later (Figure BN-5). Specifically, one species, *Scolelepis squamata*, dominated the polychaete fauna with a mean abundance of 8103/m^2 prior to the disturbance and a mean abundance of 288/m^2 one-year post construction (Appendix C). Neither polychaete abundance nor biomass were significantly different one-year later based on ANOVA tests. The extremely high polychaete abundance and biomass exhibited prior to sand placement was more likely the cause of the significant pattern seen in total abundance and biomass rather than a sand placement impact. Again since quarterly sampling was not conducted at Bald Head Island, the response of the benthic community to sand placement throughout the year is unknown.

The two measures of benthic diversity displayed differing results (Figure BN-4). Even though a significant year/beach interaction was detected one-year later in number of taxa, the significance was most likely due to the high diversity detected in the reference area as very little difference at the study beach was detected (Table BN-4, Figure BN-4). However, since the Shannon Wiener Diversity Index incorporates measures of evenness among taxa, the extremely high numbers of *Scolelepis squamata* collected in the undisturbed samples led to a low H'. The more evenly distributed benthic community found one-year later, led to a significantly higher H' (Table BN-4; Figure BN-4).

3.2.2 Caswell Beach

Caswell Beach was reconstructed in the summer of 2002 and was disturbed twice because the dredging contractor was required to add more sand to the beach after the initial construction. Therefore, no statistical tests were performed between the undisturbed study beach and immediately after sand placement because the number of undisturbed stations sampled was very low (Versar 2002). Even though no statistical tests were conducted on the immediate impact data, general patterns in the various parameters examined at the three habitats along Caswell Beach were seen and ANOVA tests were run on the data with the addition of the one-year post construction data. These patterns and statistical results are discussed below for each habitat.

The number of ghost hole crabs counted immediately after sand placement in the wrack area of Caswell Beach was lower than those counted at the undisturbed beach but the significance of this decrease could not be tested due to a small number of undisturbed data points (Figure BN-6). One-year after sand placement, the ANOVA testing for significant year/beach interactions was not significant (Table BN-1) suggesting that no long-term impact on number of ghost crabs was evident. The number of crab holes detected at Caswell Beach was lower than the reference beach for each quarter except the summer one-year later (Figure BN-6).

In the swash habitat, the number of *Donax* clams collected immediately after beach construction was depressed compared to undisturbed abundances at both the study beach and the reference beach (Figure BN-7). ANOVA test results were significant suggesting that the number of clams collected one-year later continued to be lower than undisturbed and reference stations (Figure BN-7, Table BN-2). Seasonal sampling conducted at Caswell Beach also suggests a continued depression in clam abundance after beach construction compared to reference beach abundances. Each quarterly sampling event at Caswell Beach supported fewer clams than the corresponding reference area (Figure BN-7).

Since no mole crabs were collected from the swash habitat at Caswell Beach before the beach construction, impacts of sand placement on this species were not evident (Figure BN-7). The ANOVA test including the one-year later results was significant suggesting a higher abundance one-year after construction compared to undisturbed counts (Table BN-2). The absence of mole crabs from the undisturbed beach suggests high variability in the crab data in the swash habitat. Quarterly sampling also supports the conclusion that sand placement did not impact mole crab abundance at Caswell Beach as crab abundances were higher than the reference area in two of the four seasons sampled (Figure BN-7) and the error bars were large suggesting high data variability.

In the shallow habitat at Caswell Beach, mean total abundance was lower immediately after sand placement and one-year later (Figure BN-8). ANOVA results were significant for the year/beach interaction (Table BN-3). Although it appears that total mean abundance at Caswell Beach was impacted by sand placement and had not fully recovered one year later, the quarterly data do not fully support this conclusion. Mean total abundances collected in the fall and winter at Caswell Beach were higher than the mean at the reference area (Figure BN-8). However, mean total abundance in the spring at Caswell Beach (typically the period of highest abundance) was much lower than the reference area. A closer examination of the major taxa present in the shallow habitat suggests that the significant decrease in total abundance detected one-year after beach construction may be due to a lasting effect of sand placement. Bivalves, (predominantly *Donax variabilis*) the dominant taxa group of this habitat (Appendix B), had a significantly depressed mean abundance one-year after sand placement. Additionally, bivalve abundance at Caswell Beach was lower than at the reference beach during most of the quarterly sampling (Figure BN-9).

These significant decreases in total and bivalve abundance were not reflected in mean total biomass at Caswell Beach. Total biomass exhibited a decrease immediately after sand placement but one-year later the community biomass at Caswell Beach was not significantly different from the undisturbed areas or the reference areas (Table BN-3; Figure BN-8). The seasonal data suggest that total biomass may have still been depressed in the fall but had recovered by winter (Figure BN-8).

Based on the year/beach interaction term, both measures of diversity at Caswell Beach were significantly lower one-year after beach construction compared to the undisturbed stations in the shallow area (Table BN-3, Figure BN-10). However, results of the quarterly sampling indicate that the significant difference in the one-year results may be due to natural temporal or sampling variability instead of sand placement effects. Mean number of taxa in the fall and winter (the first two quarters proceeding beach construction) at Caswell Beach was either higher than or within the standard error of the mean reference condition (Figure BN-10). The Shannon Wiener Diversity Index was higher than the reference beach in both the winter and spring (Figure BN-10).

In the deep habitat at Caswell Beach no immediate or lasting impacts of sand placement were detected in any of the benthic parameters examined for this study (Table BN-4, Figures BN-11 and BN-12)

3.2.3 Oak Island

Oak Island was replenished in the fall of 2001. Beach reconstruction at this beach followed the intended placement schedule. As a result, a reasonable number of stations were sampled before and after the disturbance to allow for statistical testing of immediate impacts as was documented in Versar 2002. Additionally, quarterly sampling events were conducted, as was a one-year later sampling event. Statistical results for these sampling events are presented below for each habitat.

The number of ghost crab holes present at the wrack habitat of Oak Island did not display an impact immediately after sand placement and the number of ghost crab holes detected one-year later was significantly higher than before the disturbance based on the year/beach interactions (Table BN-1, Figure BN-13). The quarterly sampling also supported the conclusion that sand placement impacts in the wrack habitat at Oak Island were not evident (Figure BN-13).

The Oak Island swash habitat displayed a significantly lower *Donax* clam abundance immediately after sand placement but no difference in *Emerita* crab abundance was detected (Figure BN-14). One-year later, no statistical differences in clam or crab abundances were detected based on year/beach interactions (Table BN-2). Quarterly sampling suggests high variability in the two species abundances at both the reference and study beach (Figure BN-14).

Results of all sampling events conducted in both the shallow and deep habitats at Oak Island, suggested that no sand placement impacts were evident either immediately after sand placement or one-year later. No significant impacts were detected in either total abundance, total biomass, or in both diversity measures immediately after sand placement (Figures BN-15 to BN-18) and no statistical differences in the year/beach interaction term were detected one-year after construction (Tables BN-3 and BN-4).

3.2.4 Holden Beach

At Holden Beach, reconstructed in the winter of 2002, sand placement and benthic sampling occurred over a two month period due to harsh weather conditions and equipment breakdowns. Results for the habitats are presented below.

No immediate impact on number of ghost crab holes were detected at Holden Beach nor was the ANOVA test significant for the one-year post construction data (Table BN-1; Figure BN-19). The total number of holes detected at both the study beach and the reference beach in the winter period was very low. Quarterly sampling for number of crab holes present at Holden Beach was variable (Figure BN-19).

In the swash habitat, *Donax* clam abundance was significantly lower immediately after beach construction (Figure BN-20). One-year later no clams were collected from the eight stations sampled. However, since the number of clams collected from the reference beach was also very low, the ANOVA test for year/beach interaction was not significant (Table BN-2, Figure BN-20). Quarterly sampling conducted at Holden Beach suggests that clam abundance may have recovered by the spring sampling period, as clam abundance at Holden Beach was higher than the reference beach; however, in other quarters *Donax* abundances were lower than at the reference beach (Figure BN-20). Since both the study beach and the reference beach contained low numbers of clams one-year after beach construction, the data suggest that clam abundances during the winter in the swash habitat can vary greatly from year to year.

A significant immediate impact on mole crab abundance was detected (Figure BN-20). One-year after beach construction no crabs were collected from the Holden Beach stations and the ANOVA test on crab abundance was significantly lower as indicated by the year/beach interaction suggesting that the crabs had not recovered after one-year (Figure BN-20 and Table BN-2). However, the quarterly sampling data suggest that crab abundances had recovered by spring, as the numbers of crabs collected from Holden Beach were higher in the spring and summer than the reference area and were within the standard error in the fall (Figure BN-20). Based on the quarterly results, it is unlikely that the low number of crabs collected one-year after beach construction was due to a sand placement impact. Most likely the significant difference detected one-year later was due to natural variability since mole crab abundances are naturally low in the winter.

In the shallow habitat, sand placement effects were not apparent (Figures BN-21 and BN-22). Although both total abundance and number of taxa indicated a significant year/beach interaction one-year later (Table BN-3), neither of these parameters showed a significant immediate impact during the construction year. The quarterly data suggest that the differences detected in the benthic community at Holden Beach one-year later were most likely due to natural variability. Differences between Holden Beach and the reference beach for both of these parameters were minimal based on the quarterly sampling (Figures BN-21 and BN-22).

In the deep habitat, none of the benthic parameters exhibited an immediate impact from sand placement during the construction year (Figures BN-23 and BN-24). Additionally, only number of taxa had a significant ANOVA year/beach interaction based on the yearly data (Table BN-4). As in the shallow habitat, the significant interaction appeared to be due to natural variability as the quarterly results showed no difference between the study and reference beaches (Figure BN-24).

3.3 SUMMARY

The wrack area sampled at each beach was above the area of direct sand placement for this survey. Impacts on ghost crab holes in this habitat were very limited. A significant depression on number of holes present at Bald Head Island immediately after sand placement was detected but as the quarterly sampling at all of the other beaches suggest, this type of sampling led to great variability in the data. No other impacts either immediately after sand placement or up to one-year later were detected, so sand placement had little to no effect on numbers of ghost crabs inhabiting the wrack habitat.

Based on the first year's results, in the swash habitat, the area where sand was directly placed, beach construction had an immediate impact mostly on *Donax* clam abundances and to a lesser degree on mole crab abundances. Sand placement had an immediate and long-lasting impact on *Donax* clam abundances in both the spring and summer. Clam abundances were significantly lower one-year after sand placement compared to undisturbed stations at both Bald Head Island and Caswell Beach. Unfortunately quarterly sampling at Bald Head Island was not part of the study design so it was impossible to determine whether the lack of clams collected one-year later was due to sand placement impacts or natural variability. However, at Caswell Beach, *Donax* clam abundances were depressed immediately after sand placement and were significantly lower in both the quarterly sampling and one-year later compared to the reference area and undisturbed stations. The impact on the clam populations in the spring and summer were not reflected in the mole crab data suggesting that the sand placement impacts were limited to Donax clams in the swash habitat. Immediate impacts detected for both clam and crab abundances in the fall and winter were more limited. Also, sampling conducted quarterly and one-year after revealed that in these seasons the both *Donax* and *Emerita* were capable of recovery within a year of sand placement impacts or that natural variability in these seasons confound the statistical results.

In the shallow habitat, sand placement impacts were only apparent at Caswell Beach, reconstructed twice in the summer of 2001. The other three beaches displayed few impacts either immediately after sand placement or longer term (i.e., quarterly or one-year later). At Caswell Beach, the impact appeared limited to total abundance with a significant difference apparent one-year after beach construction. Bivalves, the dominant taxa group of this habitat, were the major contributors to the decreased benthic abundance, as the abundance of bivalves was significantly lower one-year later.

In the deep habitat, sand placement impacts were minimal. Differences in several benthic parameters were detected one-year after sand placement but limitations of the data and high natural variability in the benthic community were most likely the reasons for the year/beach interactions detected in the ANOVA results. Specifically, at Bald Head Island extremely high numbers of polychaetes collected from the study beach prior to the sand placement event likely contributed to the ANOVA significance. Since quarterly data were not collected for this beach, the extent of the impact versus the natural variability in the benthic community cannot be determined.

Table BN-1. Wrack habitat ANOVA results testing for significant differences 1-year after beach construction. Significance * was determined at the 0.05 level. Arrow direction indicates whether the second mean in the comparison is higher or lower than the first mean for all significant tests. Highlighted cells indicate that the significant interaction was interpreted as a depression of the parameter one-year later.				
Total Number of Ghost Crab Holes				
Test	**Bald Head Island**	**Caswell Beach**	**Oak Island**	**Holden Beach**
Undisturbed vs. One-Year Later	* ▼	* ▼	* ▲	* ▼
Beach vs. Reference	NS	NS	* ▲	NS
Year/Beach Interaction	NS	NS	*	NS

Table BN-2 Swash habitat ANOVA results testing for significant differences 1-year after beach construction. Significance * was determined at the 0.05 level. Arrow direction indicates whether the second mean in the comparison is higher or lower than the first mean for all significant tests. Highlighted cells indicate that the significant interaction was interpreted as a depression of the parameter one-year later.				
***Donax variabilis* Abundance**				
Test	**Bald Head Island**	**Caswell Beach**	**Oak Island**	**Holden Beach**
Undisturbed vs. One-Year Later	NS	* ▼	NS	* ▼
Beach vs. Reference	NS	NS	* ▲	NS
Year/Beach Interaction	*	*	NS	NS
***Emerita talpoida* Abundance**				
Undisturbed vs. One-Year Later	NS	* ▼	* ▲	* ▼
Beach vs. Reference	NS	* ▲	NS	* ▼
Year/Beach Interaction	NS	*	NS	*

Table BN-3. Shallow habitat ANOVA results testing for significant differences 1-year after beach construction. Significance * was determined at the 0.05 level. Arrow direction indicates whether the second mean in the comparison is higher or lower than the first mean for all significant tests. Highlighted cells indicate that the significant interaction was interpreted as a depression of the parameter one-year later.

Test	Bald Head Island	Caswell Beach	Oak Island	Holden Beach
Mean Total Abundance				
Undisturbed vs. One-Year Later	*▲	*▼	NS	*▼
Beach vs. Reference	*▲	*▲	*▲	NS
Year/Beach Interaction	NS	*	NS	*
Mean Total Biomass				
Undisturbed vs. One-Year Later	*▲	NS	NS	NS
Beach vs. Reference	*▲	NS	NS	NS
Year/Beach Interaction	*	NS	NS	NS
Mean Number of Taxa				
Undisturbed vs. One-Year Later	*▲	*▼	NS	*▼
Beach vs. Reference	NS	NS	*▲	NS
Year/Beach Interaction	NS	*	NS	*
Mean Shannon Wiener				
Undisturbed vs. One-Year Later	NS	NS	NS	*▼
Beach vs. Reference	*▼	NS	NS	NS
Year/Beach Interaction	NS	*	NS	NS

Table BN-4. Deep habitat ANOVA results testing for significant differences 1-year after beach construction. Significance * was determined at the 0.05 level. Arrow direction indicates whether the second mean in the comparison is higher or lower than the first mean for all significant tests. Highlighted cells indicate that the significant interaction was interpreted as a depression of the parameter one-year later.

Test	**Bald Head Island**	**Caswell Beach**	**Oak Island**	**Holden Beach**
Mean Total Abundance				
Undisturbed vs. One-Year Later	*▼	NS	*▼	*▼
Beach vs. Reference	*▲	NS	*▲	NS
Year/Beach Interaction	*	NS	NS	NS
Mean Total Biomass				
Undisturbed vs. One-Year Later	*▼	NS	*▼	*▼
Beach vs. Reference	NS	NS	NS	NS
Year/Beach Interaction	*	NS	NS	NS
Mean Number of Taxa				
Undisturbed vs. One-Year Later	*▲	NS	*▼	*▼
Undisturbed vs. Reference	*▲	NS	NS	*▼
Year/Beach Interaction	*	NS	NS	*
Mean Shannon Wiener				
Undisturbed vs. One-Year Later	*▲	NS	NS	*▼
Beach vs. Reference	*▲	*▲	NS	NS
Year/Beach Interaction	*	NS	NS	NS

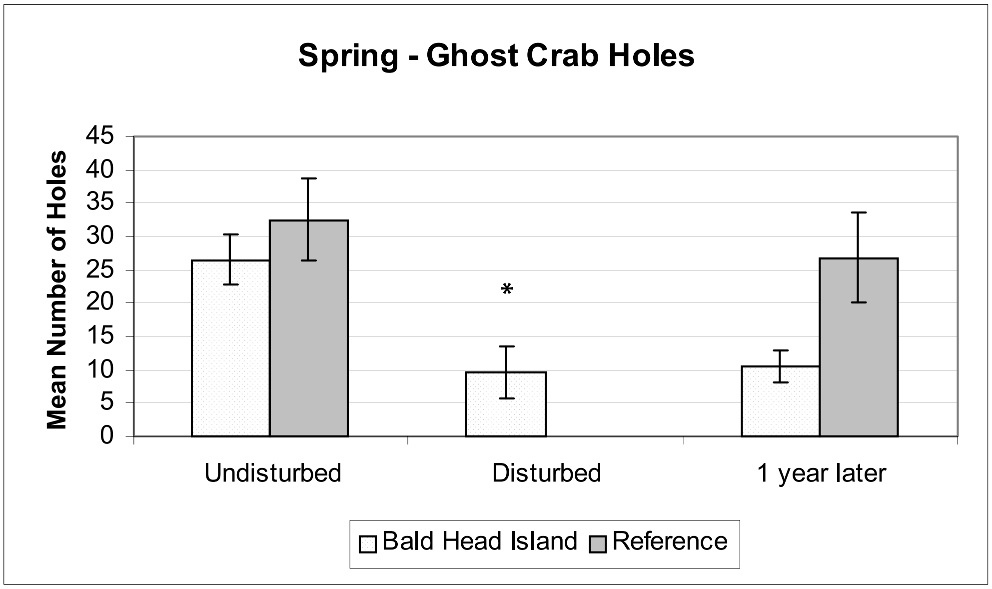


Figure BN-1. Comparison of ghost crab holes in the wrack habitat at Bald Head Island among undisturbed, disturbed, and recovery collections (1-year later). * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE.

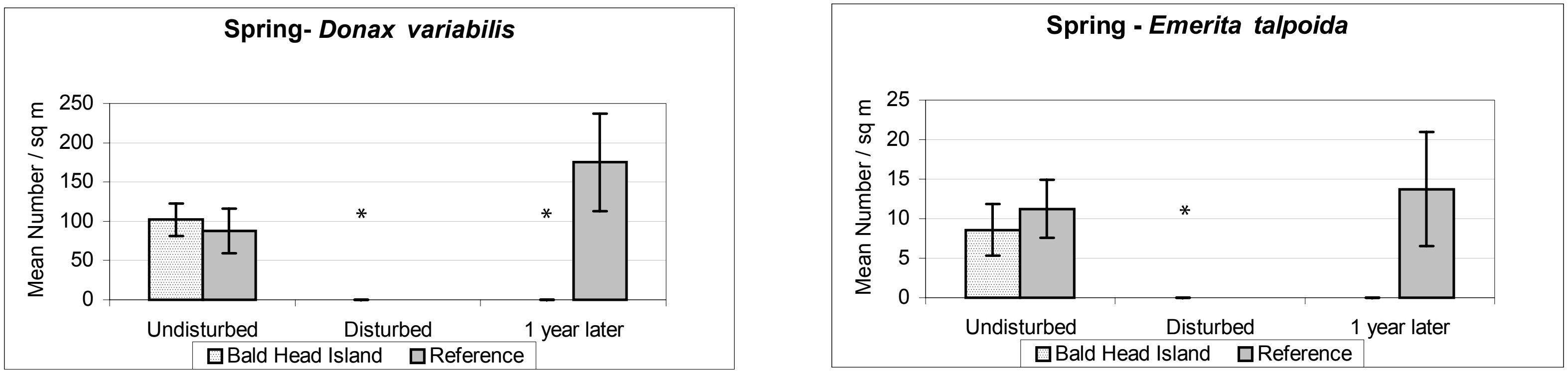


Figure BN-2. Comparison of *Donax variabilis* and *Emerita talpoida* abundances in the swash habitat at Bald Head Island among undisturbed, disturbed, and recovery collections (1-year later). * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE.

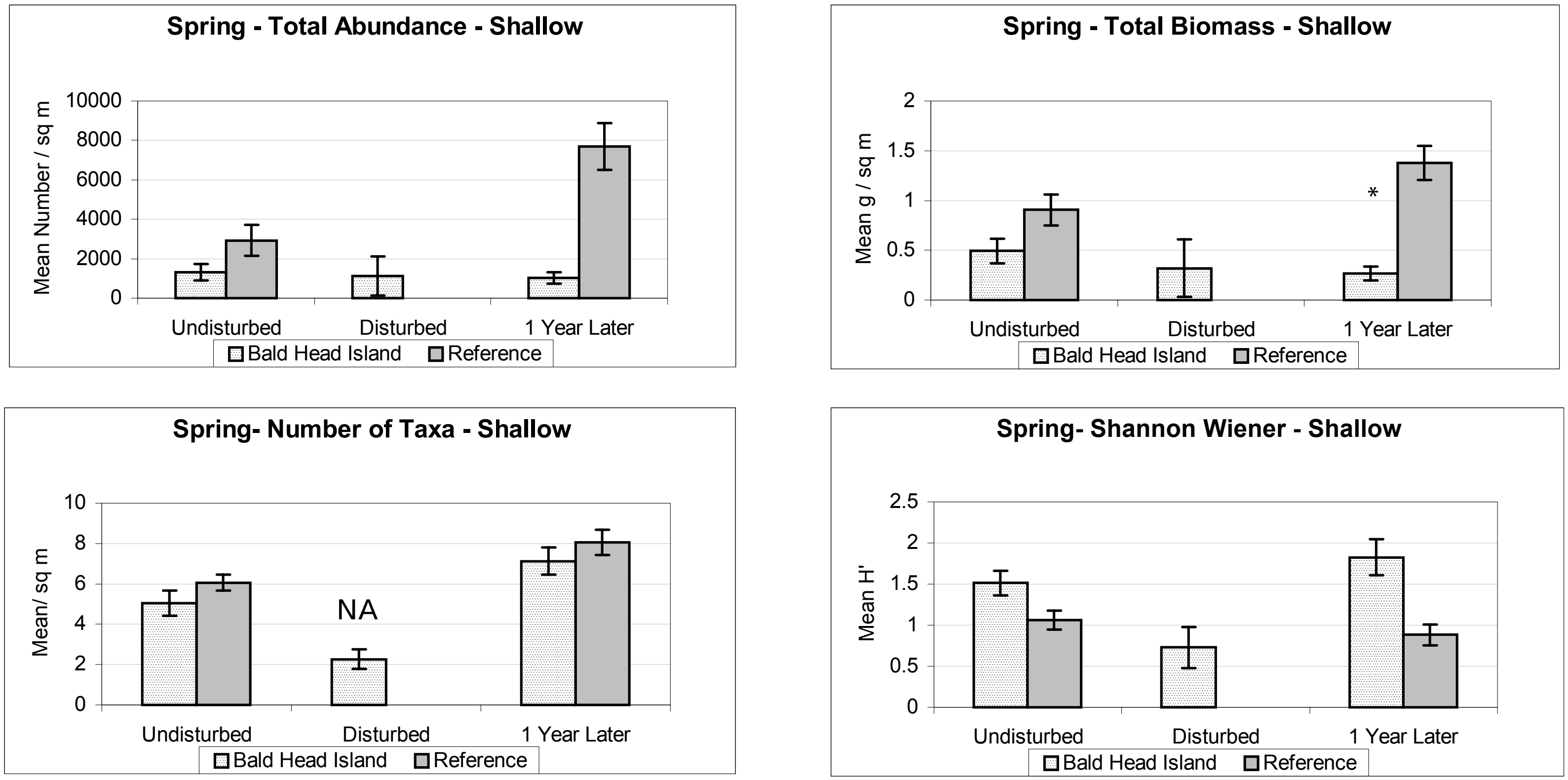


Figure BN-3. Comparison of mean total abundance, total biomass, number of taxa, and the Shannon Wiener Diversity Index in the shallow habitat at Bald Head Island among undisturbed, disturbed, and recovery collections (1-year later). * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. NA = no test conducted.

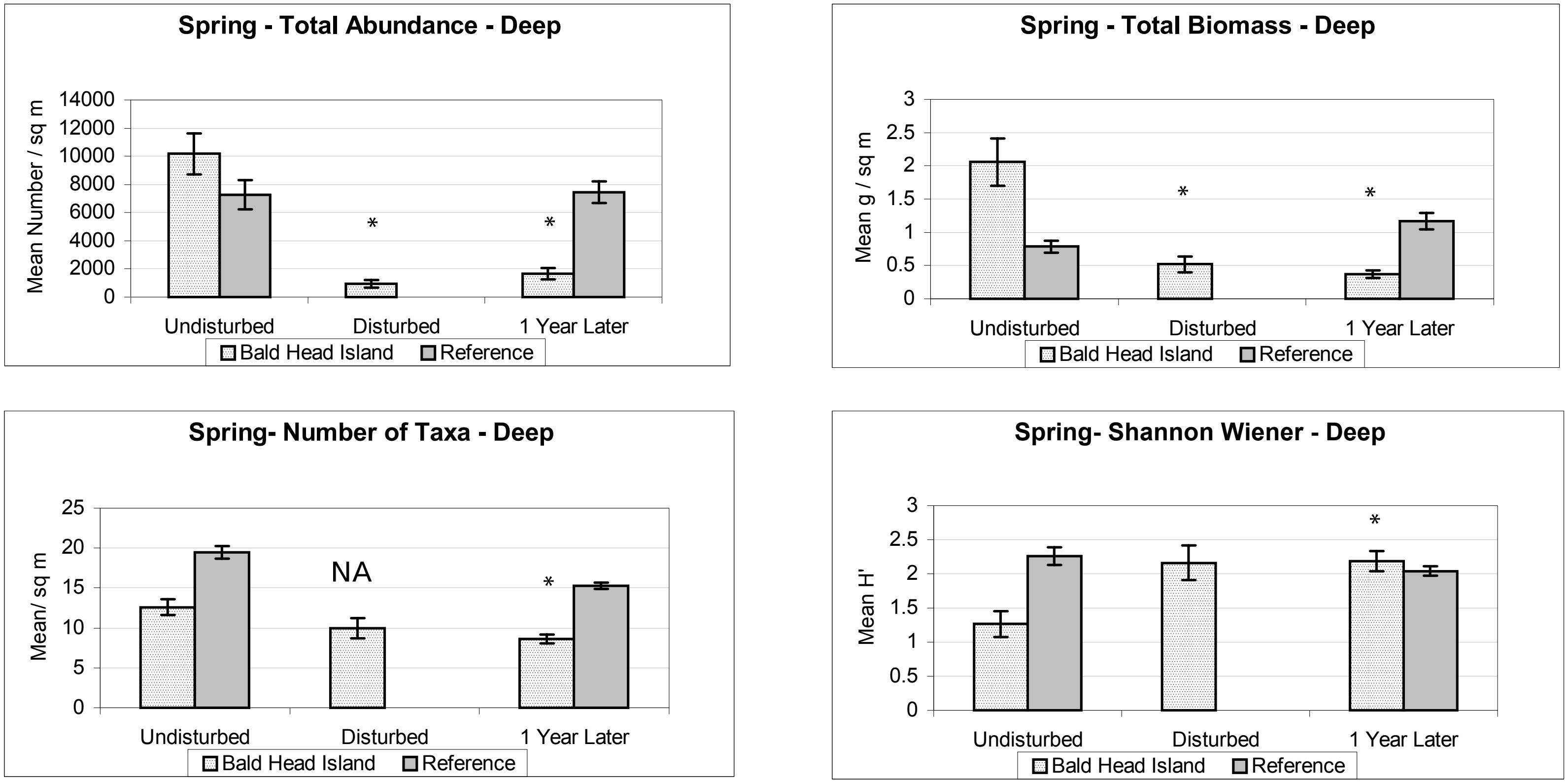
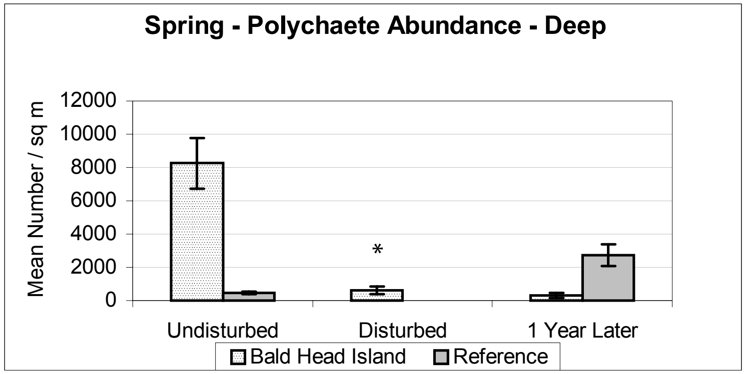


Figure BN-4. Comparison of mean total abundance, total biomass, number of taxa, and the Shannon Wiener Diversity Index in the deep habitat at Bald Head Island among undisturbed, disturbed, and recovery collections (1-year later). * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. NA = no test conducted.



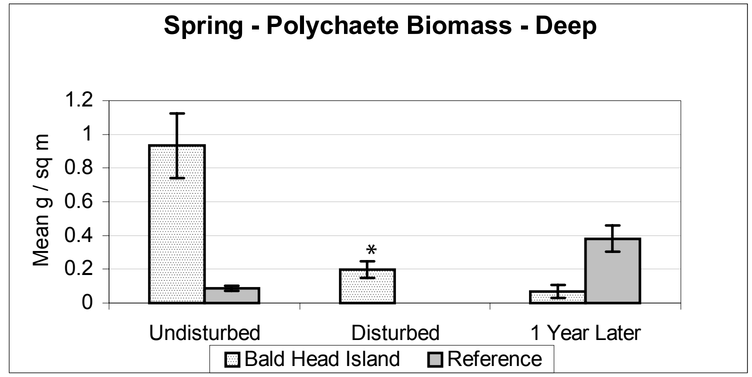


Figure BN-5. Comparison of mean polychaete abundance and biomass in the deep habitat at Bald Head Island among undisturbed, disturbed, and recovery collections (1-year later). * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE.

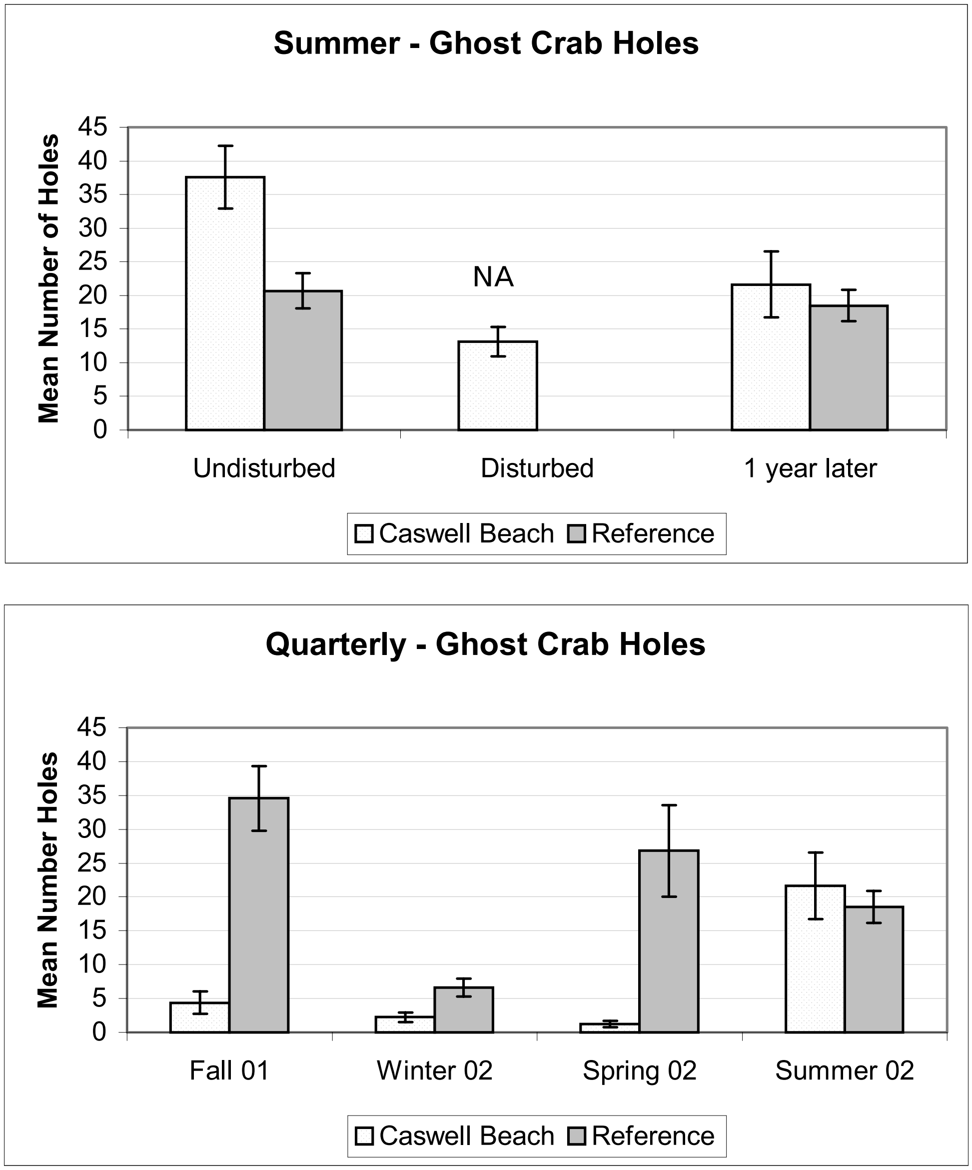


Figure BN-6. Comparison of ghost crab holes in the wrack habitat at Caswell Beach among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. NA = no test conducted. No statistical tests were conducted on the quarterly data.

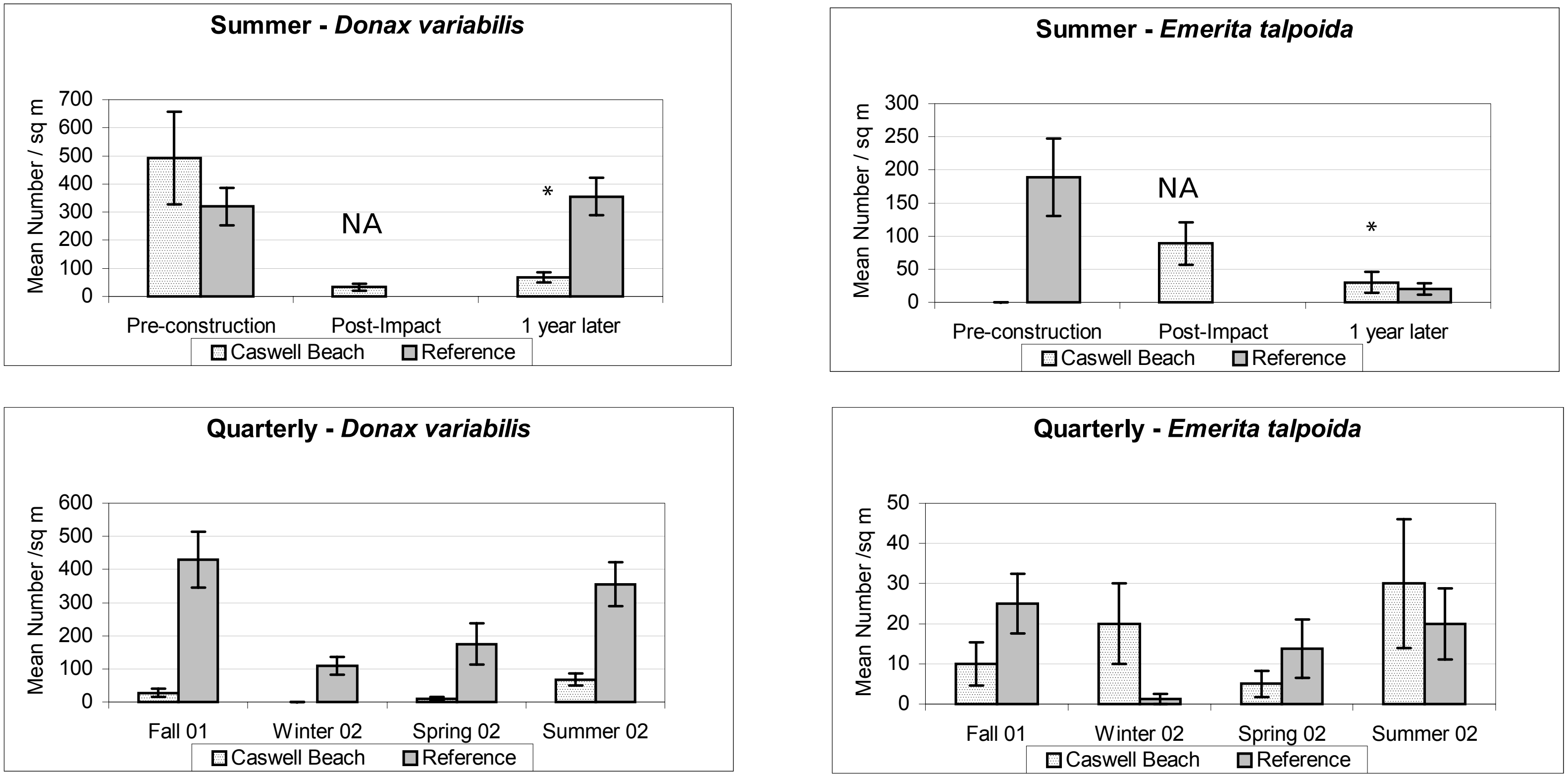


Figure BN-7. Comparison of *Donax variabilis* and *Emerita talpoida* abundances in the swash habitat at Caswell Beach among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. NA = no test conducted. No statistical tests were conducted on the quarterly data.

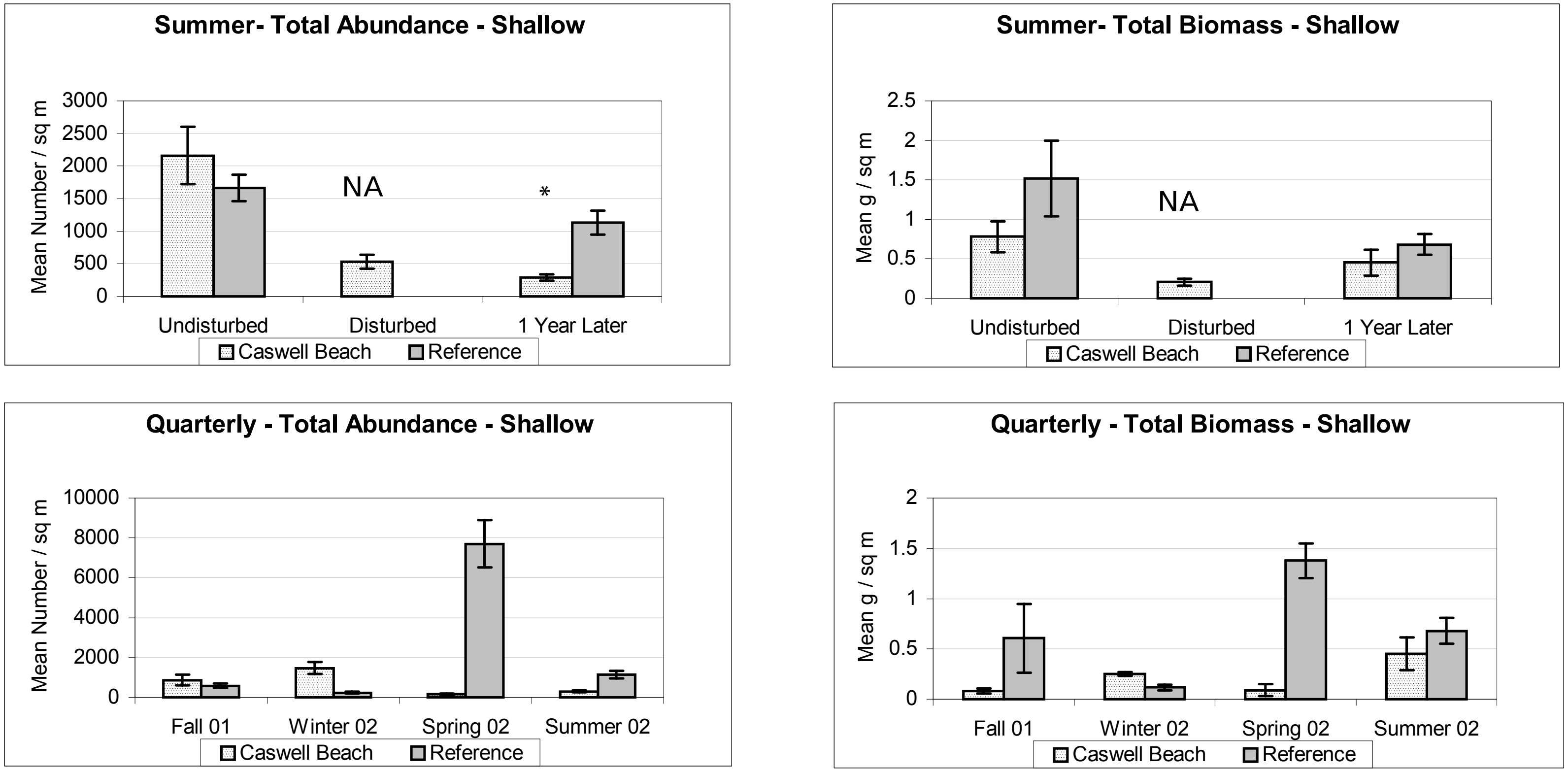


Figure BN-8. Comparison of mean total abundance and total biomass in the shallow habitat at Caswell Beach among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. NA = no test conducted. No statistical tests were conducted on the quarterly data.

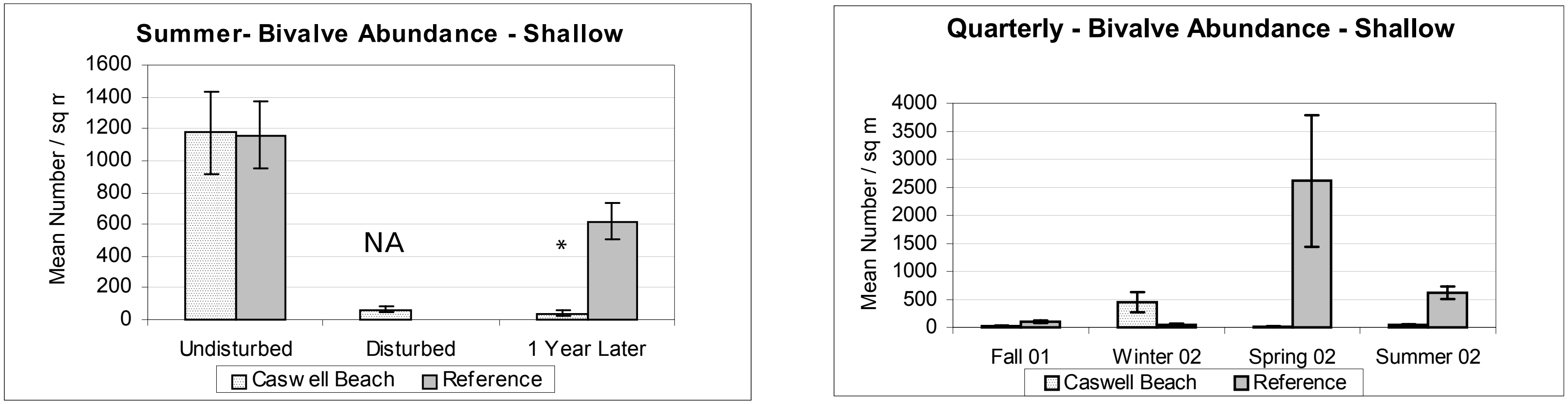


Figure BN-9. Comparison of mean bivalve abundance in the shallow habitat at Caswell Beach among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. NA = no test conducted. No statistical tests were conducted on the quarterly data.

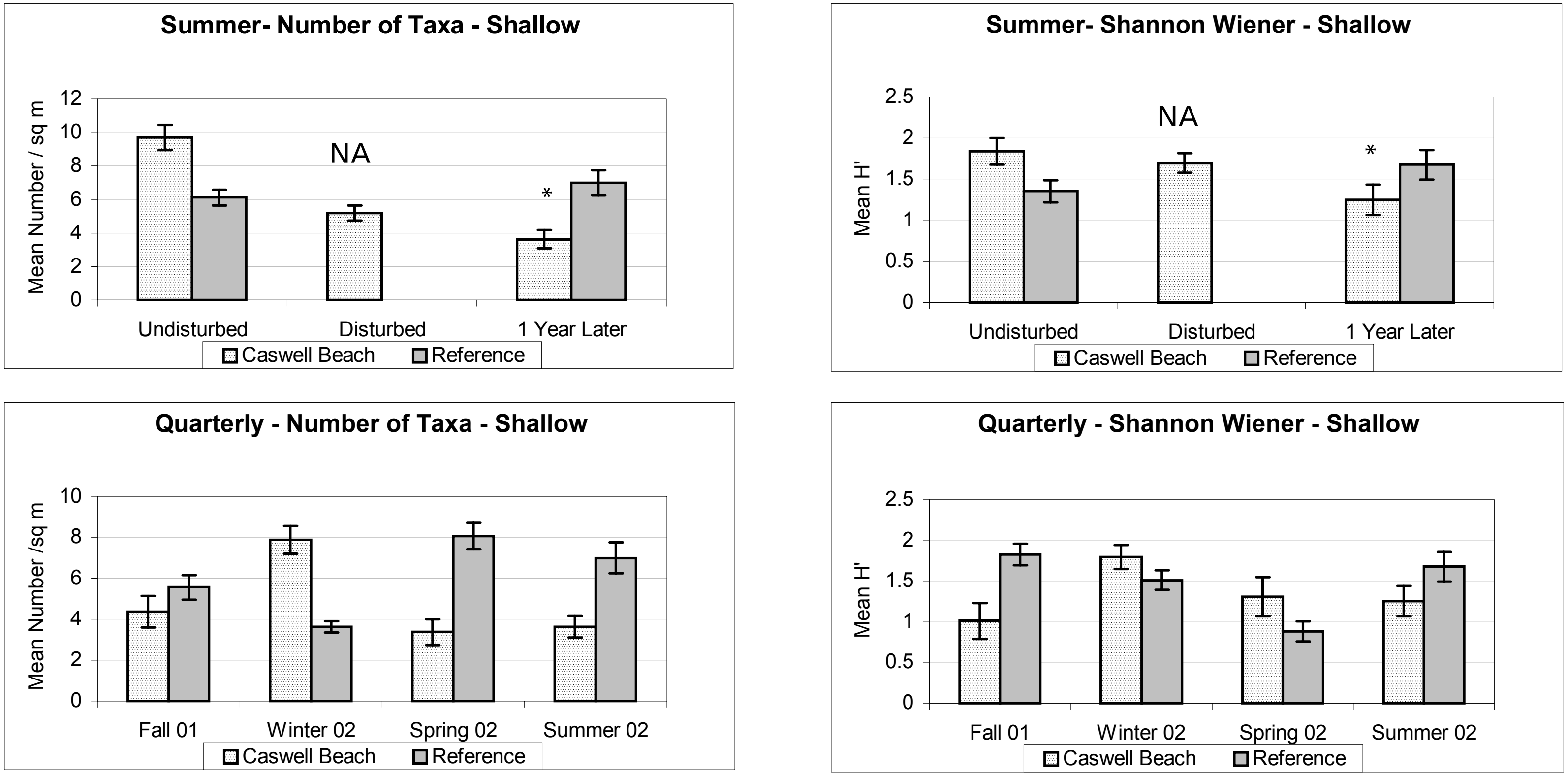


Figure BN-10. Comparison of mean number of taxa and the Shannon Wiener Diversity Index in the shallow habitat at Caswell Beach among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. NA = no test conducted. No statistical tests were conducted on the quarterly data.

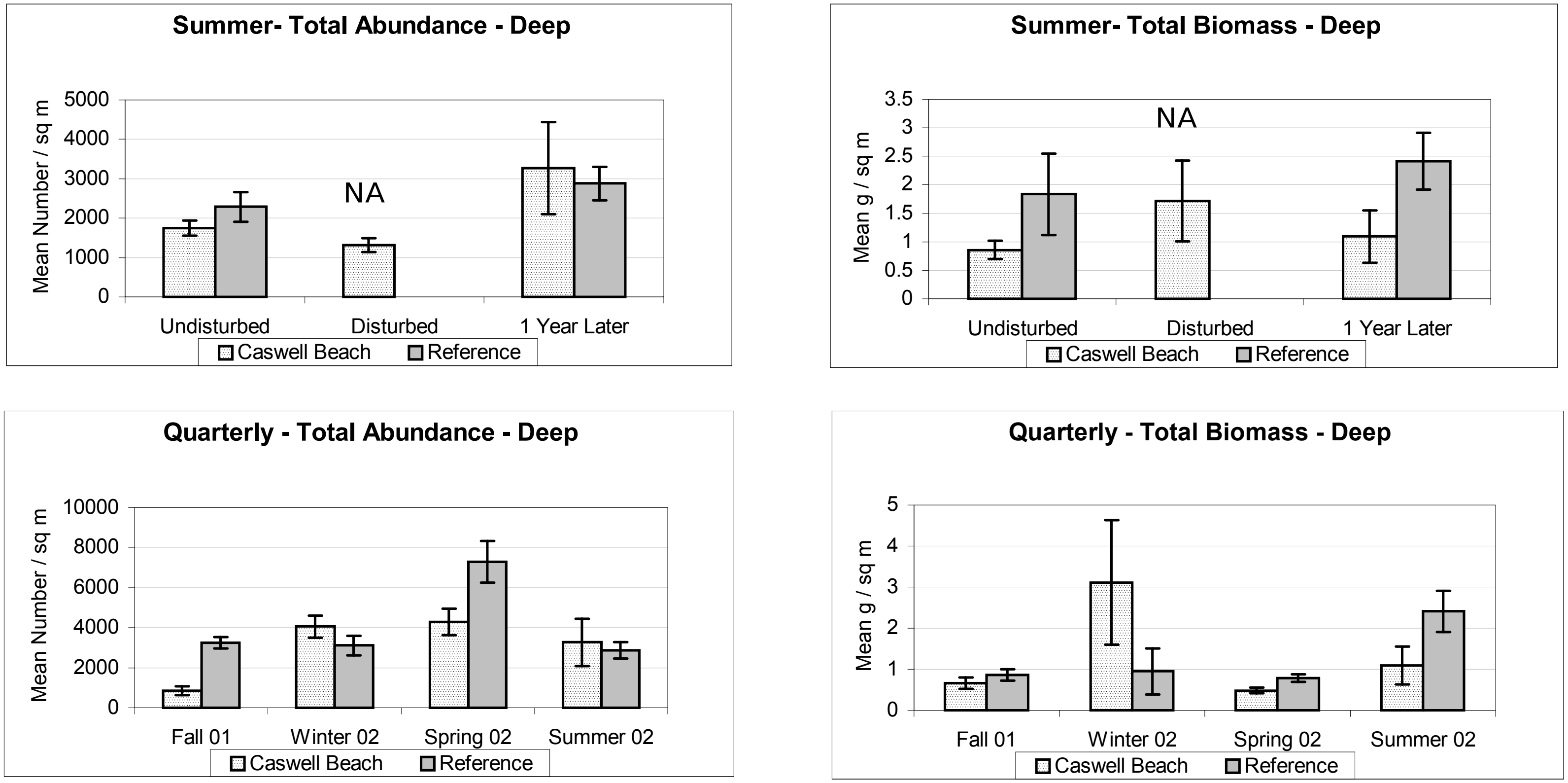


Figure BN-11. Comparison of mean total abundance and total biomass in the deep habitat at Caswell Beach among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. NA = no test conducted. No statistical tests were conducted on the quarterly data.

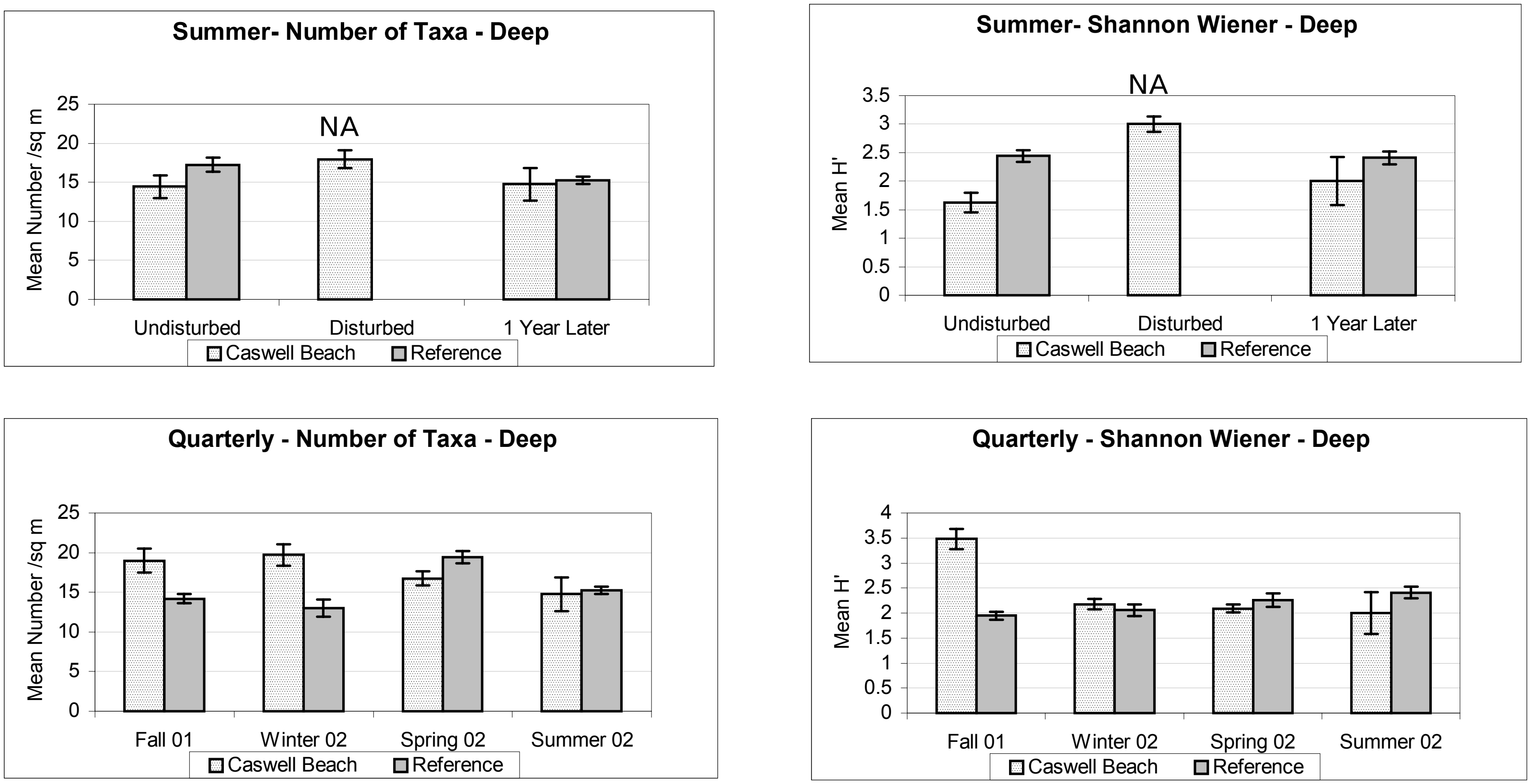
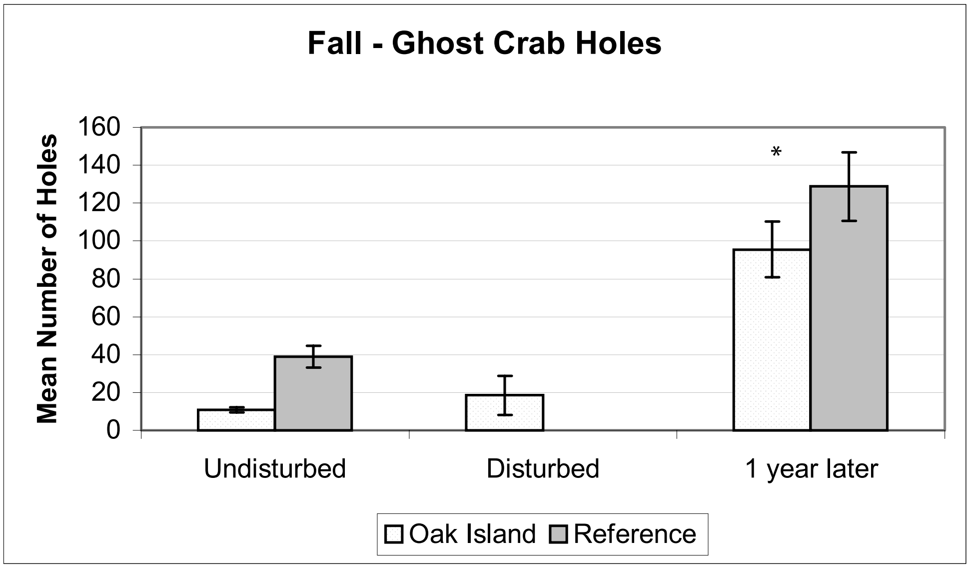


Figure BN-12. Comparison of mean number of taxa and the Shannon Wiener Diversity Index in the deep habitat at Caswell Beach among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. NA = no test conducted. No statistical tests were conducted on the quartelry data.



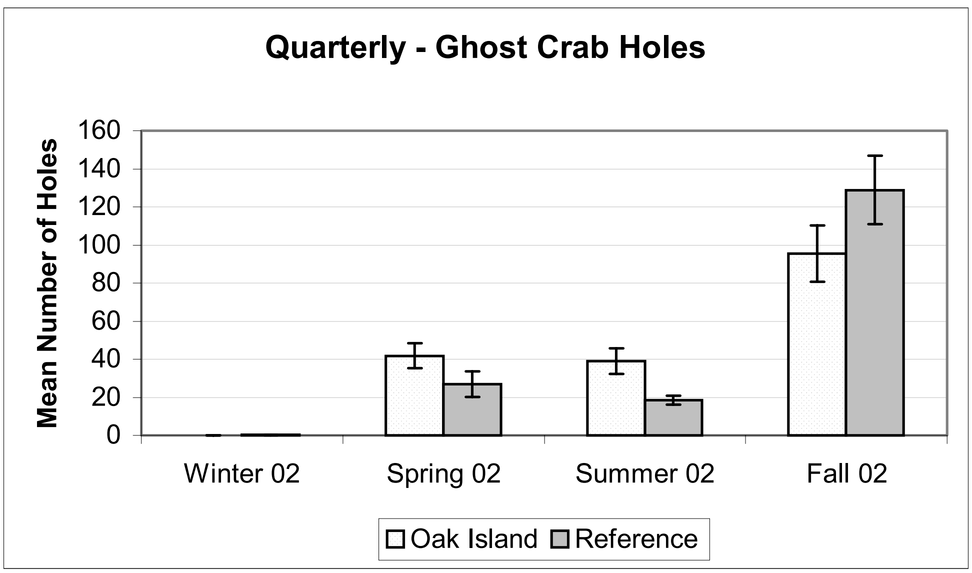


Figure BN-13. Comparison of ghost crab holes in the wrack habitat at Oak Island among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. No statistical tests were conducted on the quarterly data.

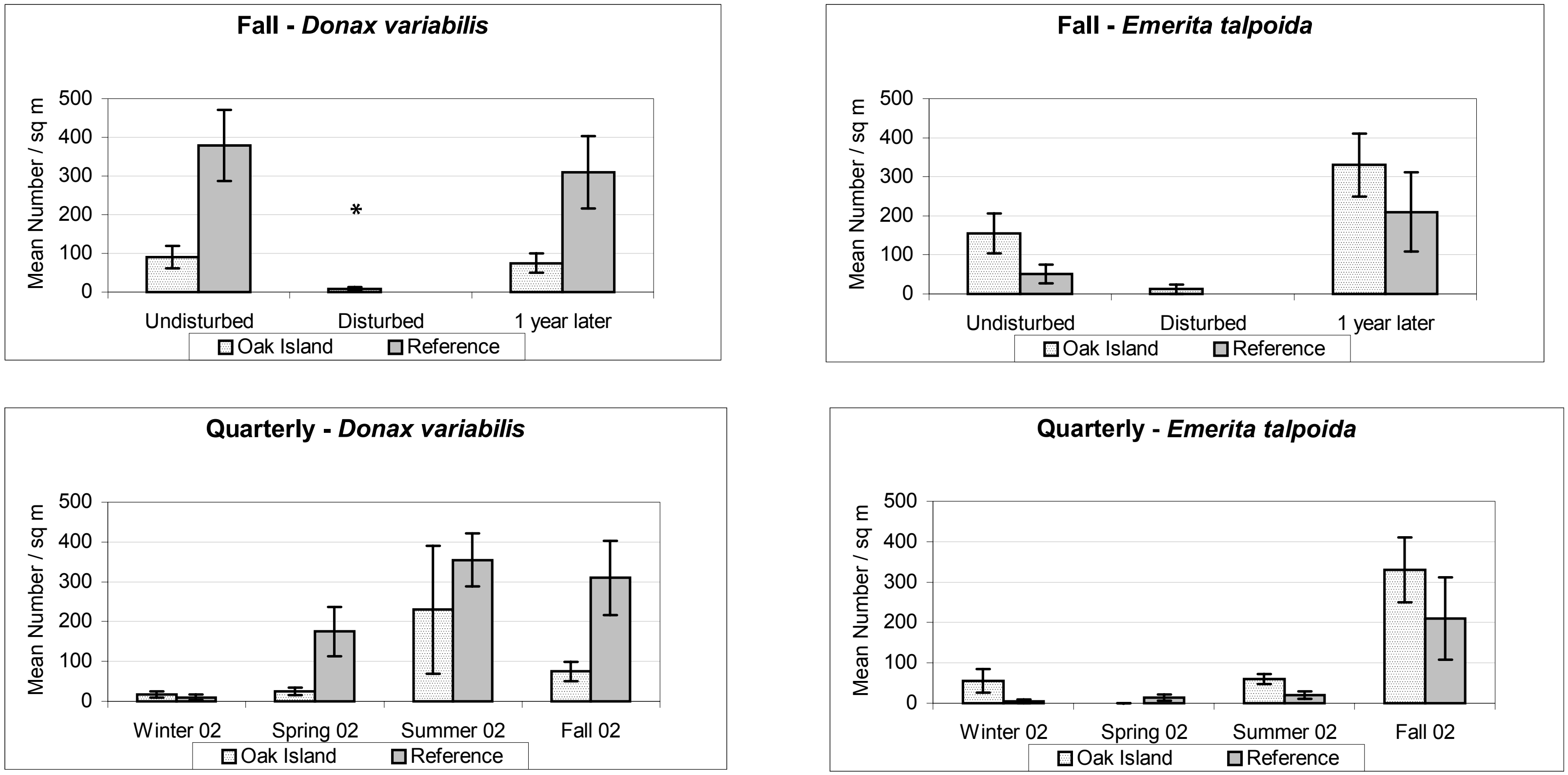


Figure BN-14. Comparison of *Donax variabilis* and *Emerita talpoida* abundances in the swash habitat at Oak Island among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. No statistical tests were conducted on the quarterly data.

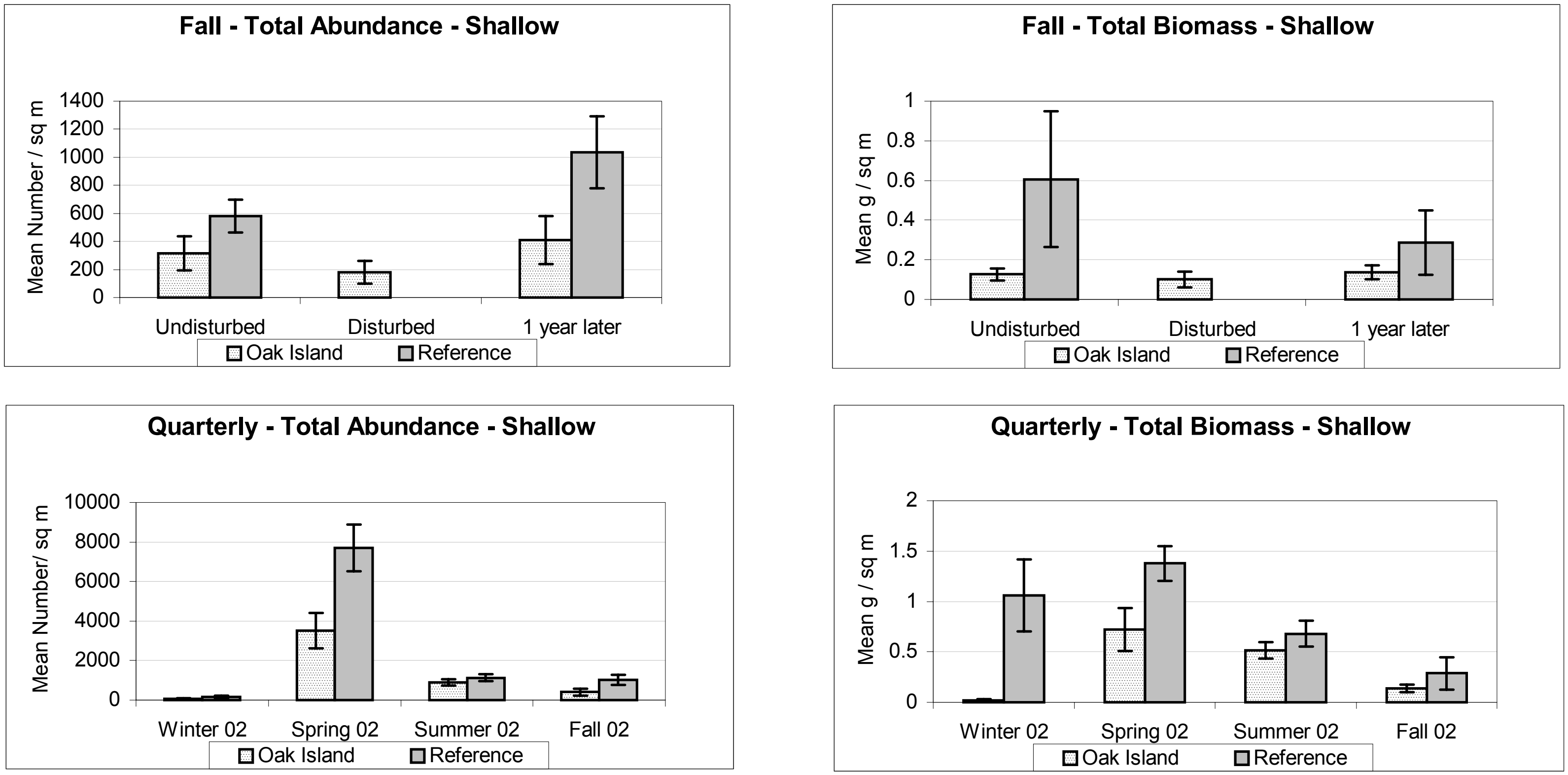


Figure BN-15. Comparison of mean total abundance and total biomass in the shallow habitat at Oak Island among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. No statistical tests were conducted on the quarterly data.

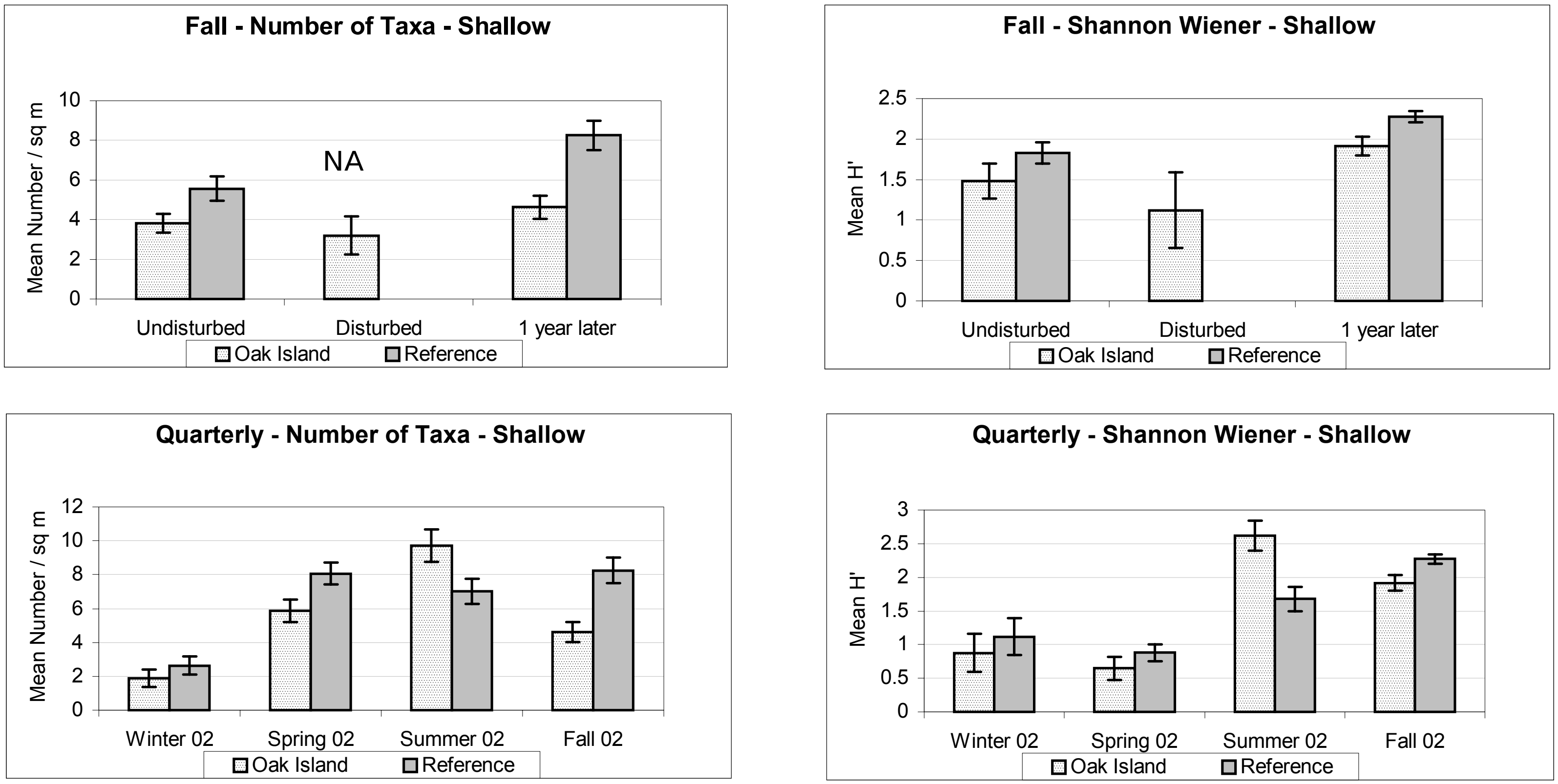


Figure BN-16. Comparison of mean number of taxa and the Shannon Wiener Diversity Index in the shallow habitat at Oak Island among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. NA = no test conducted. No statistical tests were conducted on the quarterly data.

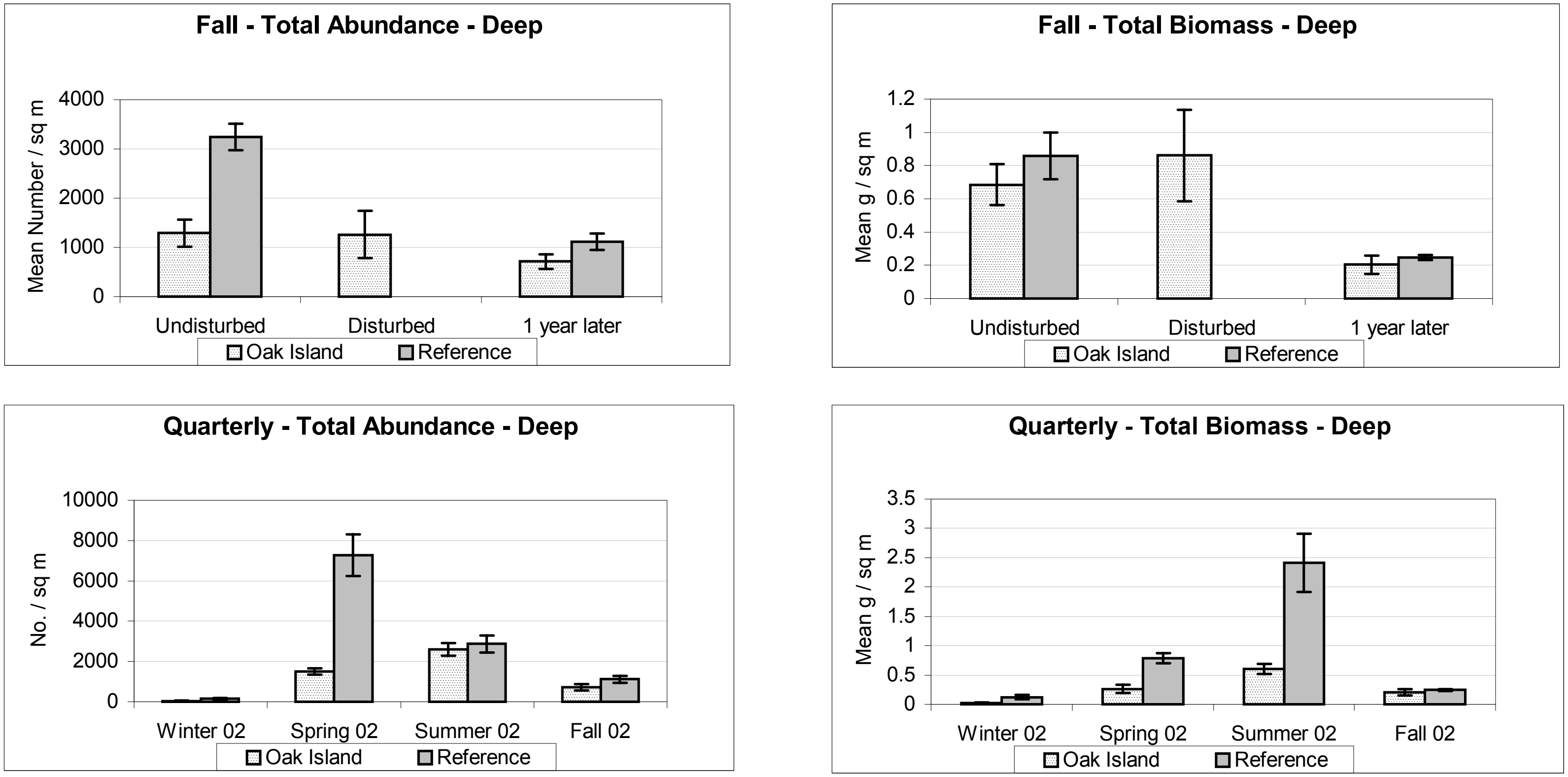


Figure BN-17. Comparison of mean total abundance and total biomass in the deep habitat at Oak Island among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. No statistical tests were conducted on the quarterly data.

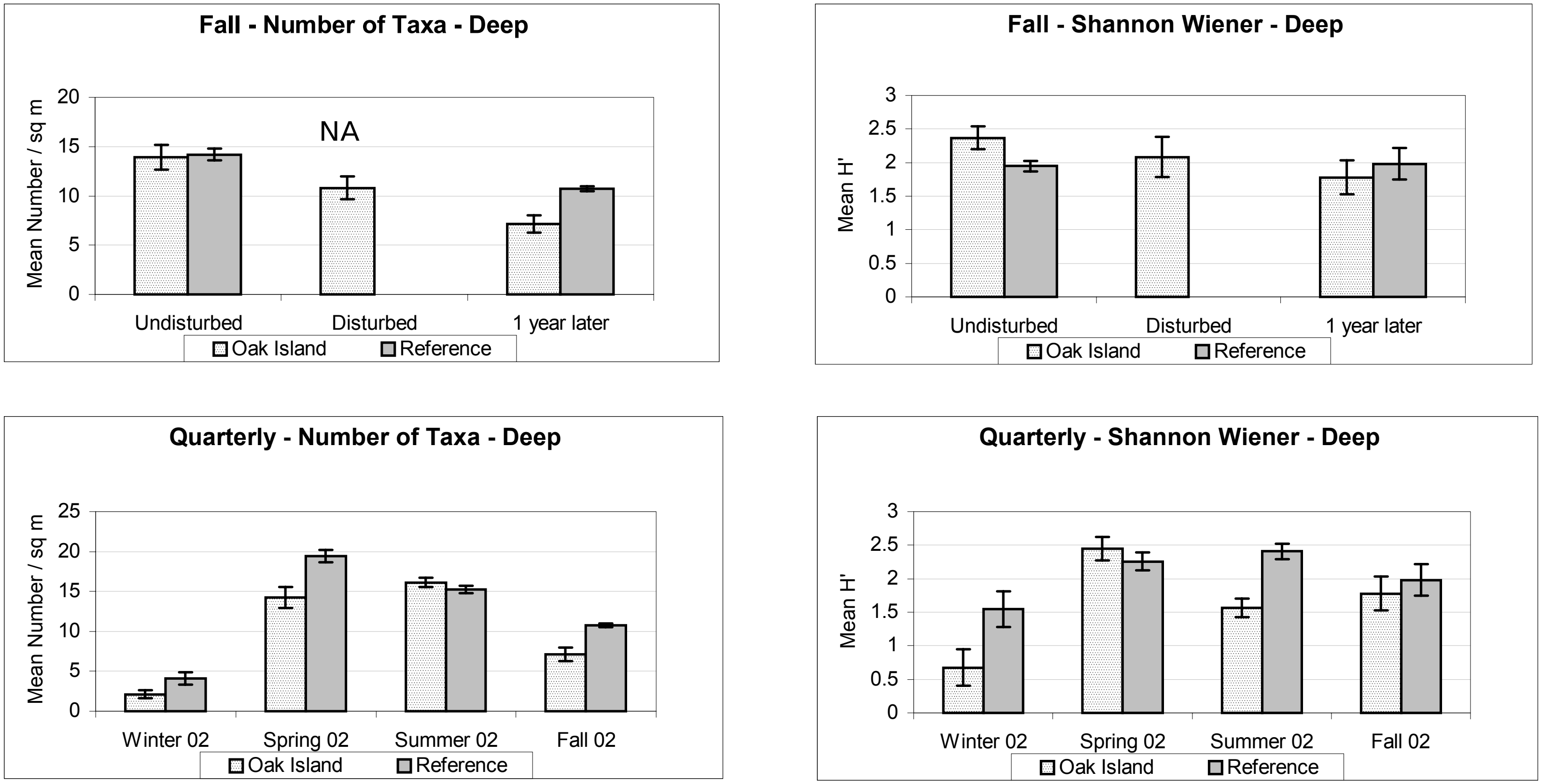
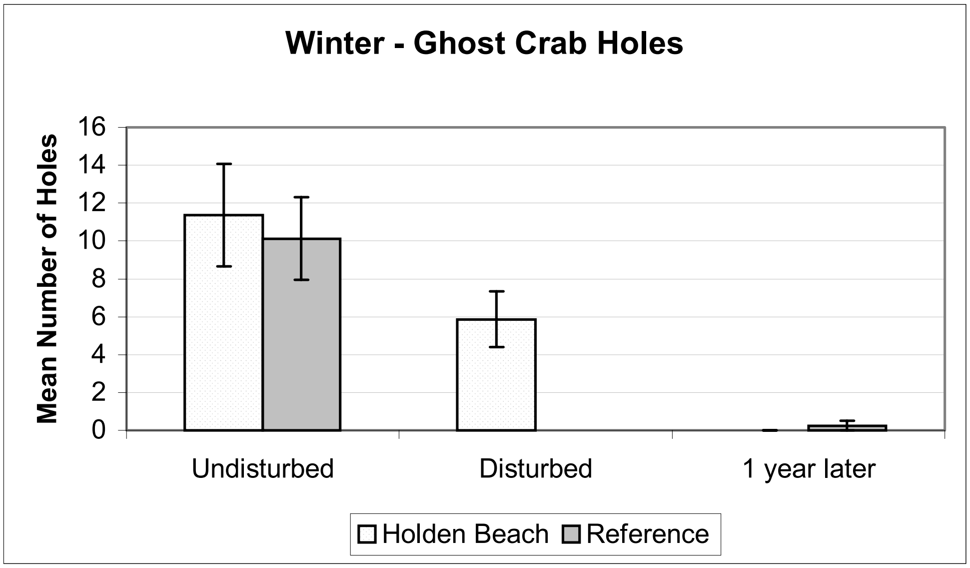


Figure BN-18. Comparison of mean number of taxa and the Shannon Wiener Diversity Index in the deep habitat at Oak Island among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. NA = no test conducted. No statistical tests wee conducted on the quarterly data.



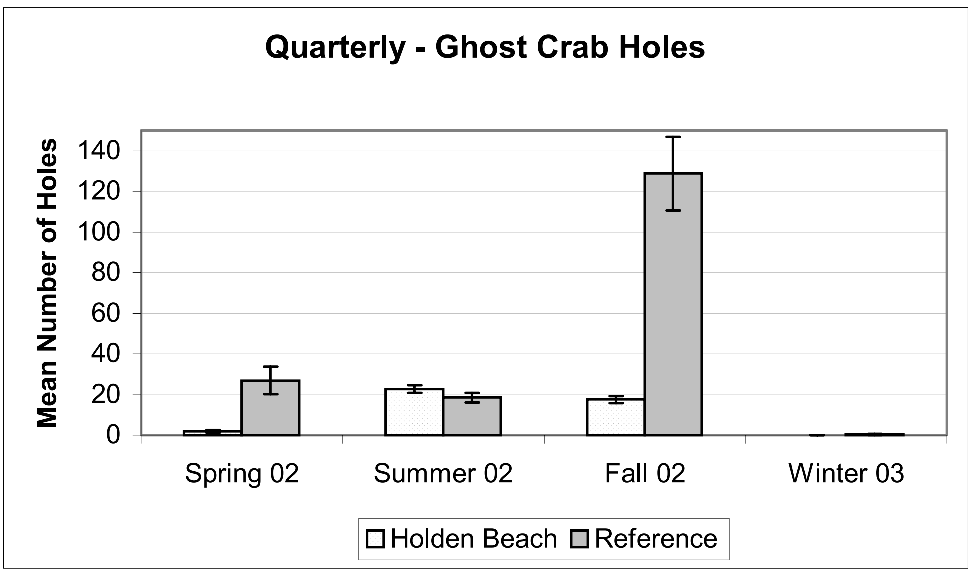


Figure BN-19. Comparison of ghost crab holes in the wrack habitat at Holden Beach among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. No statistical tests were conducted on the quarterly data.

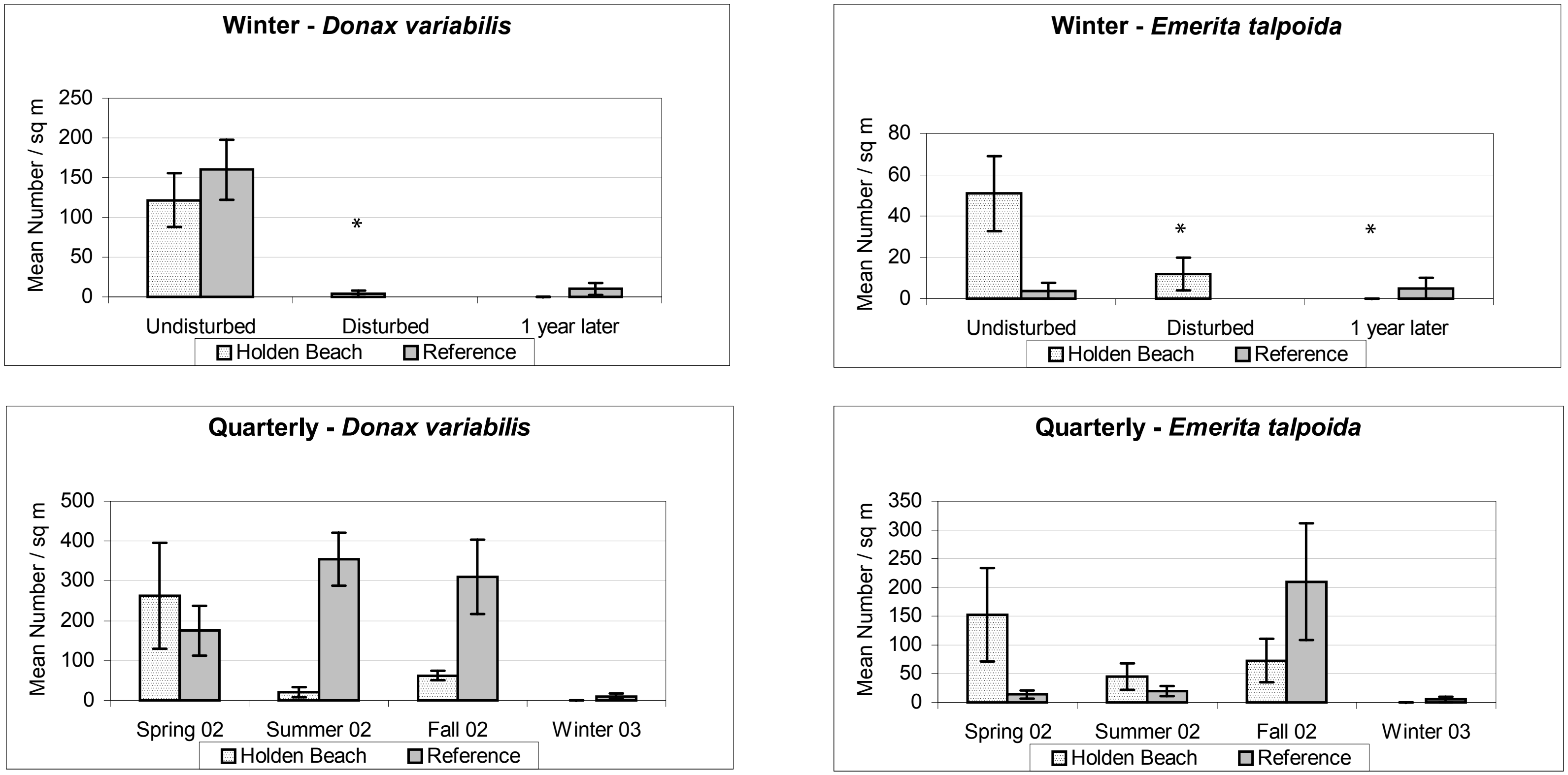


Figure BN-20. Comparison of *Donax variabilis* and *Emerita talpoida* abundances in the swash habitat at Holden Beach among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. No statistical tests were conducted on the quarterly data.

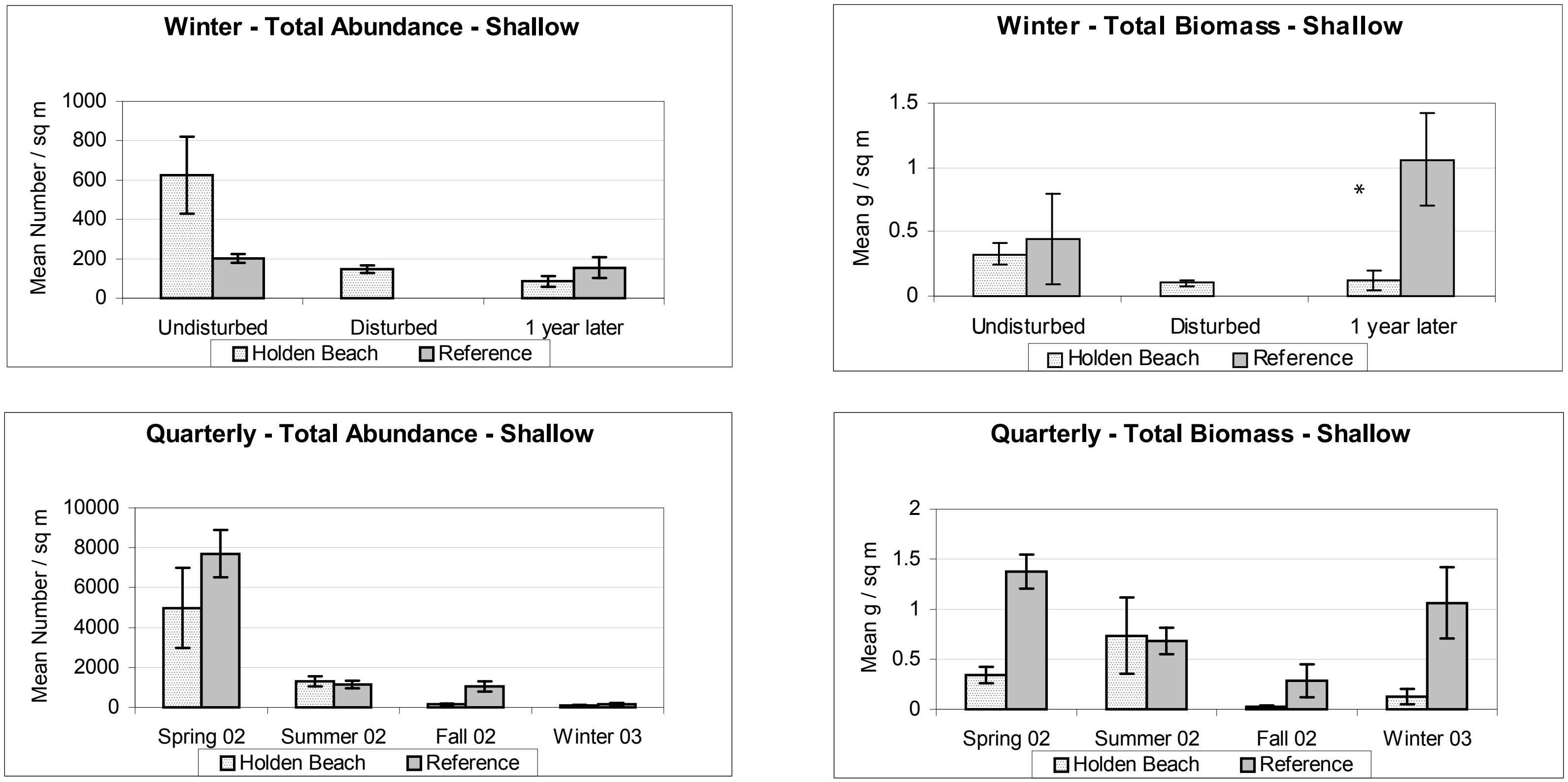


Figure BN-21. Comparison of mean total abundance and total biomass in the shallow habitat at Holden Beach among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. No statistical tests were conducted on the quarterly data.

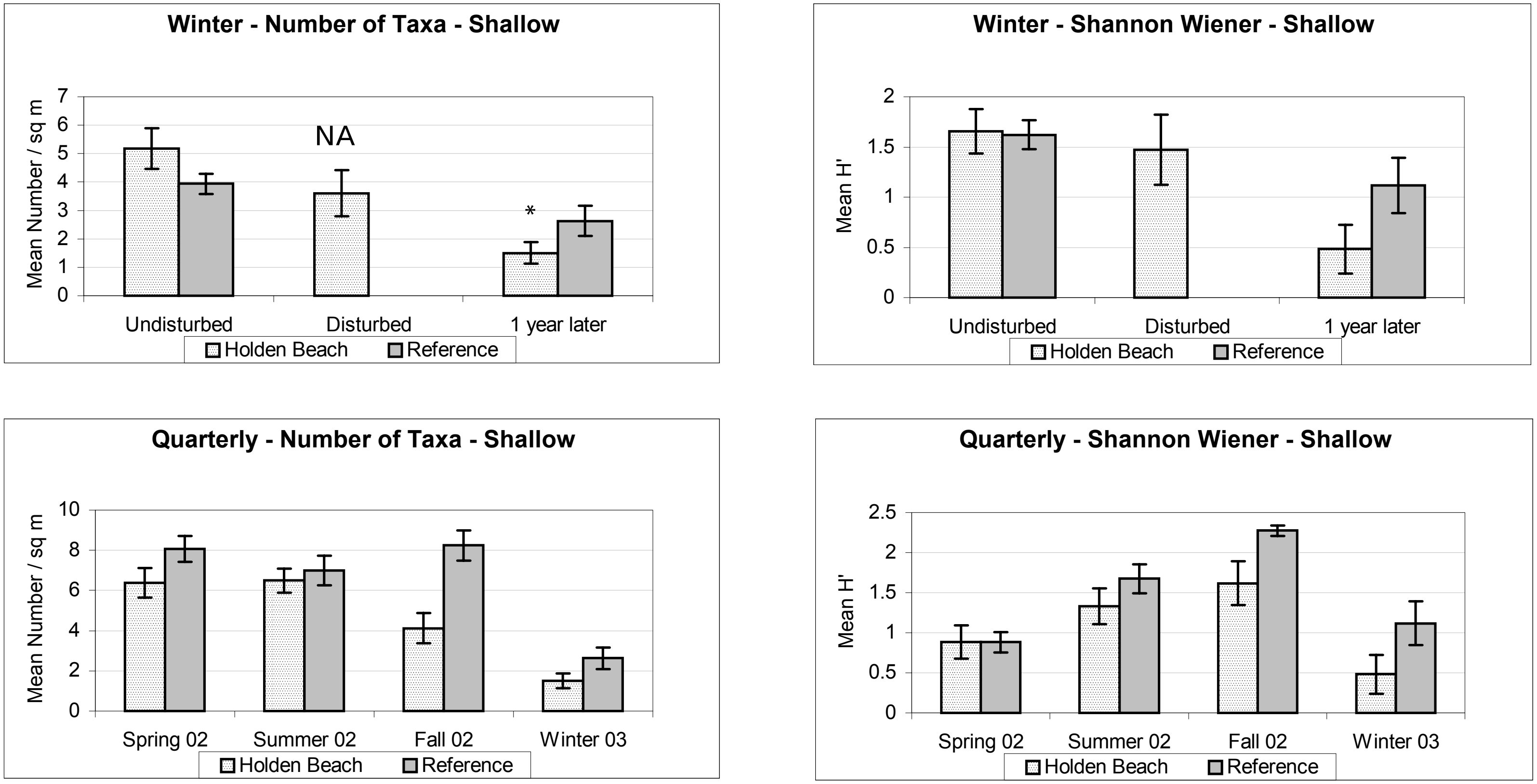


Figure BN-22. Comparison of mean number of taxa and the Shannon Wiener Diversity Index in the shallow habitat at Holden Beach among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. NA = no test conducted. No statistical tests were conducted on the quarterly data.

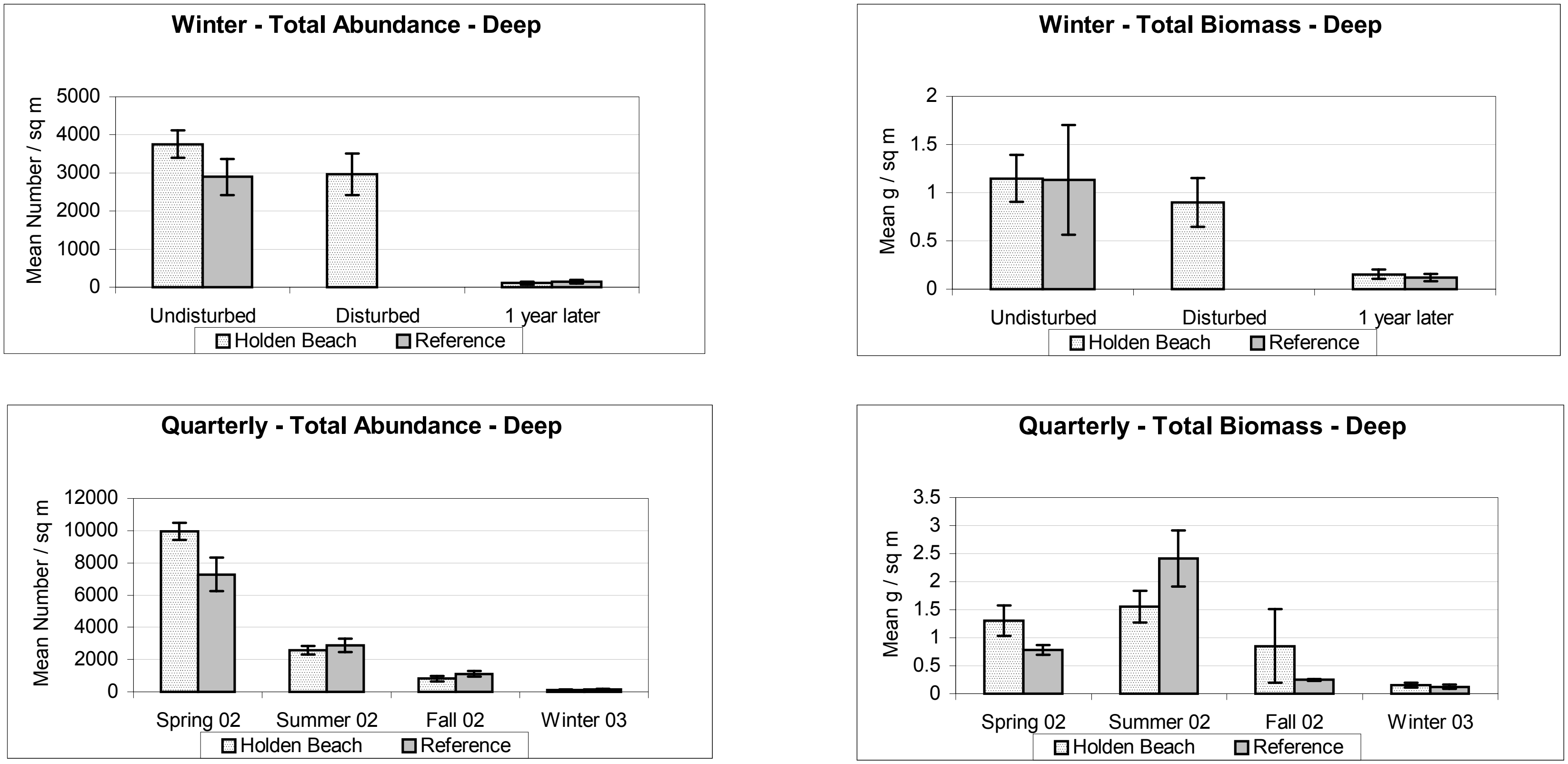


Figure BN-23. Comparison of mean total abundance and total biomass in the deep habitat at Holden Beach among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. No statistical tests were conducted on the quarterly data.

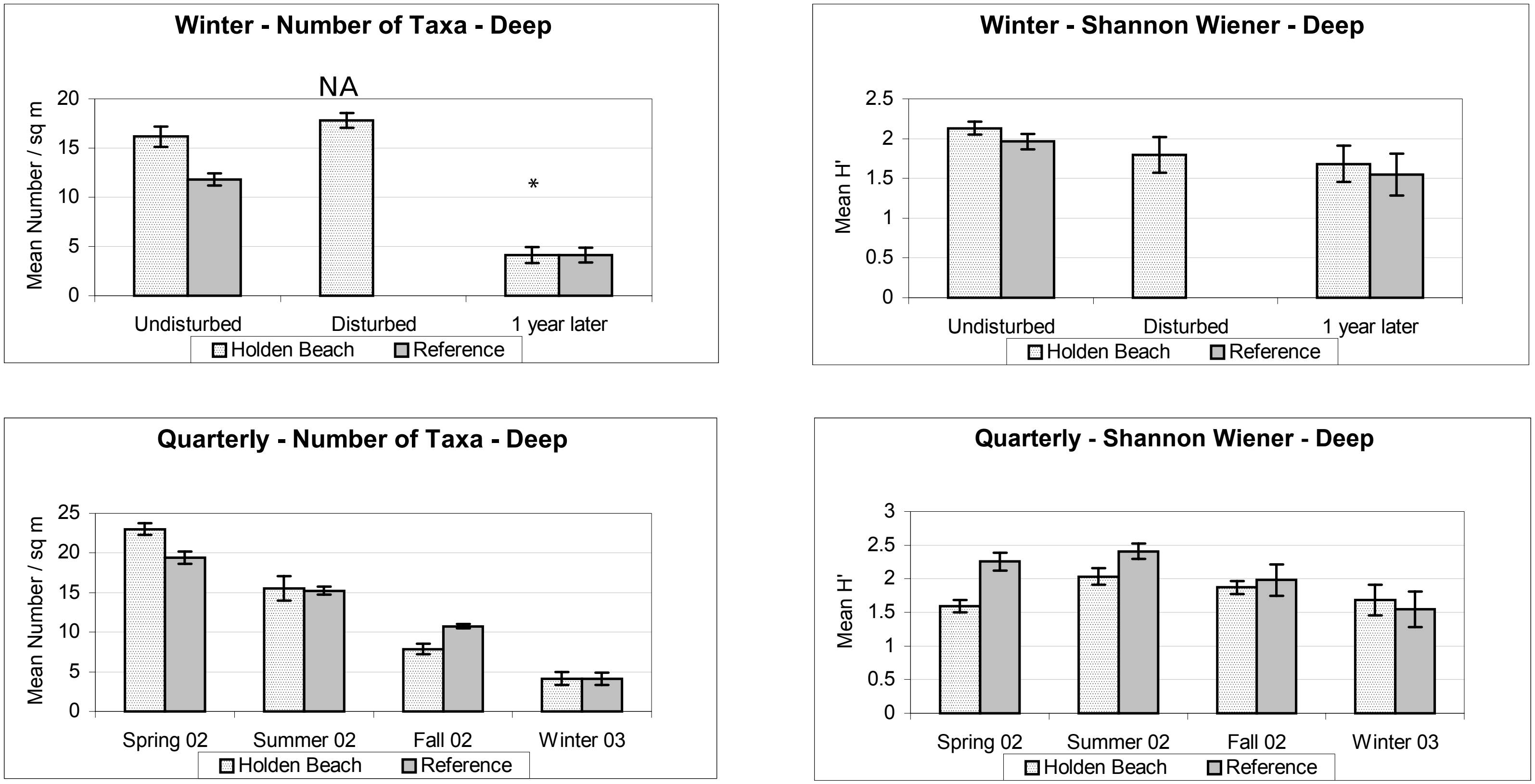


Figure BN-24. Comparison of mean number of taxa and the Shannon Wiener Diversity Index in the deep habitat at Holden Beach among undisturbed, disturbed, and recovery collections (1-year later) and during quarterly sampling conducted after sand placement. * = significant difference at the 0.05 p-level. A significant difference between undisturbed vs. disturbed was based on differences among means (Versar 2002), whereas a significant difference displayed for one-year later was based on ANOVA year/beach interactions. Error bars = ± 1 SE. NA = no test conducted. No statistical tests were conducted on the quarterly data.

3.4 FISH AND NEKTON SAMPLING RESULTS

3.4.1 Overall Summary by Gear

3.4.1.1 Seine Survey (Surf Zone)

Among all seine collections taken in the second year of the beach monitoring, 2,946 fish and nekton comprising 47 species were caught in the surf zone. The catch composition included 41 species of finfish and 6 decapod crustacean species (Figure SE-1; Table SE-1 in Appendix D). During the second year survey, the highest mean abundance of fish were collected in the fall (58/haul) followed by the spring (24/haul), summer (15/haul) and winter (0.4/haul; Appendix D). Catches throughout the quarterly samplings were dominated by bay anchovies (47%) followed by spot (14%; Figure SE-1). Gulf kingfish and Florida pompano were the most prevalent demersal feeding fish species. The speckled swimming crab was the most prevalent decapod crustacean taken in the seine collections. All sites exhibited similar trends in species composition and abundance; however, there was a general tendency of lower diversity at the reference beach.

During the spring 2002 seine collections, bay anchovies accounted for 66% of the 2,081 individuals caught while 20% were spot (Figure SE-1). In the summer 2002, 35% of the 705 organisms taken in the beach seines were white mullett, 33% were Florida pompano, and 13% were Gulf kingfish. Of the 153 fish and macroinvertebrates caught in the fall 2002 seine collections, 47% were Atlantic bumper, 25% were Florida pompano, 7% were Gulf kingfish, and 4% were windowpane. In the winter of 2003, only 7 total organisms and 2 species were caught by this gear. Only one of the two species caught during the winter collection was a finfish, the Gulf kingfish, which contributed 86% to the total catch. Mudcrabs were the other taxa contributing 14% to the total catch (Figure SE-1)

3.4.1.2 Trawl Survey (Deep Habitat)

More species and a greater number of individuals were collected in the trawls towed just outside the surf zone in about 15 feet of water compared to beach seine collections in the surf zone (Table 1 in Appendix E). The sum of all catches in the trawl samples standardized to 500 m of tow length for the second year was 37,612 fish and macroinvertebrates. Overall, 91 species were collected, with catch composition being dominated by bay anchovies (65%) followed by striped anchovies (18%; Figure TR-1). For the trawl survey, an average of 312/500 m were collected in the spring 2002 surveys and an average of 809 organisms/500 m were collected in the summer 2002 (Appendix E). Many fewer organisms per trawl were collected in the fall (8/500 m) and winter seasons (26/500 m; Appendix E).

During the spring, 71% of the 12,474 specimens caught in the trawls (standardized to 500m tow length) were bay anchovies (Figure TR-1). In summer 2002, 62% of the 24,271 specimens caught were bay anchovies and 25% were striped anchovies. Of the 79 organisms caught in the fall 2002 trawl collections, 58% were southern kingfish and 14% were striped anchovies. Bay anchovies disappeared during the fall sampling period. In the winter of 2003, 56% of the 788 organisms caught were bay anchovies, 14% were pinfish, and 12% were Atlantic silverside.

3.4.2 Assessment of Long-term Impact of Beach Replenishment

The mean catch per unit effort (CPUE) for the seine and trawl collections provide estimates of relative abundance in the surf zone and deep habitat, respectively. Although the beach seine and trawl samples represent catch per area or volume swept, results are presented as mean number of fish per beach seine haul, and mean catch per 500 m trawling distance. Because fish generally are highly patchy with a variance in CPUE related to the mean, a log transformation (CPUE +1) was used in the analysis of variance to normalize the data. Abundance indices for all species combined (i.e., fish and macroinvertebrates), and for all species except bay anchovies were analyzed. The analysis of CPUE data without bay anchovies was conducted to evaluate if the large variability in catches of this patchily distributed schooling fish masked effects of beach replenishment on other species.

3.4.3 Bald Head Island (Initial Impact: Spring 2001)

3.4.3.1 Beach Survey (Surf Zone)

Bald Head Island was replenished in the spring of 2001, with beach seine collections taken before and after at the subject beach and the reference beach to assess the short-term impacts during an 8 week sampling period. To evaluate long-term impact, samples were collected one-year after impact at the study beach and reference beach. No quarterly samples were collected at Bald Head Island.

The comparison of undisturbed beach seines during spring 2001 to samples collected one-year later during spring of 2002 indicated that the mean CPUE collected per haul and the species diversity was not depressed one-year after the beach construction (Table SE-1, Figure SE-2). Bald Head Island and the reference beach had similar mean CPUE during 2001, but the CPUE at Bald Head Island was significantly higher than at the reference beach one-year later. The year/beach interaction term in the ANOVA, which accounts for both year and beach effects in the comparisons, indicated statistically significant differences in mean CPUE (all species combined) and number species between the undisturbed samples and recovery samples one-year later (Table SE-1, Figure SE-2).

The mean CPUE and total number of species at Bald Head Island were significantly higher one-year post construction. Furthermore, as indicated in Figure SE-2 the mean CPUE and number of species taken at the disturbed stations immediately after beach construction were either similar to or greater than levels observed at the undisturbed stations. Analysis of variance of seine data without bay anchovies showed no significant reduction in CPUE at the subject beach one-year after the replenishment when compared to the reference beach. As expected for patchy fish populations, the species composition in the samples from both the subject beach and the reference beach exhibited large variability across years. However, bay anchovy and rough silverside made up a large portion of the catches at Bald Head Island before disturbance while one-year after beach construction bay anchovy and spot became the dominant species (Figures SE-3 and SE-4). Based on the assessment results, the beach seine survey does not support the hypothesis that beach replenishment caused a significant reduction in fish abundance and diversity one-year later at Bald Head Island.

3.4.3.2 Trawl Survey (Deep Habitat)

Fish collections in the deep habitat near Bald Head Island with the trawl generally resulted in larger catches and more species relative to the seine collections. No statistically significant long-term reduction in mean CPUE and diversity were observed at Bald Head Island after adjusting for the annual variation at the reference beach (i.e., the year/beach interaction term was not significant for all the parameters tested) (Table TR-1). Although the estimated mean CPUE at Bald Head Island shifted from being higher than at the reference before the replenishment occurred in 2001, to being lower one-year later, this relative change in CPUE was not significant. As can be seen from Figure TR-2, the estimated mean CPUE at the reference beach during spring 2002 had large sampling errors. The species diversity was similar at Bald Head Island and the reference beach before and after impact. Analysis of variance of trawl catches excluding bay anchovies did not show any significant reduction in mean CPUE one-year after the beach replenishment. As with the seine collection, no quarterly sampling with the trawl was conducted off Bald Head Island to assess seasonal differences prior to the one-year post-construction sampling. The species composition at the Bald Head Island and the reference beach before and one-year after construction were dominated by bay anchovy (Figure TR-3). Species composition at Bald Head Island without bay anchovies indicated that, coarse hand ladycrab, ladycrab, and butterfish were prevalent in catches before impact and one-year post construction (Figure TR-4).

3.4.4 Caswell Beach (Initial Impact: Summer 2001)

Caswell Beach was replenished in the summer of 2001, and was disturbed twice during the beach construction because the dredging contractor was required to add more sand to the beach after initial construction. Based on the studies conducted during the construction year (Versar 2002) this "double impact" affected the benthic communities more than the other beaches monitored in the construction year.

3.4.4.1 Seine Survey (Surf Zone)

Despite the fact that no immediate reduction in mean CPUE and number of species was observed between first year disturbed and undisturbed samples, the ANOVA of long-term effects suggest there may have been a long-term effect. The mean CPUE across species and the mean number of species per seine haul one-year after replenishment were significantly lower based on the year/beach interaction than the means for the seine hauls taken before construction (Table SE-1, Figure SE-5). However, the Shannon Wiener Diversity Index one-year after construction did not significantly differ from the diversity observed before the construction. The apparent impairment in abundance and mean number of fish species in the surf zone a year after impact was not corroborated by collections taken during the quarterly sampling because the impacted beach actually had higher abundance and diversity than the reference beach in the three subsequent seasons following initial impact (Figure SE-6). If the beach construction significantly altered the fish communities, depressed values would be expected in at least some seasons following the construction. Since this was not the case at Caswell Beach, the significant depression in mean CPUE and number of species one-year later is more likely a result of natural fluctuations not fully accounted for in the experimental design, and not directly a result of the beach construction. The species composition at the subject beach before and one-year after impact was comparable, with Florida pompano and Gulf kingfish being most common in the catches both years (Figure SE-7).

3.4.4.2 Trawl Survey (Deep Habitat)

As observed for Bald Head Island, higher catches representing more species were taken in the Caswell Beach trawl sampling conducted a few hundred feet off-shore of the study beaches. ANOVA testing for differences between construction year sampling and post construction sampling one-year later did not detect any significant year/beach interactions, although significantly higher mean CPUE were indicated for the post construction sampling conducted in the second year of the program (Table TR-1, Figure TR-5). Subsequent quarterly trawl sampling in the fall resulted in extremely high mean CPUE of bay anchovies when 96% of nearly 50,000 fish/500 m was made up of this species (Figure TR-6). Catches at the subject beach relative to the reference beach in all subsequent quarterly samplings were similar, ranging from 125 to nearly 2,000 organisms/500 m. The ANOVA of trawl catches excluding bay anchovies did not show any significant reduction in mean CPUE one-year after construction when compared to the reference beach. The species composition of trawl catches in deep waters showed appreciable variation across years at both the subject beach and the references beach, but bay anchovy was the most prevalent species in both years at Caswell Beach (Figures TR-7 and TR-8).

3.4.5 Oak Island (Initial Impact: Fall 2001)

Oak Island was replenished in the fall of 2001. Limited short-term impact on the surf zone fish communities were observed during the first year's study (Versar 2002).

3.4.5.1 Seine Survey (Surf Zone)

The ANOVA of long-term effects for the surf zone showed a significant decline in the mean number of species one-year after construction when compared to the pre-construction community, but no significant long-term reduction in the mean CPUE and diversity (Shannon Wiener) were detected (Table SE-1, Figure SE-8). The ANOVA of seine catches excluding bay anchovies indicated a reduction in mean CPUE at the subject beach one-year later, although not significant ($p=0.07$ for the year/beach interaction). As for the Caswell beach comparison, the quarterly sampling at the subject beach and the reference beach showed that in two of the four subsequent seasonal samplings events the number of species was actually higher at the affected beach relative to the reference beach (e.g., winter 2002, spring 2002 and summer 2002; Figure SE-9). Again, this suggests that the annual difference in number of species was a result of natural variability in abundance and species composition, rather than being caused by the beach construction. The species composition in the catches at Oak Island before and shortly after the construction was dominated by Gulf kingfish (Figure SE-10), and was similar to the composition of the catches at the reference beach during fall 2001. Gulf kingfish accounted for 55% to 84% of all specimens caught at Oak Island and the reference beach during fall 2001 sampling events, but was less prevalent in catches along both beaches one-year after construction (8% to 5%). The catch composition at Oak Island one-year later was dominated by Atlantic bumper (52%), but this species was not recorded at the reference beach.

3.4.5.2 Trawl Survey (Deep Habitat)

The ANOVA of trawl collections in the deep habitat did not detect any significant long-term impact from the beach replenishment on mean CPUE across species, number of species, and diversity at Oak Island, after controlling for annual variation also observed at the reference beach (Table TR-1, Figure TR-9). The ANOVA of trawl catches excluding bay anchovies showed no significant reduction in mean CPUE when compared to changes at the reference beach. Quarterly sampling at Oak Island revealed few differences among the parameters measured in the trawl samples (Figure TR-10). Trawl catches at Oak Island before and shortly after the beach construction were dominated by bay anchovies (42% - 63%), while the contemporary catches at the reference beach were dominated by squids and striped anchovies (Figure TR-11). Catches at Oak Island and the reference beach one-year later were dominated by Southern kingfish (41% and 84%). Striped anchovies were prevalent at Oak Island during all sampling events but was not a dominant at the reference beach one-year later. No bay anchovies were caught at either beach one-year after the disturbance. The differences in species composition appear to be driven by natural spatial and temporal variation, and not by the beach construction.

3.4.6 Holden Beach (Initial Impact: Winter 2002)

Holden Beach East was replenished in the winter of 2002 over a relatively long period (about two months) due to dredging equipment breakdowns and weather related problems. Few if any short-term impacts on the surf zone fish communities were observed during the first year's study (Versar 2002).

3.4.6.1 Seine Survey (Surf Zone)

Winter beach seine sampling at Holden Beach produced much lower total catches and number of species relative to the other sampling seasons as would be expected for wintertime fish communities. The ANOVA of seine catches at the subject beach and reference beach before the replenishment started (winter 2002) and one-year after disturbance (winter 2003) did not show any significant long-term reduction in mean CPUE, number of species, and H′ when adjusting for natural yearly variation (Table SE-1, Figure SE-11) quarterly sampling produced similar catches between the subject beach and the reference beach (Figure SE-12). The number of species and the Shannon Wiener Index for the study beach and the reference beach during the seasonal quarterly samples displayed no differences due to beach construction activities (Figure SE-12). The ANOVA of seine catches excluding bay anchovies showed no significant reduction in mean CPUE one-year after in comparison to results at the reference beach. Gulf kingfish was prevalent in the seine catches at Holden Beach before (33%) and shortly after construction (34%), and in the contemporary catches at the reference beach (70%; Figure SE-13). One-year after construction, no fish were caught at Holden Beach, while only one Gulf kingfish was caught at the reference beach. This shift in abundance among years is likely to be caused by patchiness and natural fluctuations in local abundance.

3.4.6.2 Trawl Survey (Deep Habitat)

The ANOVA of trawl collections in the deep habitat at Holden Beach and the reference did not detect any significant long-term impacts from beach replenishment on mean CPUE across all species, number of species, and H′, after controlling for annual variation also observed at the reference beach (Table TR-1, Figure TR-12). The mean CPUE during winter 2003 at the reference beach was substantially lower than at the reference beach during winter 2002 suggesting natural variation not related to the replenishment. The ANOVA of trawl catches excluding bay anchovies indicated no effect of the beach replenishment on mean CPUE one-year after. Additionally, quarterly sampling revealed few differences between Holden Beach and the reference beach among the parameters measured in the trawl survey (Figure TR-13). Bay anchovies were prevalent in the catches at Holden Beach before construction (34%), shortly after (56%), and one-year later (45%); bay anchovies also accounted for a significant portion of the catches at the reference beach before (41%) and one-year after construction (36%; Figure TR-14). Excluding bay anchovies, striped anchovies and spot were common in the catches at Holden Beach before and shortly after construction (Figure TR-15). A change in composition was observed for Holden Beach as well for the reference beach one-year after construction, with Atlantic silverside being the most prevalent species.

3.4.7 Summary of Seine and Trawl Findings

Annual and quarterly beach seine and trawl sampling conducted to examine long-term effects of beach reconstruction on the surf zone fish and nekton communities indicated that there were no significant depressions in abundance and diversity one-year after the initial disturbance. When significant differences where observed between year 1 disturbed and year 2 recovery collections, either an enhancement was indicated or seasonal differences between the subject beach and reference beach were inconsistent. If a significant depression in fish community parameters was caused by the beach construction then the negative effects should be seen in subsequent seasonal collections. This was not the case for the Brunswick County beaches.

Table SE-1. ANOVA results testing for significant differences 1-year after beach construction for mean CPUE, total number of species and the Shannon Wiener Index in seine collections in the surf zone habitat. Significance * was determined at the 0.05 level. Arrow direction indicates whether the second mean in the comparison is higher or lower than the first mean for all significant tests. Highlighted cells indicate that the significant interaction was interpreted as a depression of the parameter one-year later.

Test	Bald Head Island	Caswell Beach	Oak Island	Holden Beach
Mean CPUE				
Undisturbed vs. One-year Later	* ▼	* ▼	NS	* ▼
Beach vs. Reference	* ▼	NS	* ▼	NS
Year/Beach Interaction	*	*	NS	NS
Mean Number of Species				
Undisturbed vs. One-year Later	NS	* ▼	NS	* ▼
Beach vs Reference	NS	* ▼	NS	NS
Year/Beach Interaction	*	*	*	NS
Mean Shannon Wiener				
Undisturbed vs. One-year Later	NS	NS	NS	* ▼
Beach vs. Reference	NS	* ▼	NS	NS
Year/Beach Interaction	NS	NS	NS	NS

Table TR-1. ANOVA results testing for significant differences 1-year after beach construction for mean CPUE, total number of species and the Shannon Wiener Index in trawl collections in the deep habitat. Significance * was determined at the 0.05 level. Arrow direction indicates whether the second mean in the comparison is higher or lower than the first mean for all significant tests. Highlighted cells indicate that the significant interaction was interpreted as a depression of the parameter one-year later.

Test	Bald Head Island	Caswell Beach	Oak Island	Holden Beach
Mean CPUE				
Undisturbed vs. One-year Later	NS	* ▲	* ▼	* ▼
Beach vs. Reference	NS	NS	NS	* ▼
Year/Beach Interaction	NS	NS	NS	NS
Mean Number of Species				
Undisturbed vs. One-year Later	NS	NS	* ▼	* ▼
Beach vs. Reference	NS	NS	* ▼	NS
Year/Beach Interaction	NS	NS	NS	NS
Mean Shannon Wiener				
Undisturbed vs. One-year Later	NS	NS	NS	NS
Beach vs. Reference	NS	NS	* ▼	NS
Year/Beach Interaction	NS	NS	NS	*

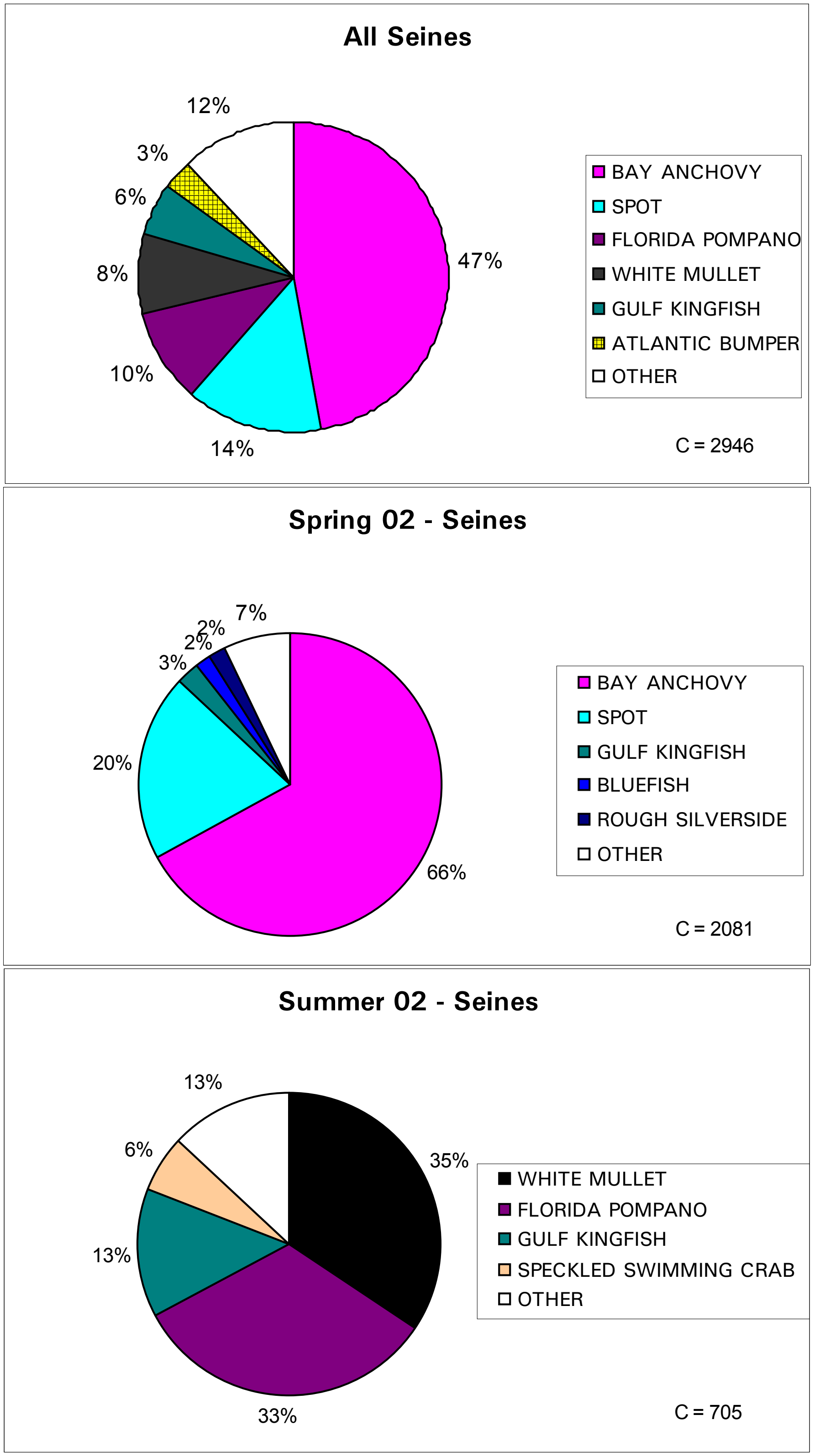
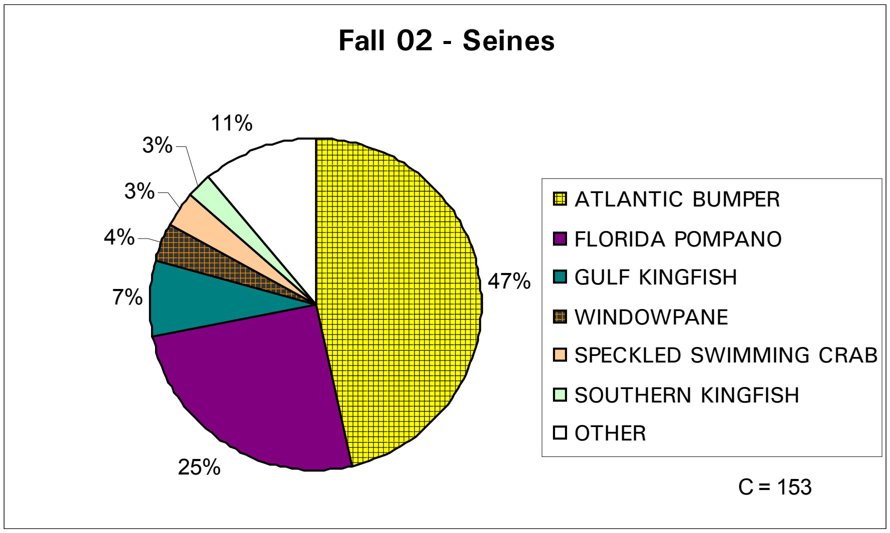


Figure SE-1. Species catch composition for the seine collections taken in the second year of monitoring at Brunswick County beaches. C = standardized total catch per effort.



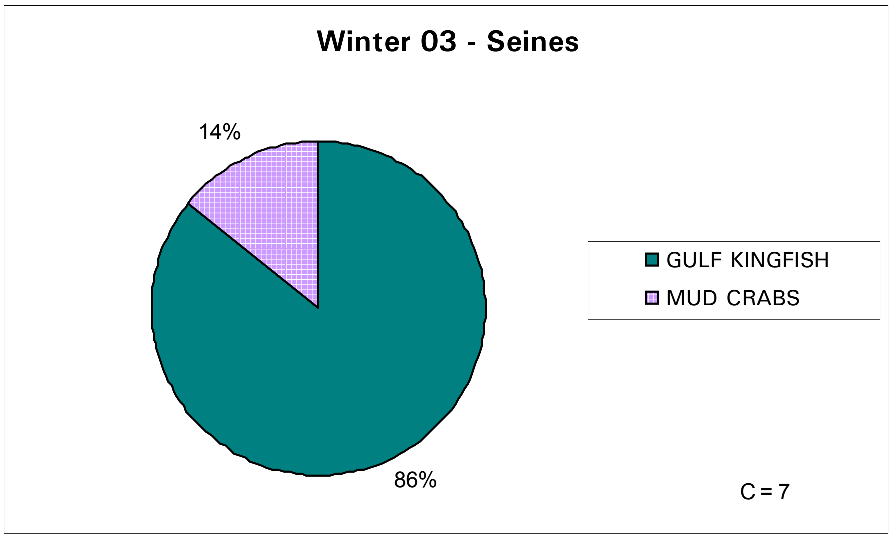


Figure SE-1. (Continued)

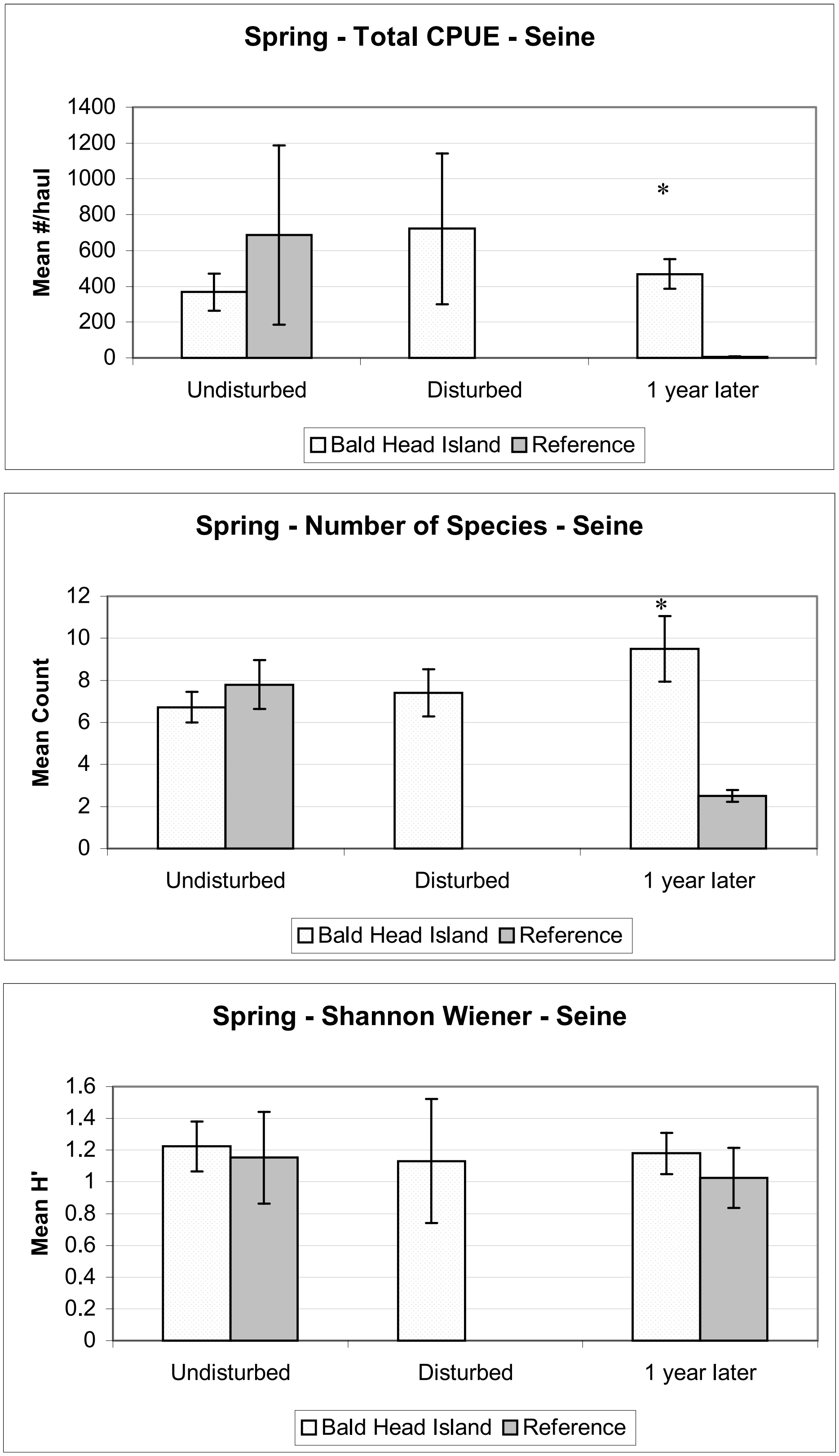


Figure SE-2. Comparison of seine CPUE, number of species, and the Shannon Wiener Diversity Index at Bald Head Island among undisturbed, disturbed, and recovery collections (1-year later).

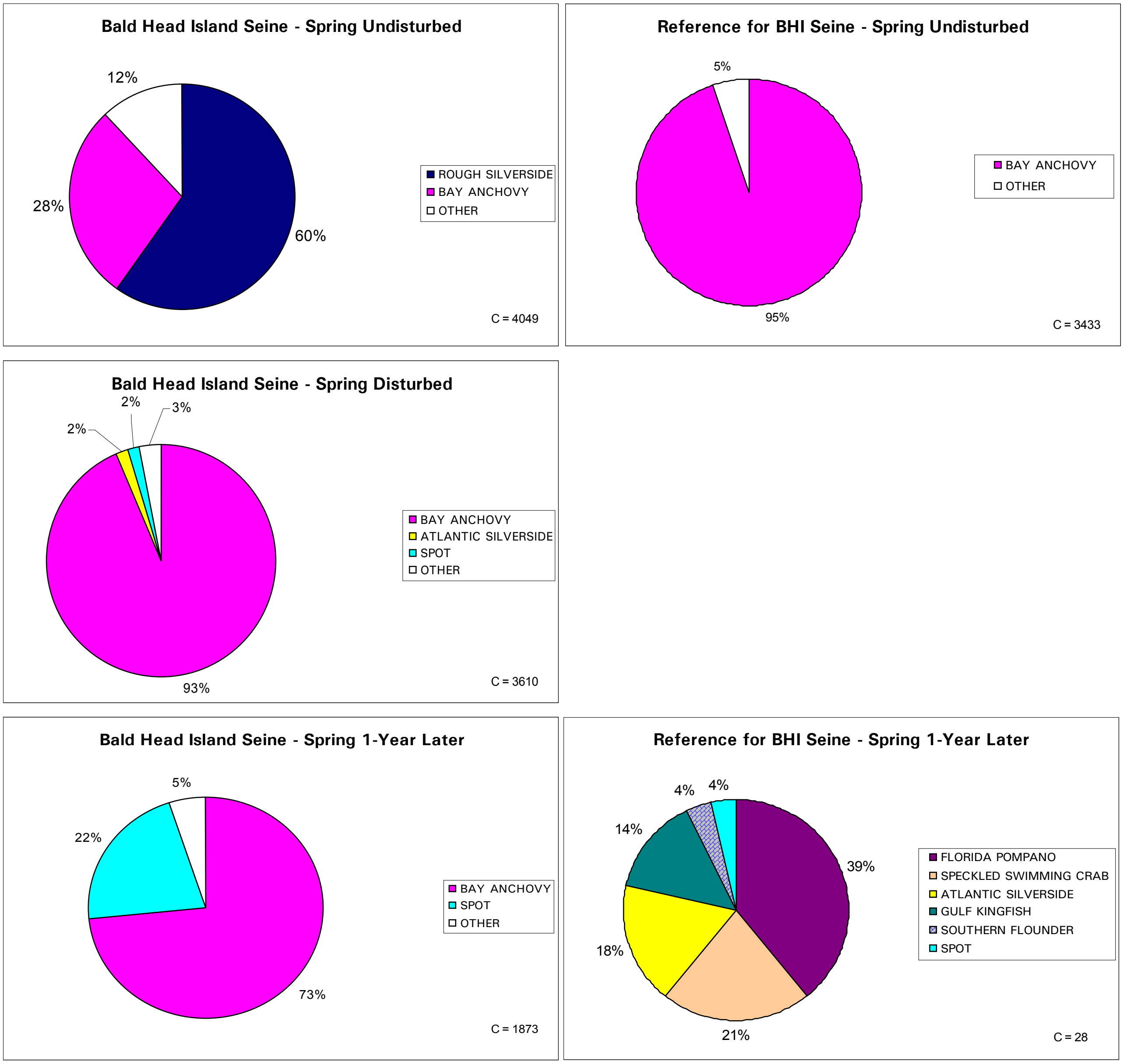


Figure SE-3. Species composition in seine collections from Bald Head Island and the reference beach before and after the disturbance and 1-year after sand placement. C = standardized total catch per effort.

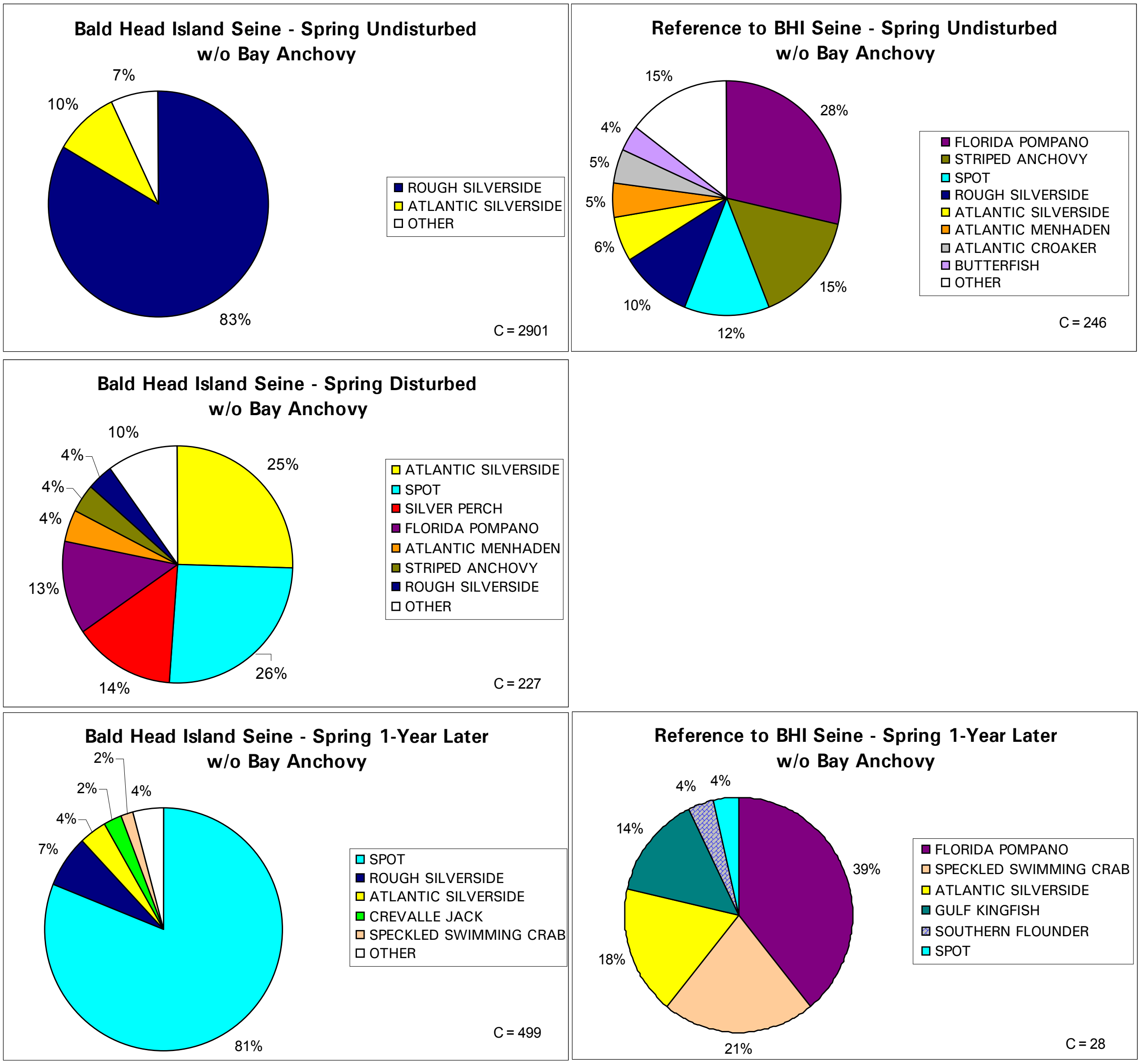


Figure SE-4. Species composition without bay anchovies in seine collections from Bald Head Island and the reference beach before and after the disturbance and 1-year after sand placement. C = standardized total catch per effort.

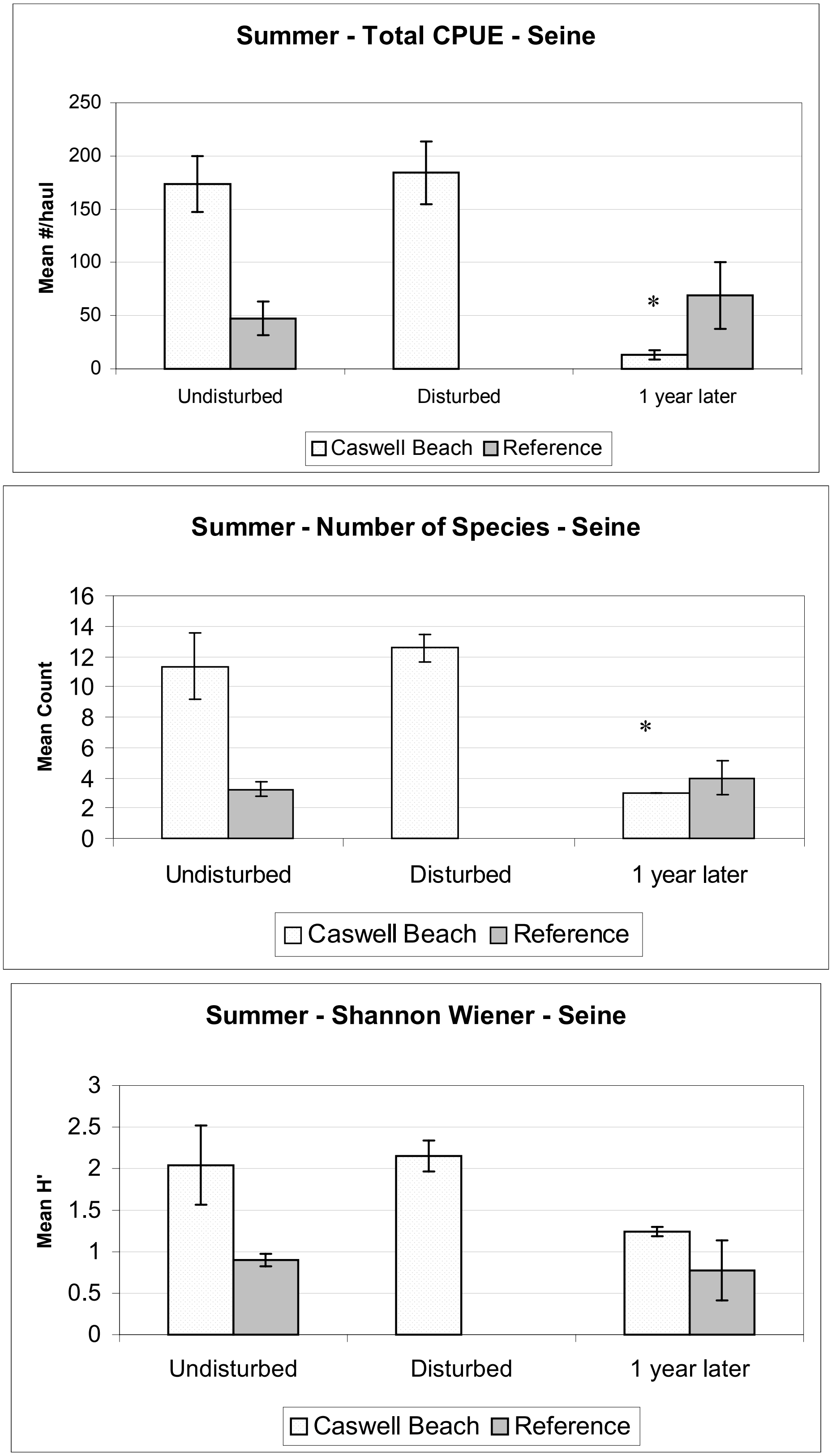


Figure SE-5. Comparison of seine CPUE, number of species, and the Shannon Wiener Diversity Index at Caswell Beach among undisturbed, disturbed, and recovery collections (1-year later).

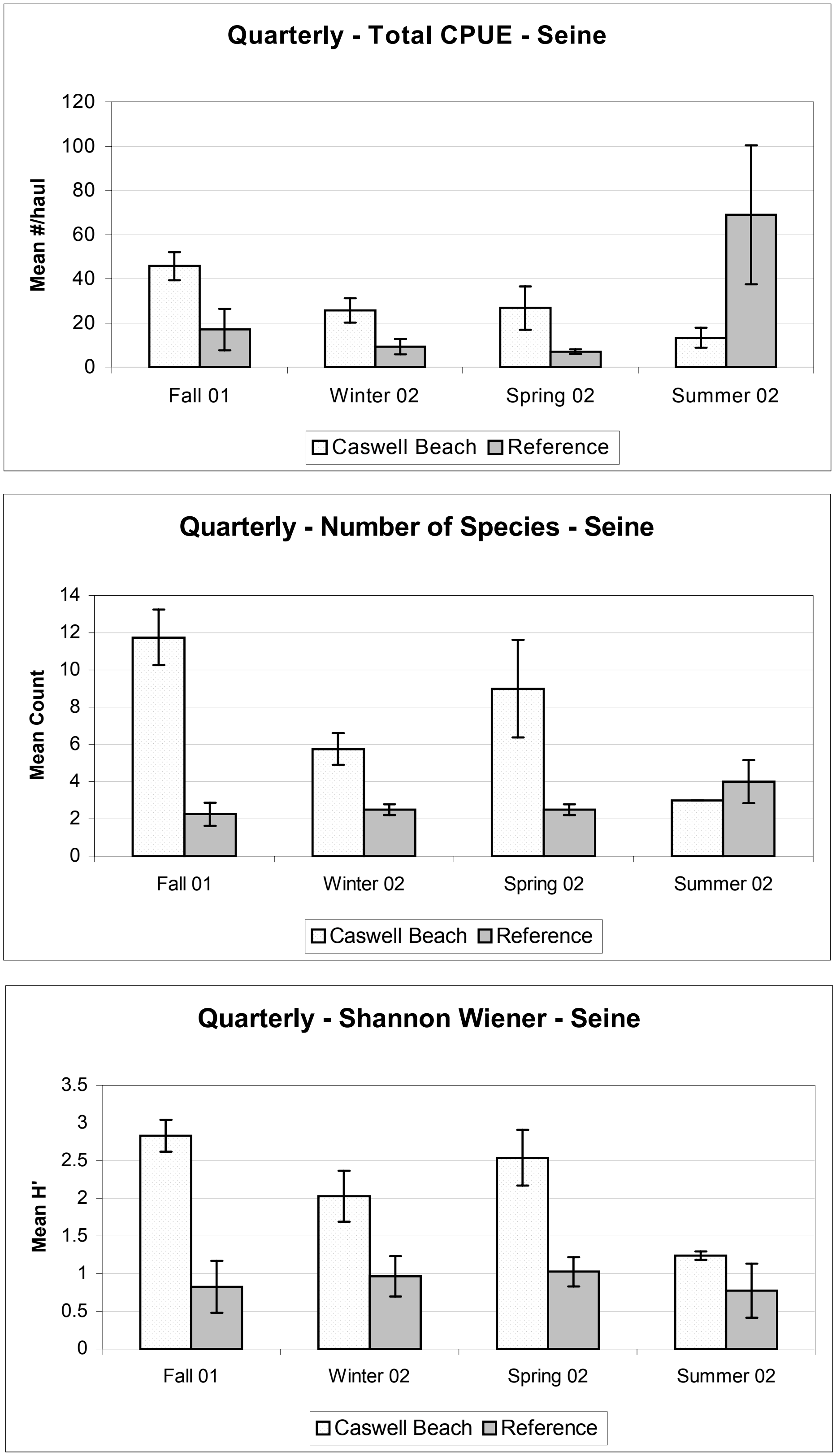


Figure SE-6. Comparison of quarterly seine CPUE, number of species and the Shannon Wiener Diversity Index conducted at Caswell Beach after sand placement.

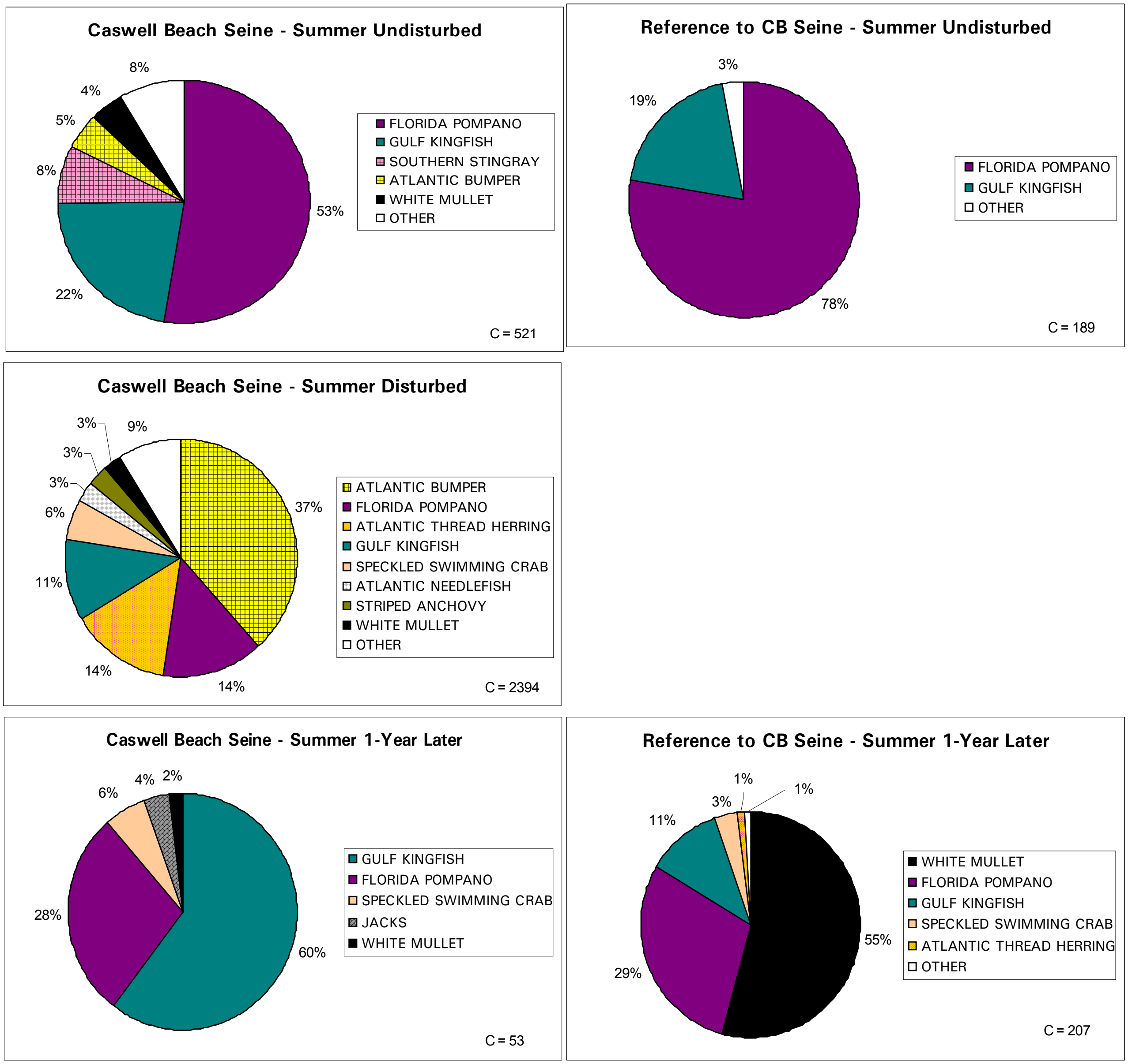
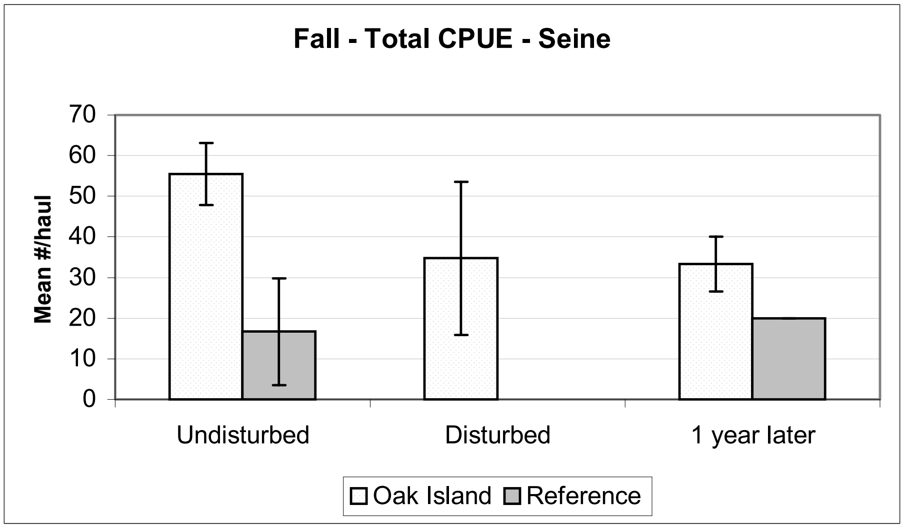
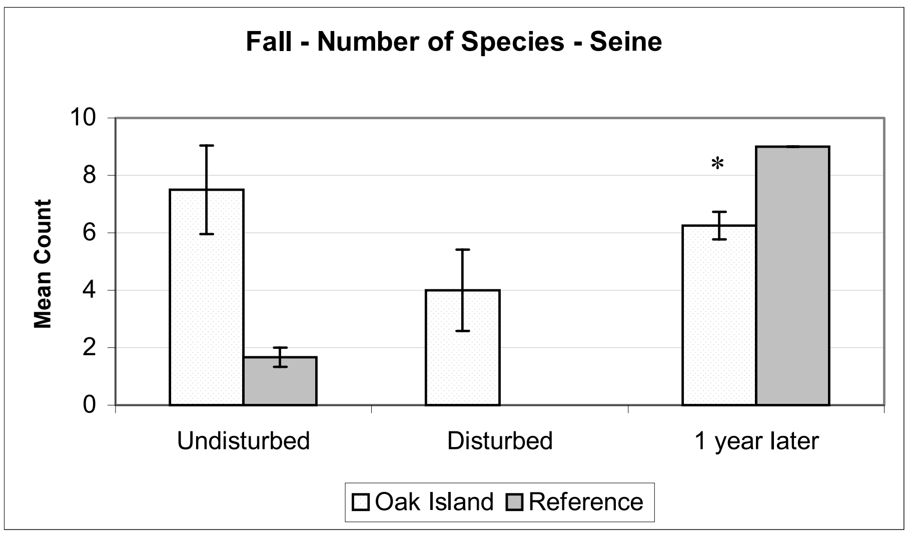


Figure SE-7. Species composition in seine collections from Caswell Beach and the reference beach before and after the disturbance and 1-year after sand placement. C = standardized total catch per effort.





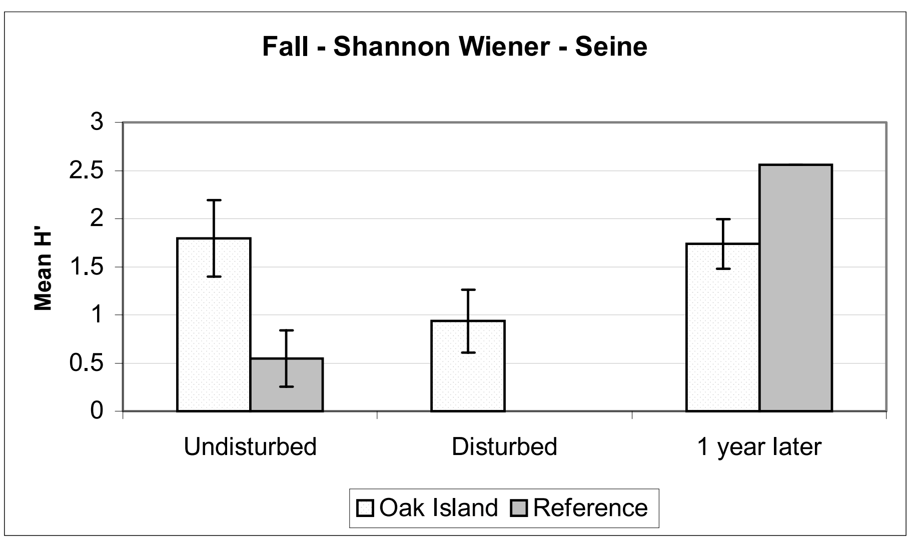


Figure SE-8. Comparison of seine CPUE, number of species, and the Shannon Wiener Diversity Index at Oak Island among undisturbed, disturbed, and recovery collections (1-year later). Only one reference sample was collected during the recovery collection so there are no standard error bars.

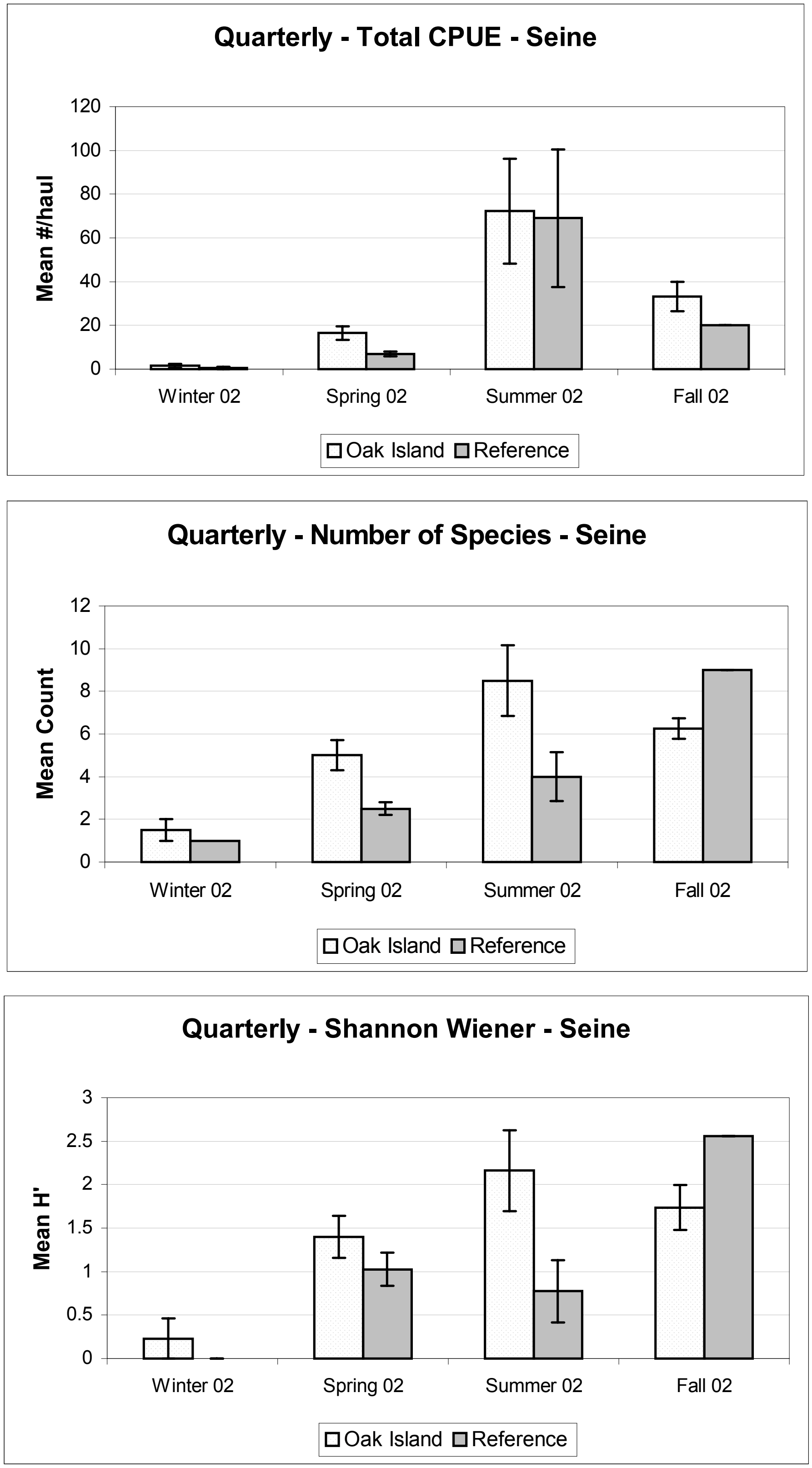


Figure SE-9. Comparison of quarterly seine CPUE, number of species and the Shannon Wiener Diversity Index conducted at Oak Island after sand placement. Only one reference sample was collected during the recovery collection so there are no standard error bars.

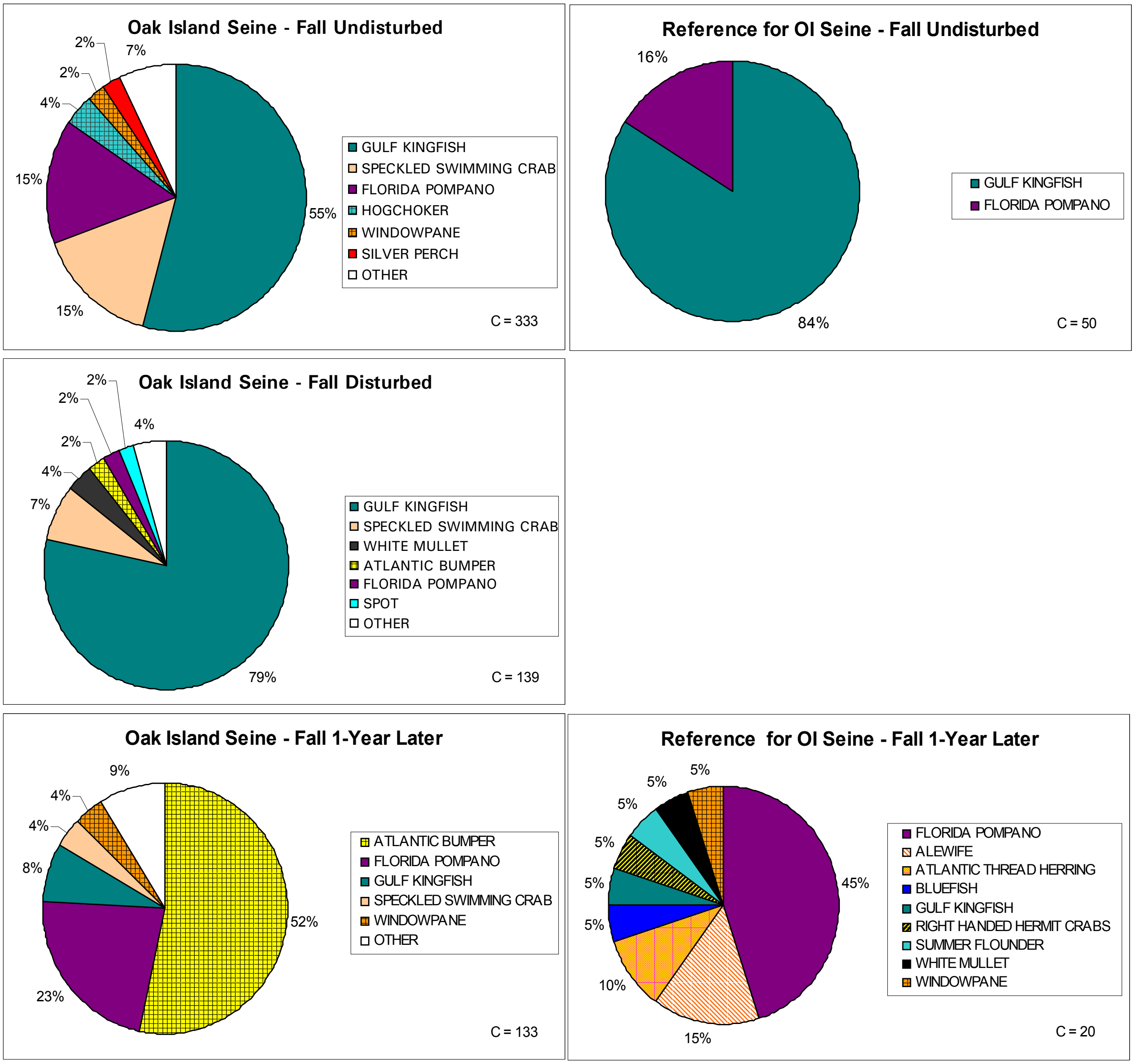


Figure SE-10. Species composition in seine collections from Oak Island and the reference beach before and after the disturbance and 1-year after sand placement. C = standardized total catch per effort.

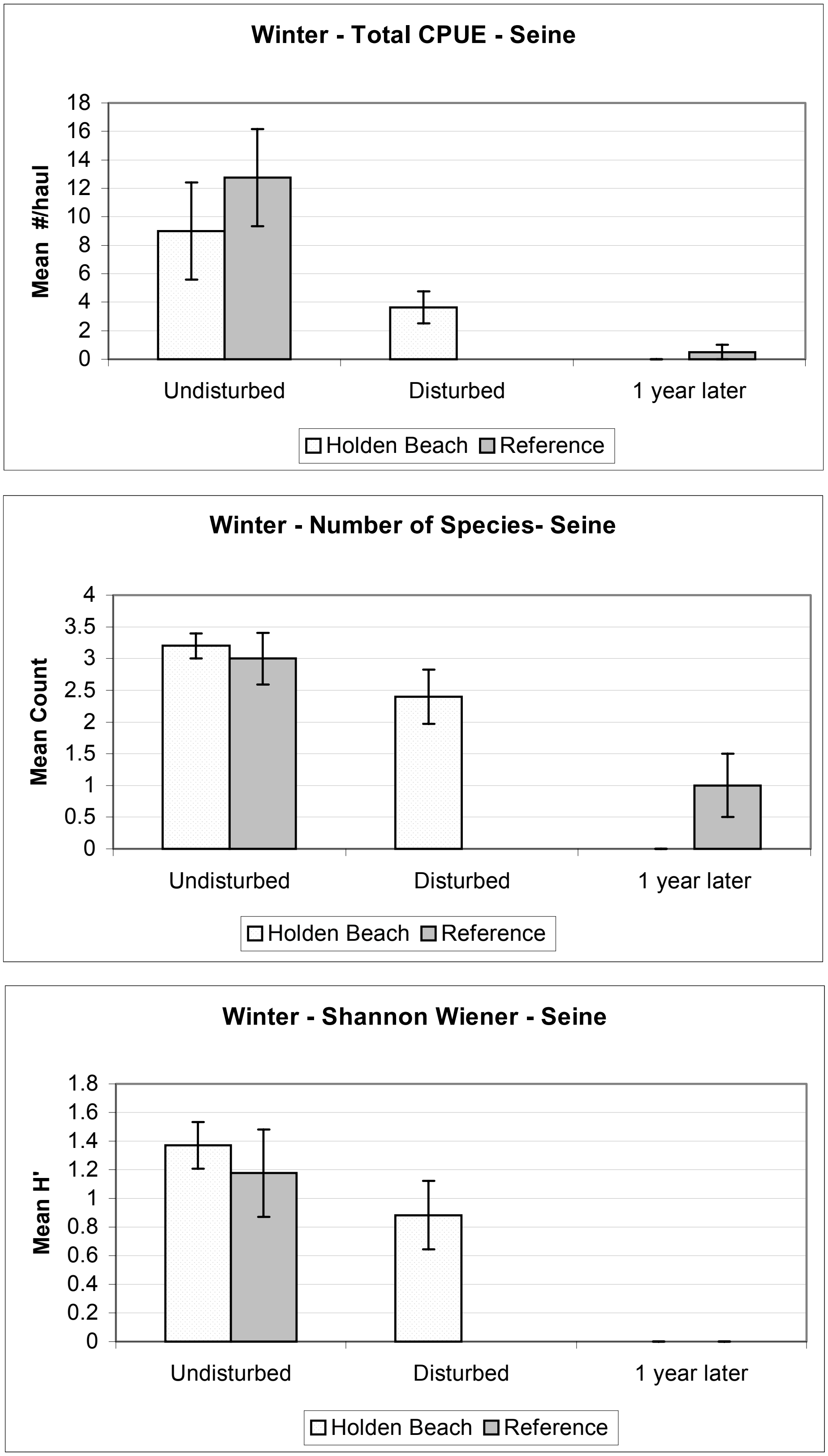


Figure SE-11. Comparison of seine CPUE, number of species, and the Shannon Wiener Diversity Index at Holden Beach among undisturbed, disturbed, and recovery collections (1-year later).

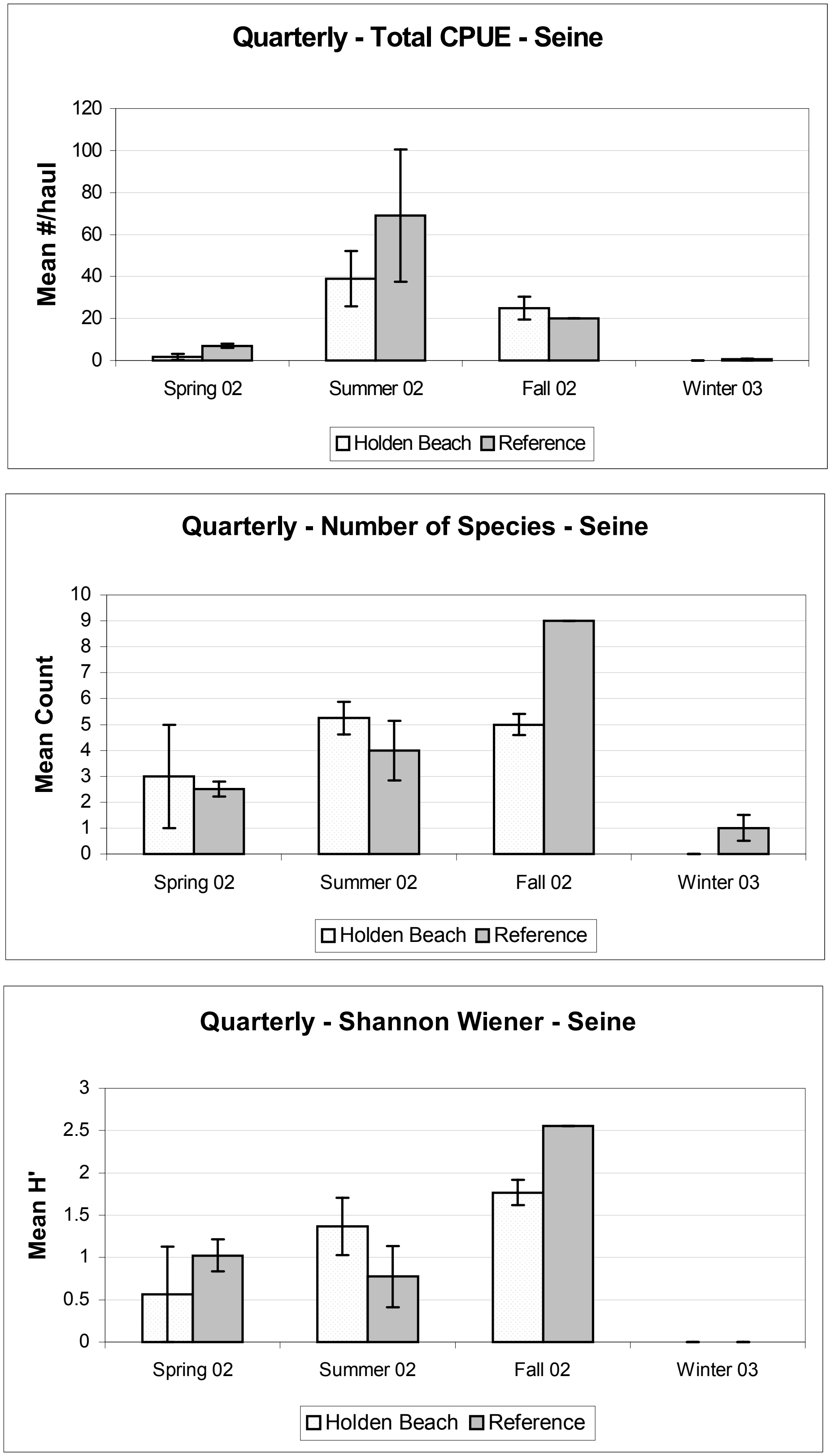


Figure SE-12. Comparison of quarterly seine CPUE, number of species and the Shannon Wiener Diversity Index conducted at Holden Beach after sand placement. Only one reference sample was collected during the fall 2002 recovery collection so there are no standard error bars.

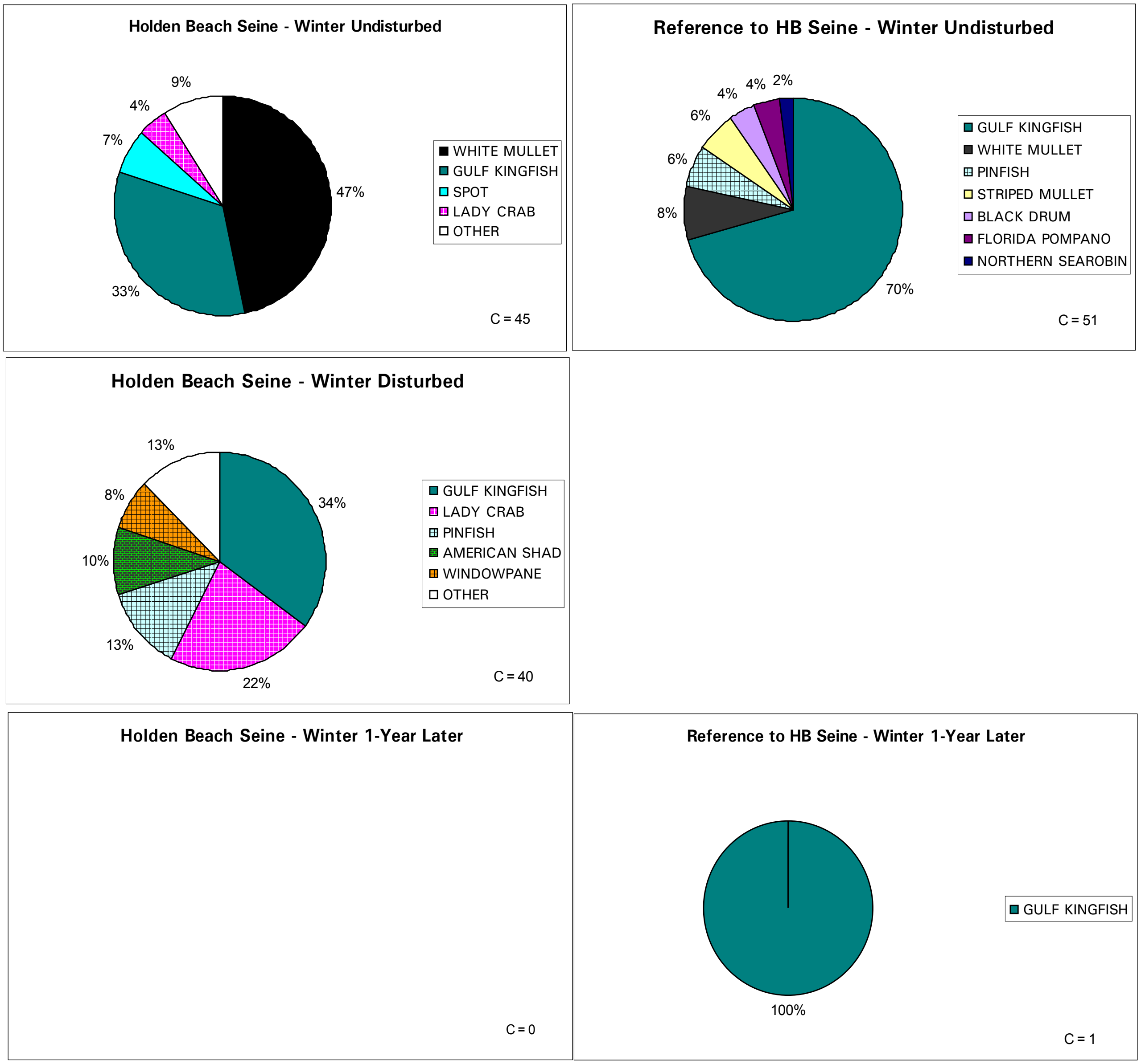


Figure SE-13. Species composition in seine collections from Holden Beach and the reference beach before and after the disturbance and 1-year after sand placement. C = standardized total catch per effort.

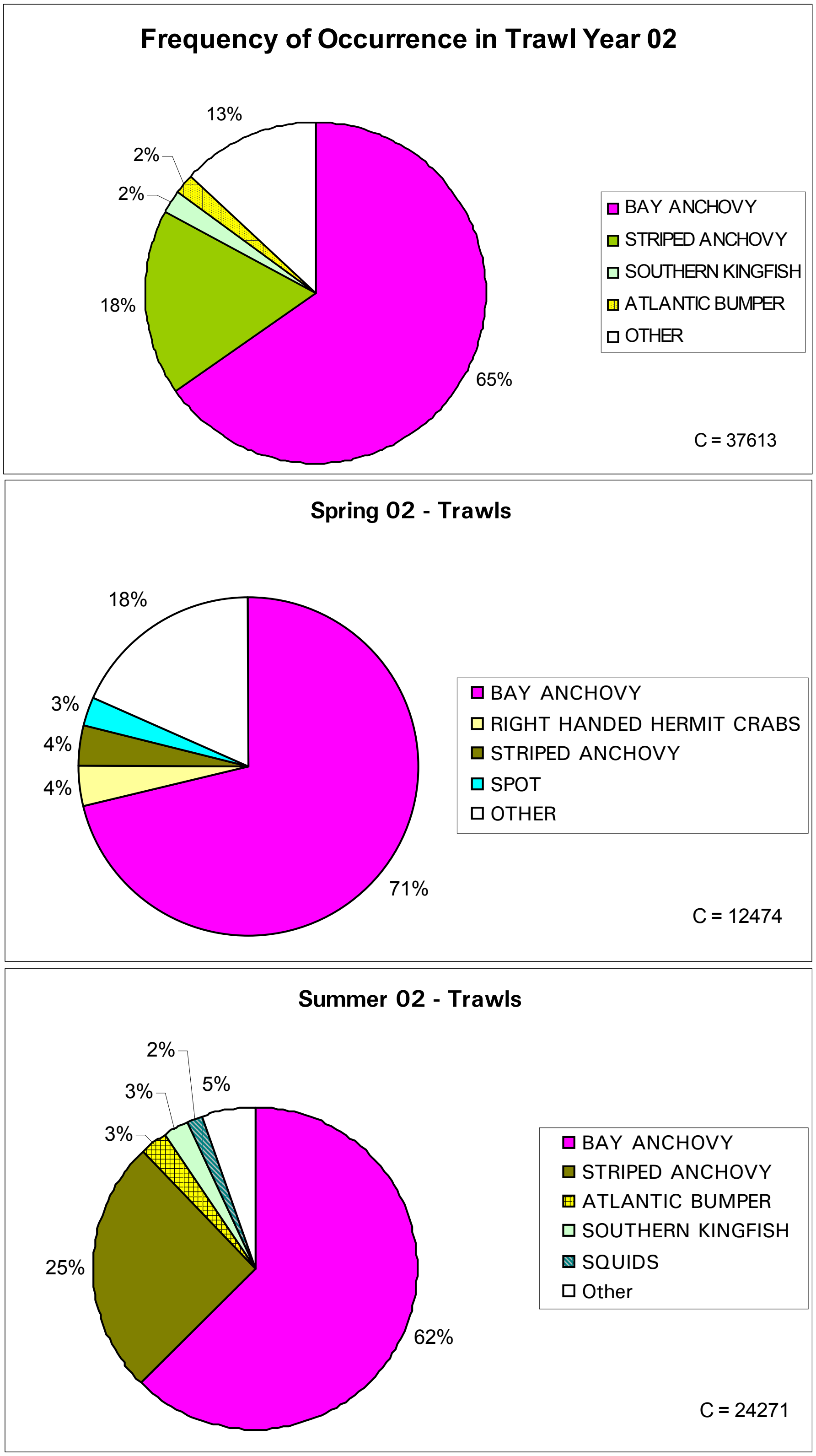
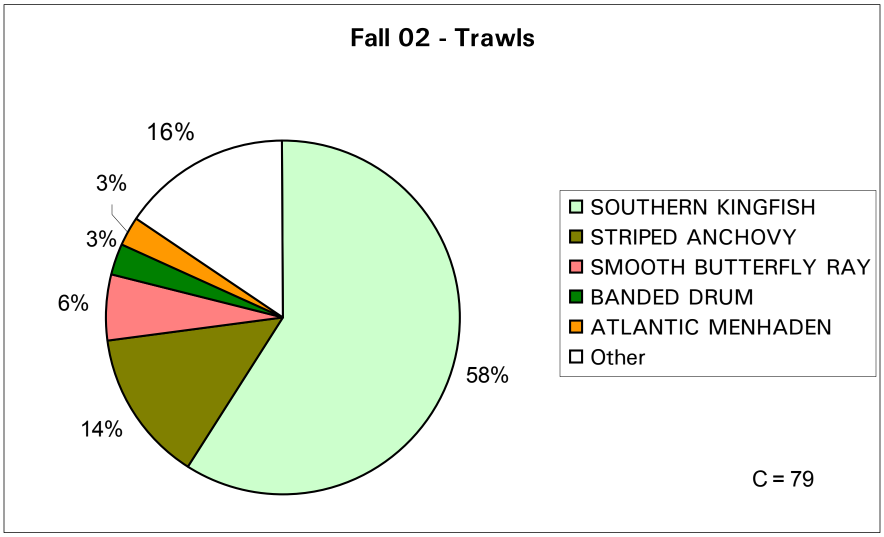


Figure TR-1. Standardized species catch composition for the trawl collections taken in the second year of monitoring at Brunswick County beaches. C = standardized total catch per effort.



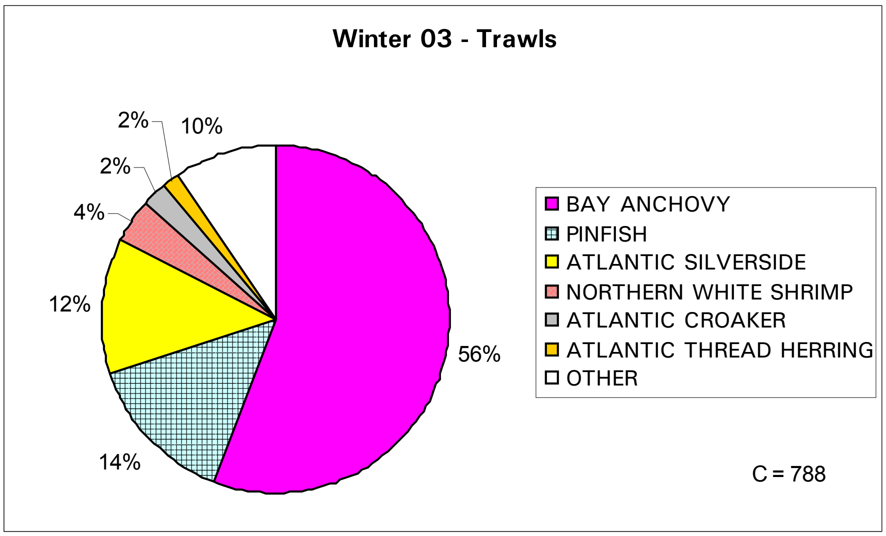


Figure TR-1. (Continued)

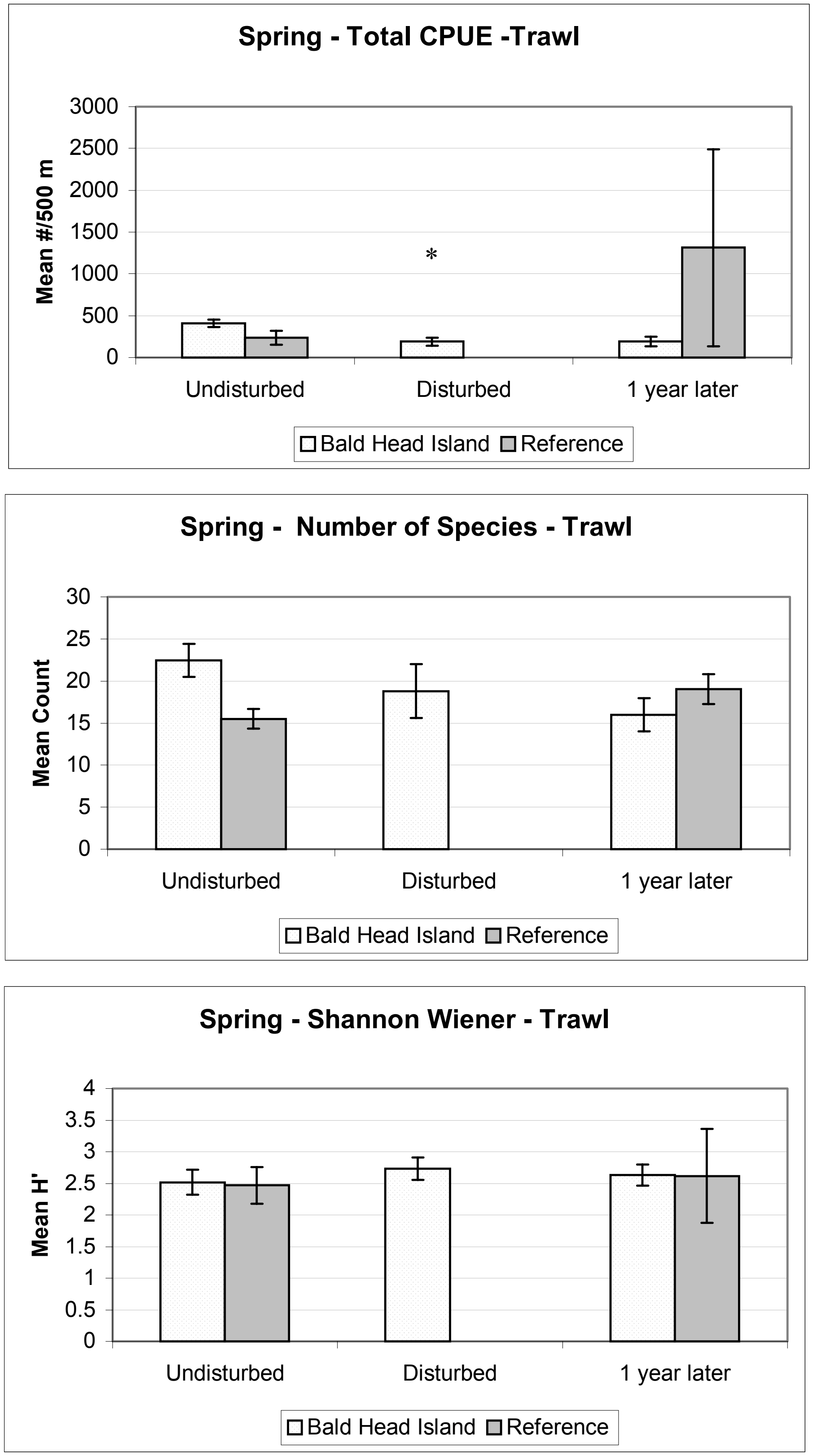


Figure TR-2. Comparison of trawl CPUE, number of species, and the Shannon Wiener Diversity Index at Bald Head Island among undisturbed, disturbed, and recovery collections (1-year later).

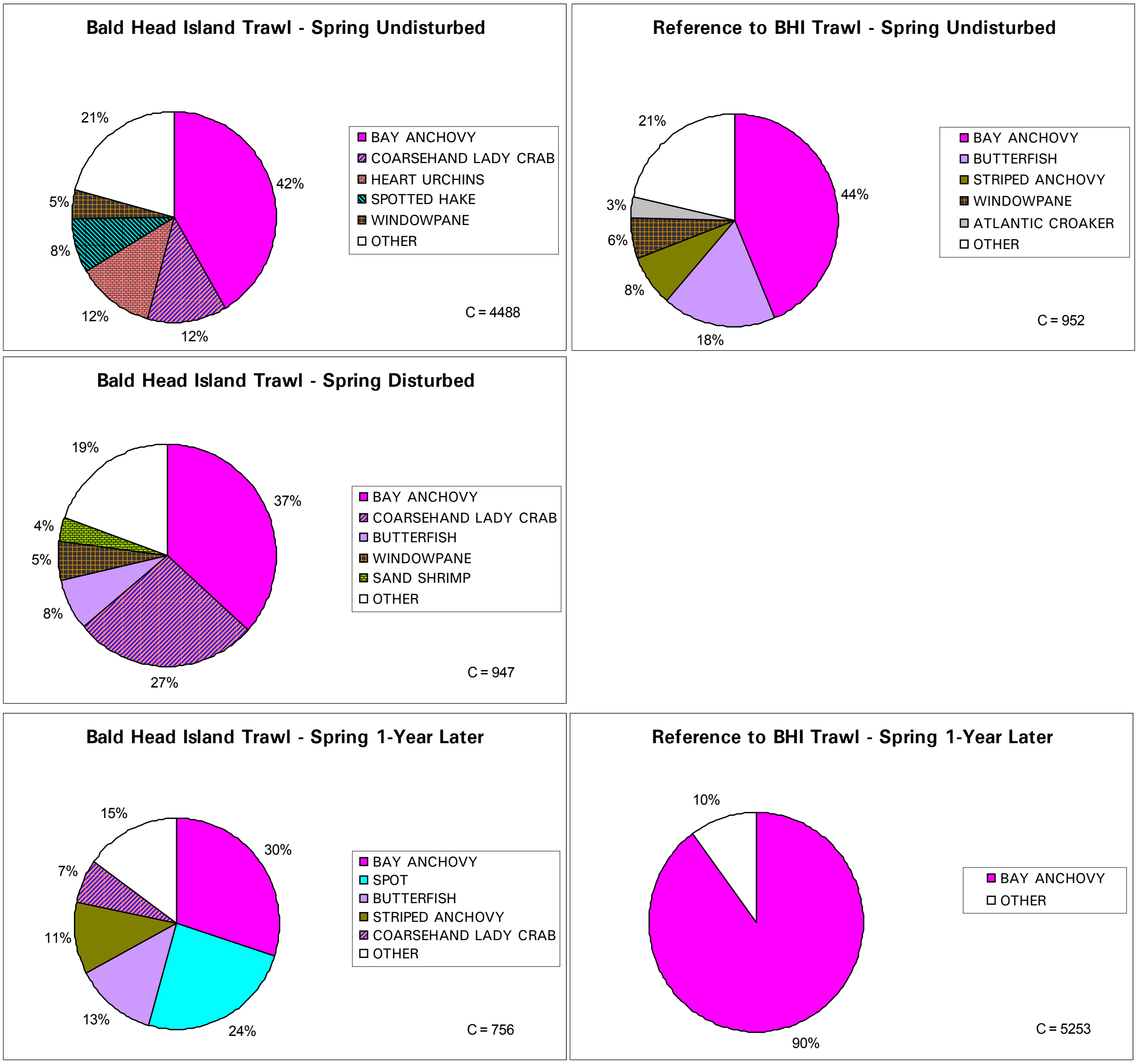


Figure TR-3. Species composition in trawl collections from Bald Head Island and the reference beach before and after the disturbance and 1-year after sand placement. C = standardized total catch per effort.

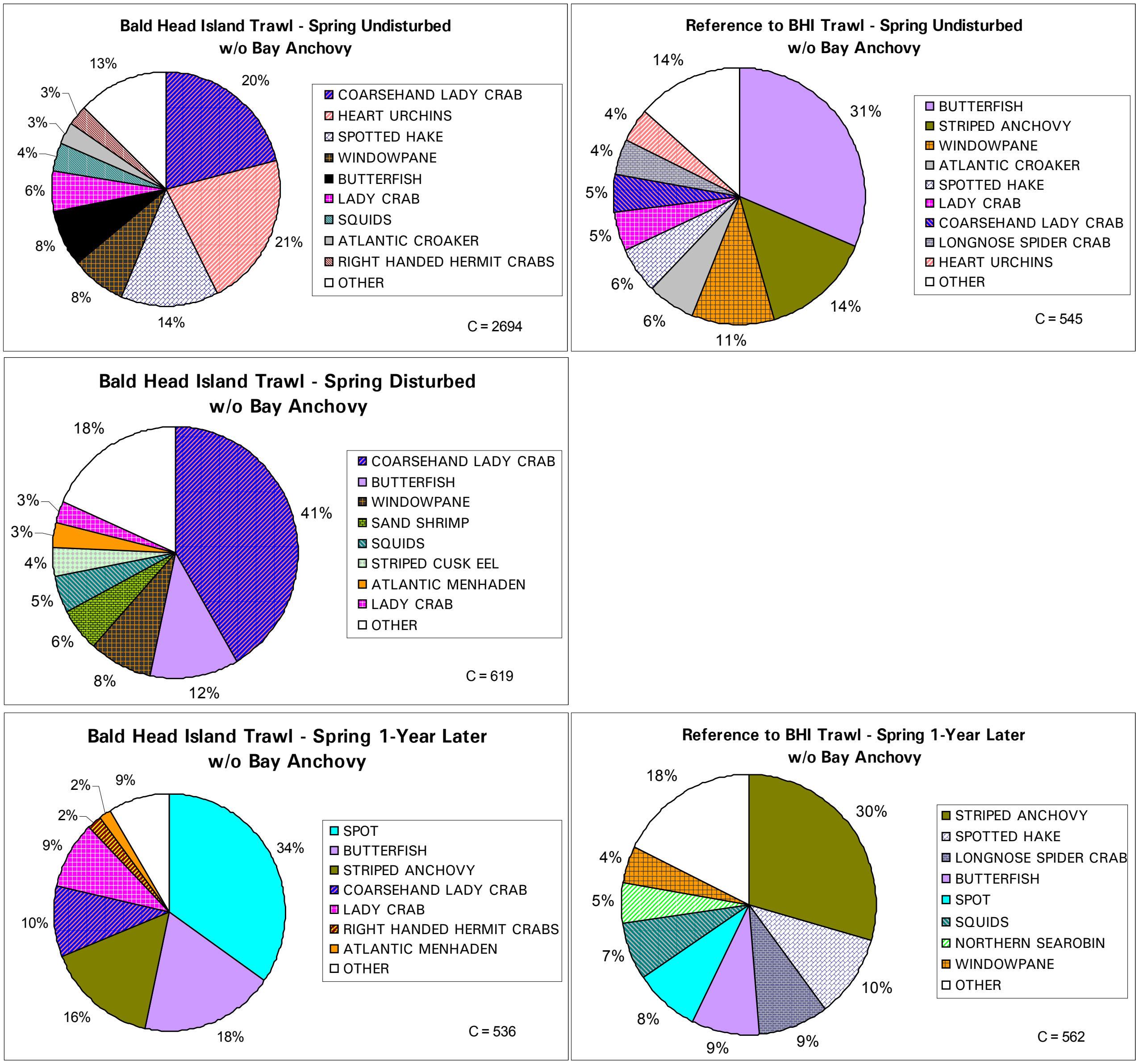


Figure TR-4. Species composition without bay anchovies in trawl collections from Bald Head Island and the reference beach before and after the disturbance and 1-year after sand placement. C = standardized total catch per effort.

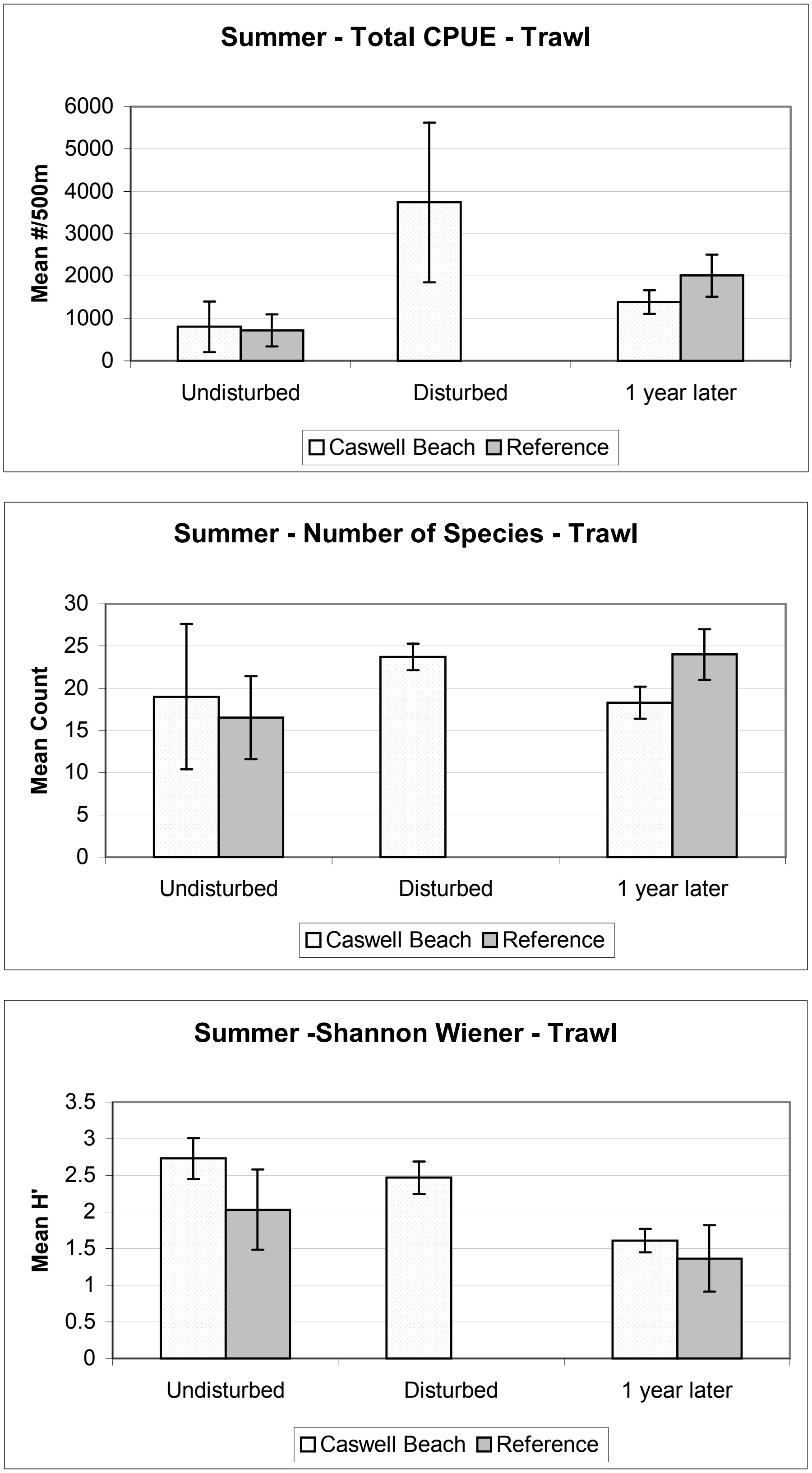


Figure TR-5. Comparison of trawl CPUE, number of species, and the Shannon Wiener Diversity Index at Caswell Beach among undisturbed, disturbed, and recovery collections (1-year later).

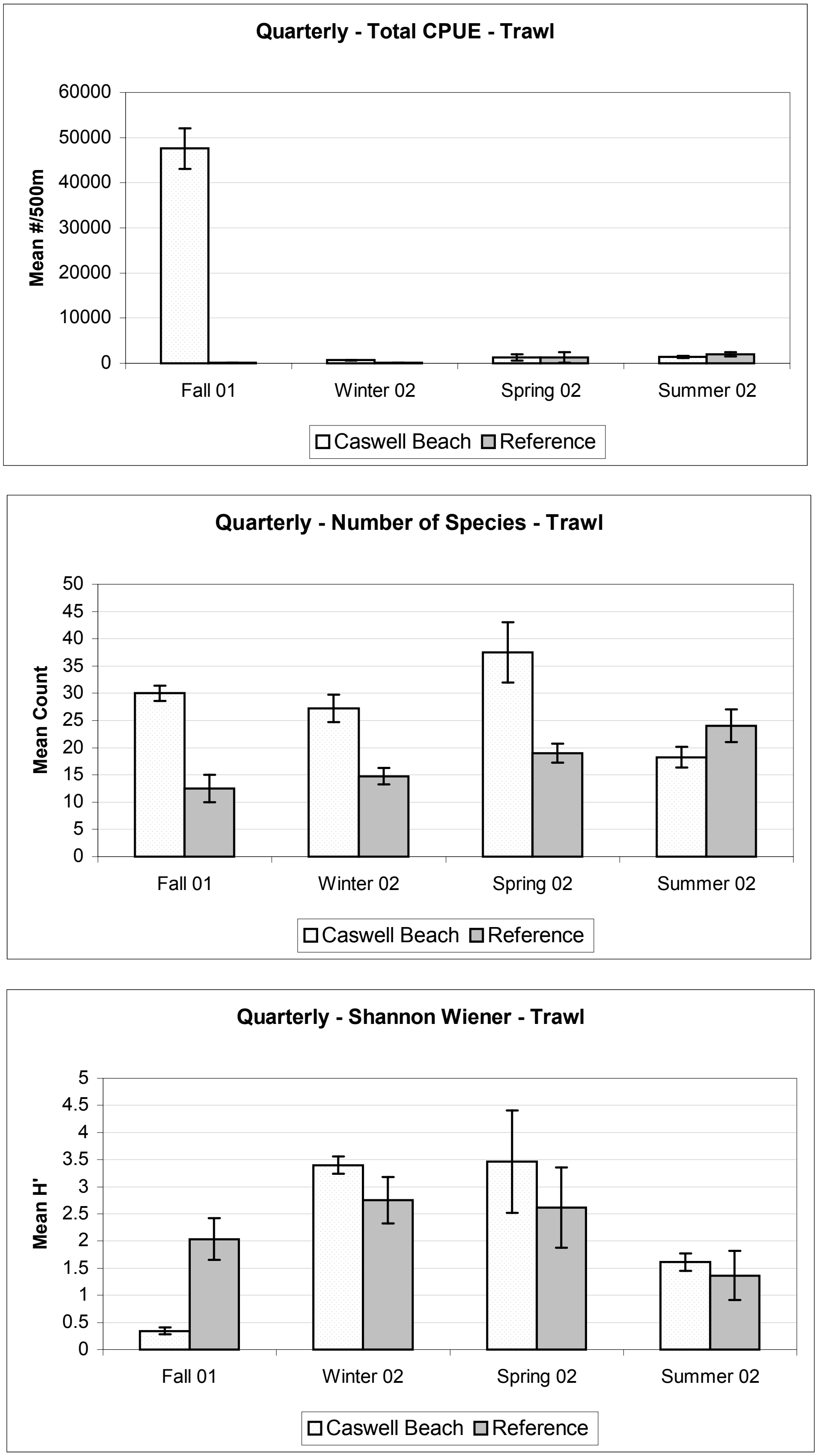


Figure TR-6. Comparison of quarterly trawl CPUE, number of species and the Shannon Wiener Diversity Index conducted at Caswell Beach after sand placement.

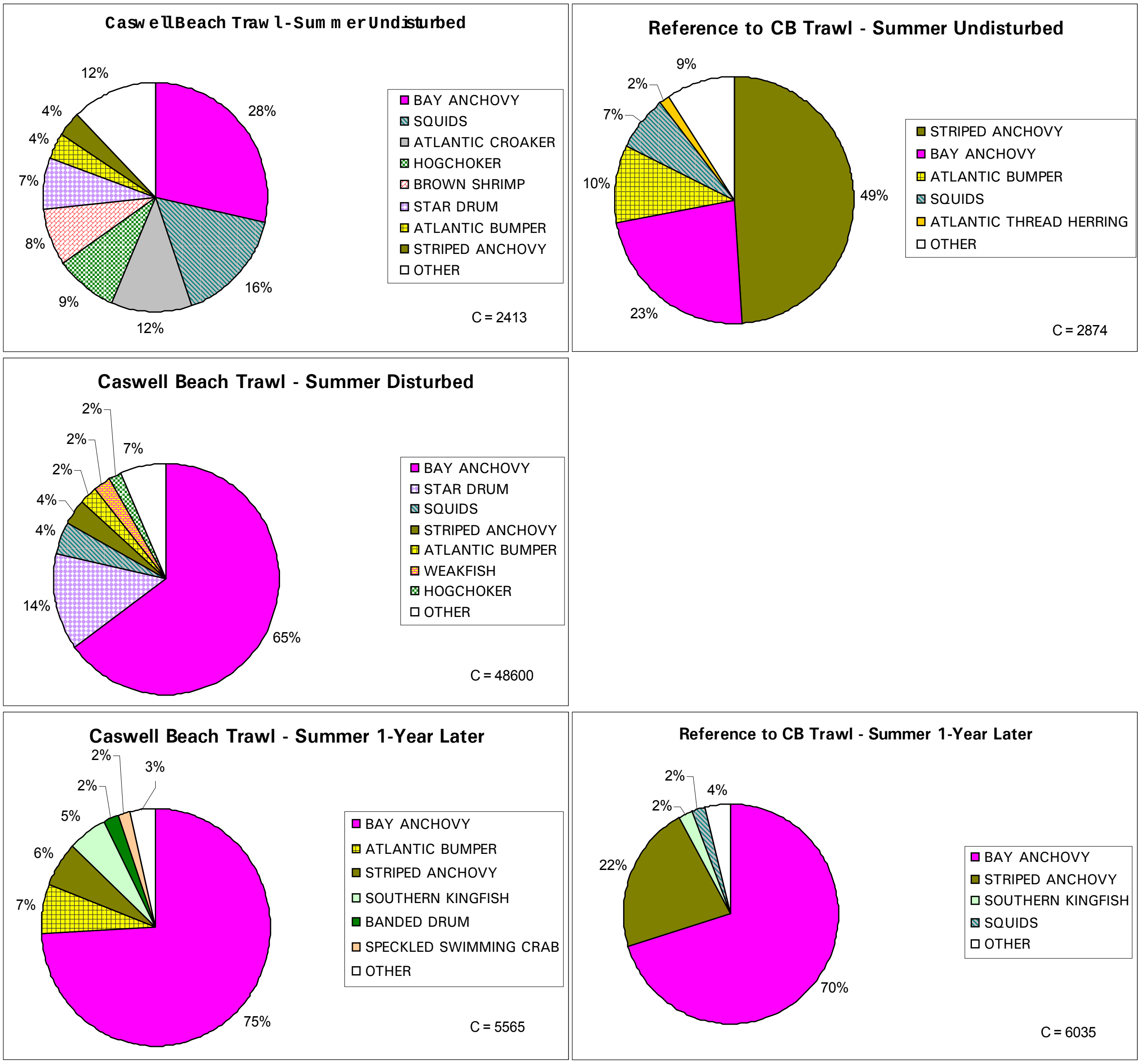


Figure TR-7. Species composition in trawl collections from Caswell Beach and the reference beach before and after the disturbance and 1-year after sand placement. C = standardized total catch per effort.

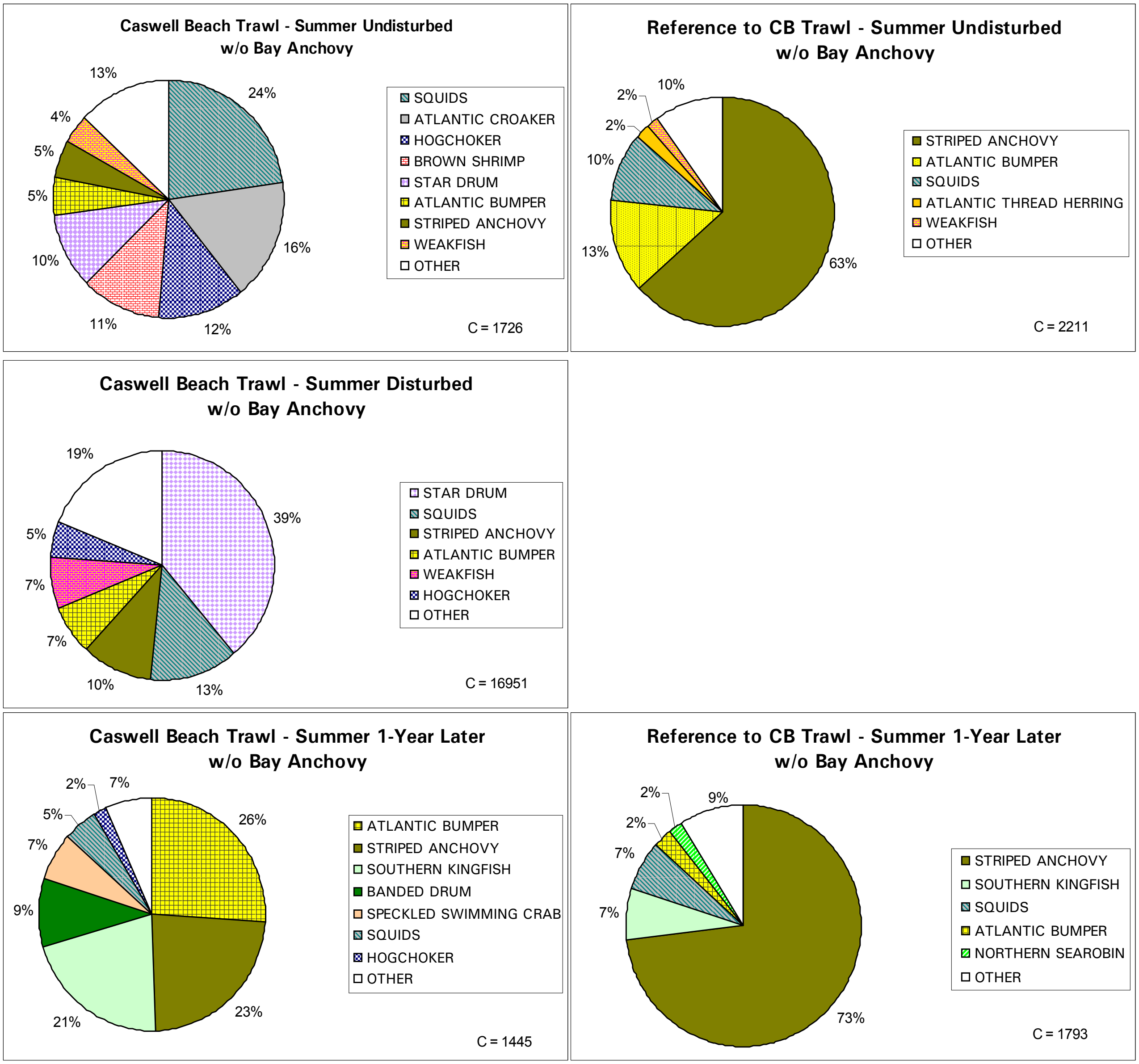


Figure TR-8. Species composition without bay anchovies in trawl collections from Caswell Beach and the reference beach before and after the disturbance and 1-year after sand placement. C = standardized total catch per effort.

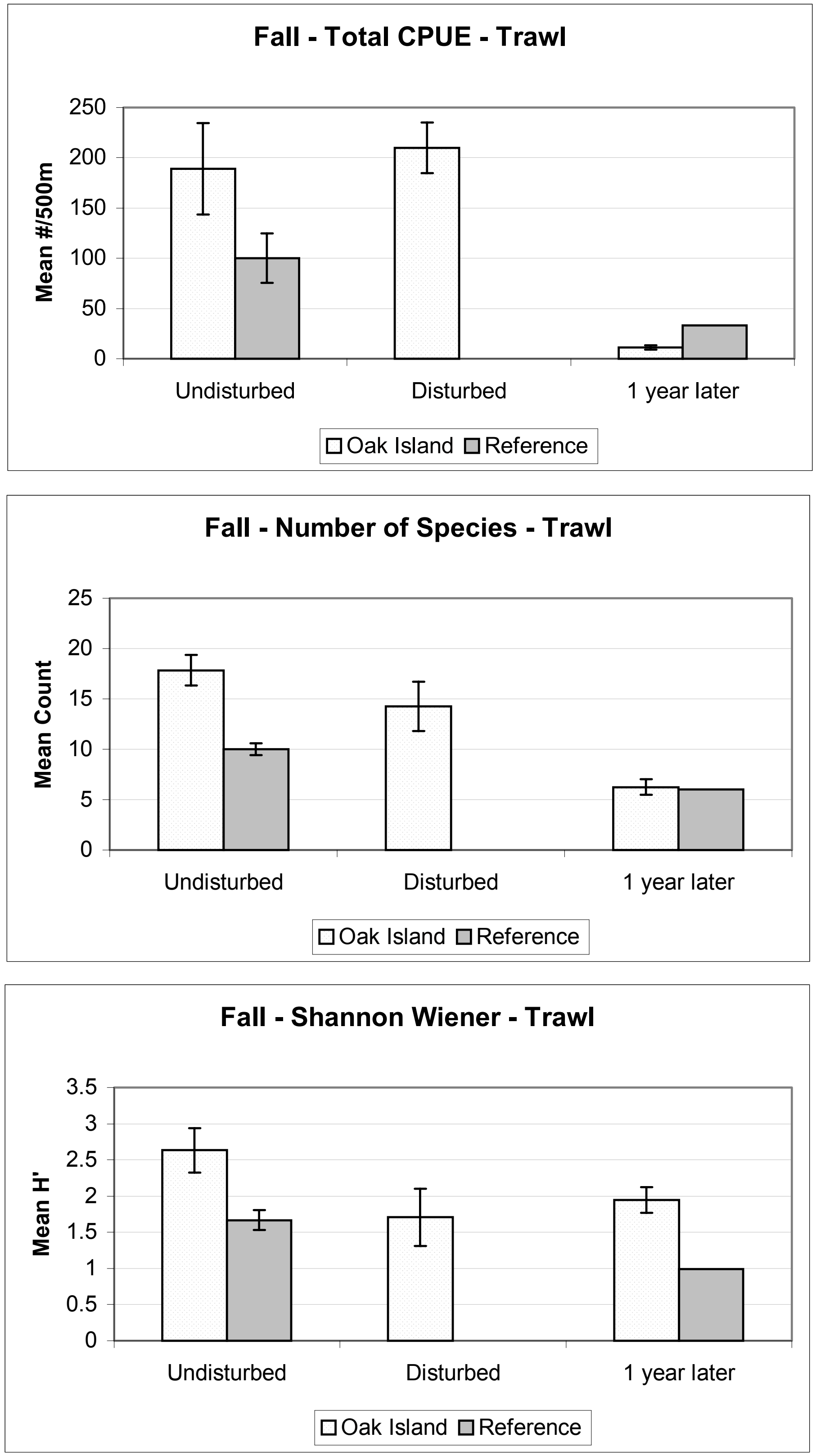
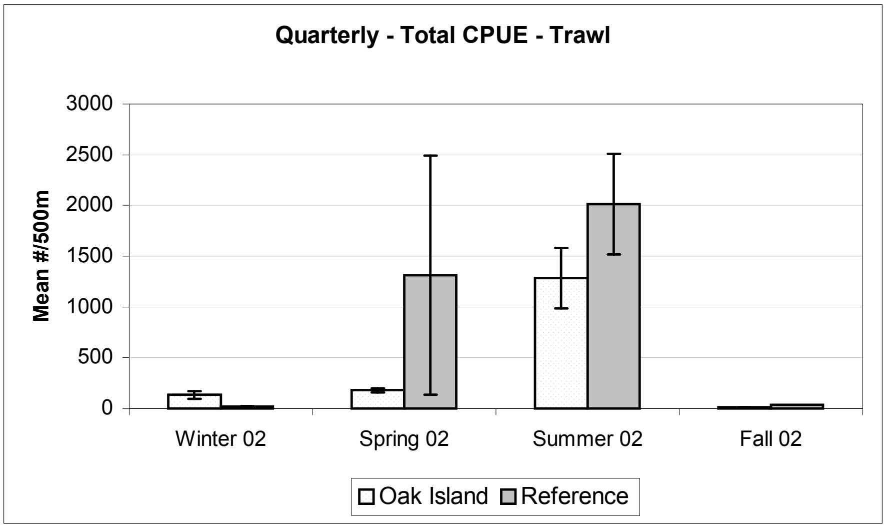
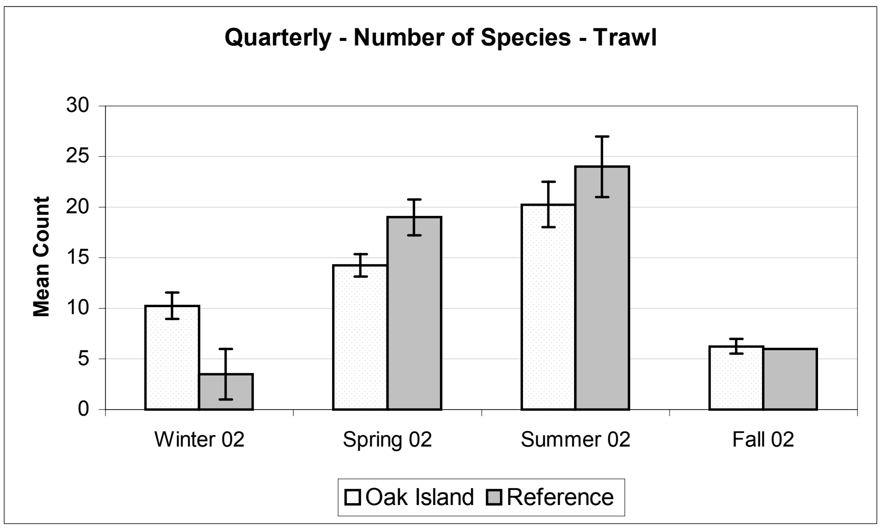


Figure TR-9. Comparison of trawl CPUE, number of species, and the Shannon Wiener Diversity Index at Oak Island among undisturbed, disturbed, and recovery collections (1-year later). Only one reference sample was collected during the recovery collection so there are no standard error bars.





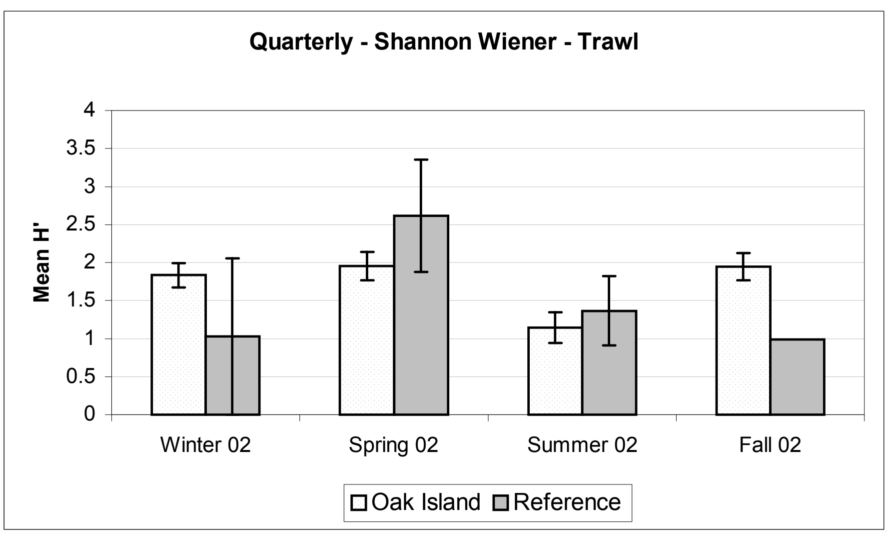


Figure TR-10. Comparison of quarterly trawl CPUE, number of species and the Shannon Wiener Diversity Index conducted at Oak Island after sand placement. Only one reference sample was collected during the Fall 02 collection so there are no standard error bars.

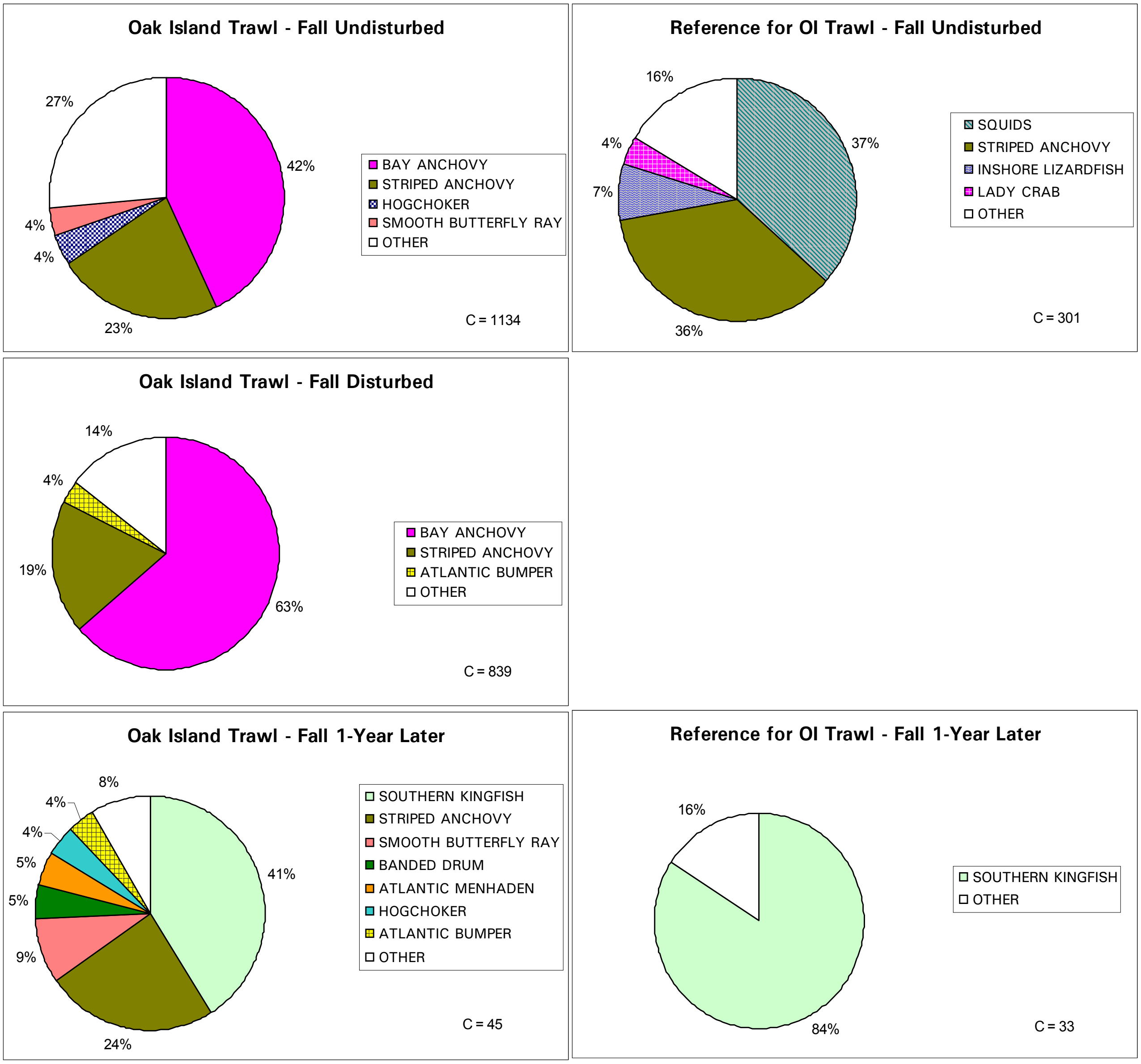


Figure TR-11. Species composition in trawl collections from Oak Island and the reference beach before and after the disturbance and 1-year after sand placement. C = standardized total catch per effort.

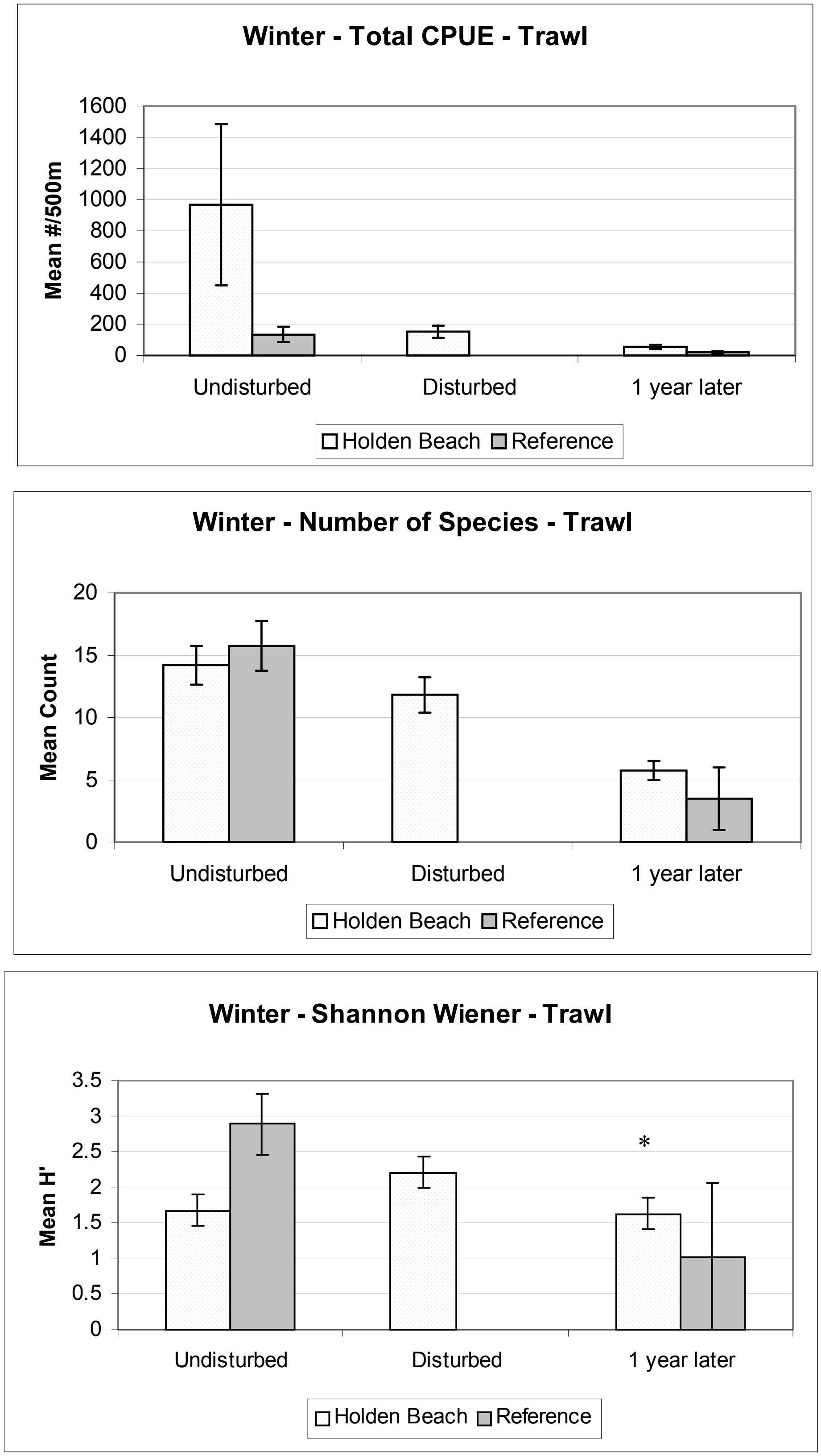


Figure TR-12. Comparison of trawl CPUE, number of species, and the Shannon Wiener Diversity Index at Holden Beach among undisturbed, disturbed, and recovery collections (1-year later).

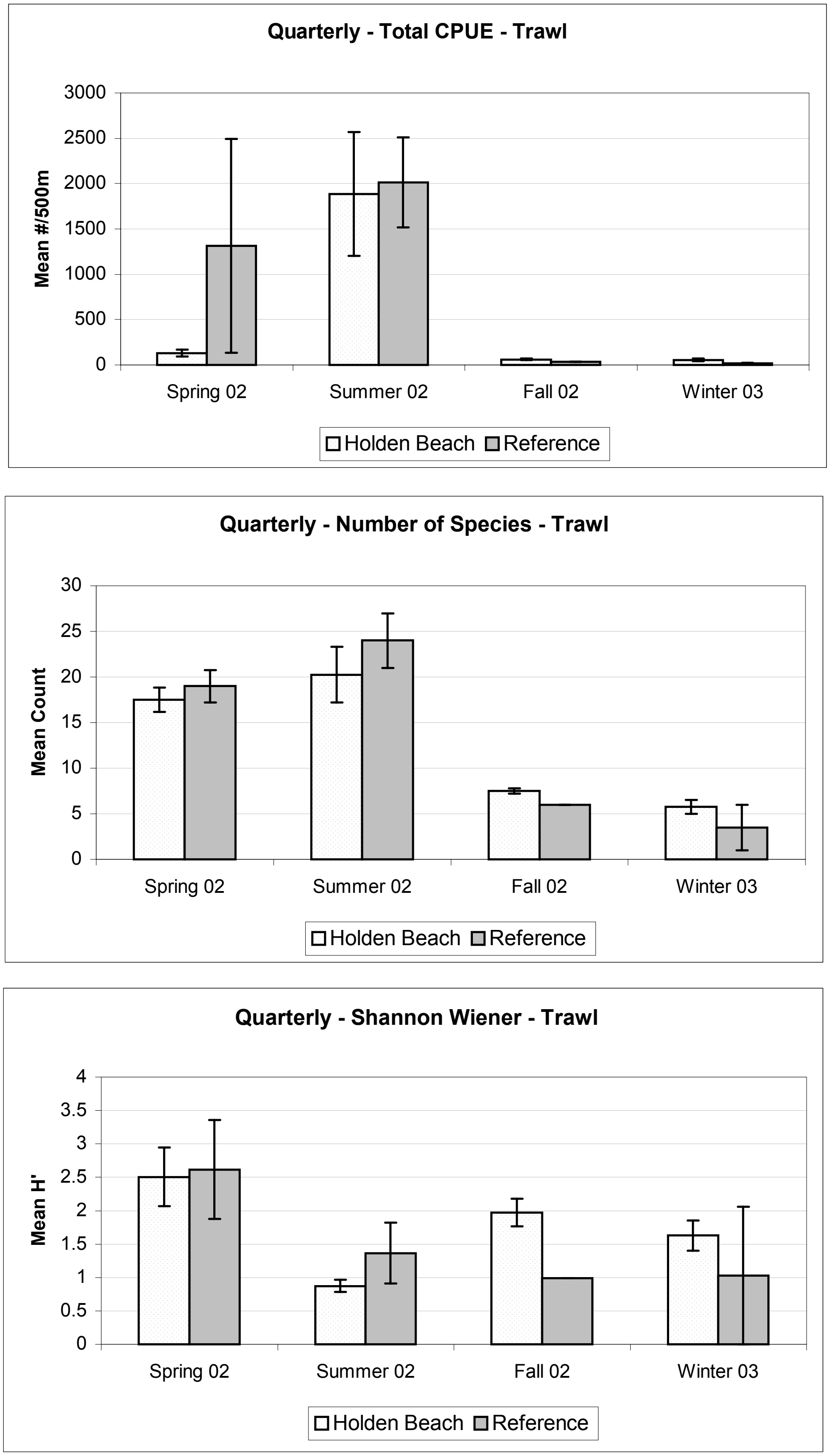


Figure TR-13. Comparison of quarterly trawl CPUE, number of species and the Shannon Wiener Diversity Index conducted at Holden Beach after sand placement. Only one reference sample was collected during the Fall 02 collection so there are no standard error bars.

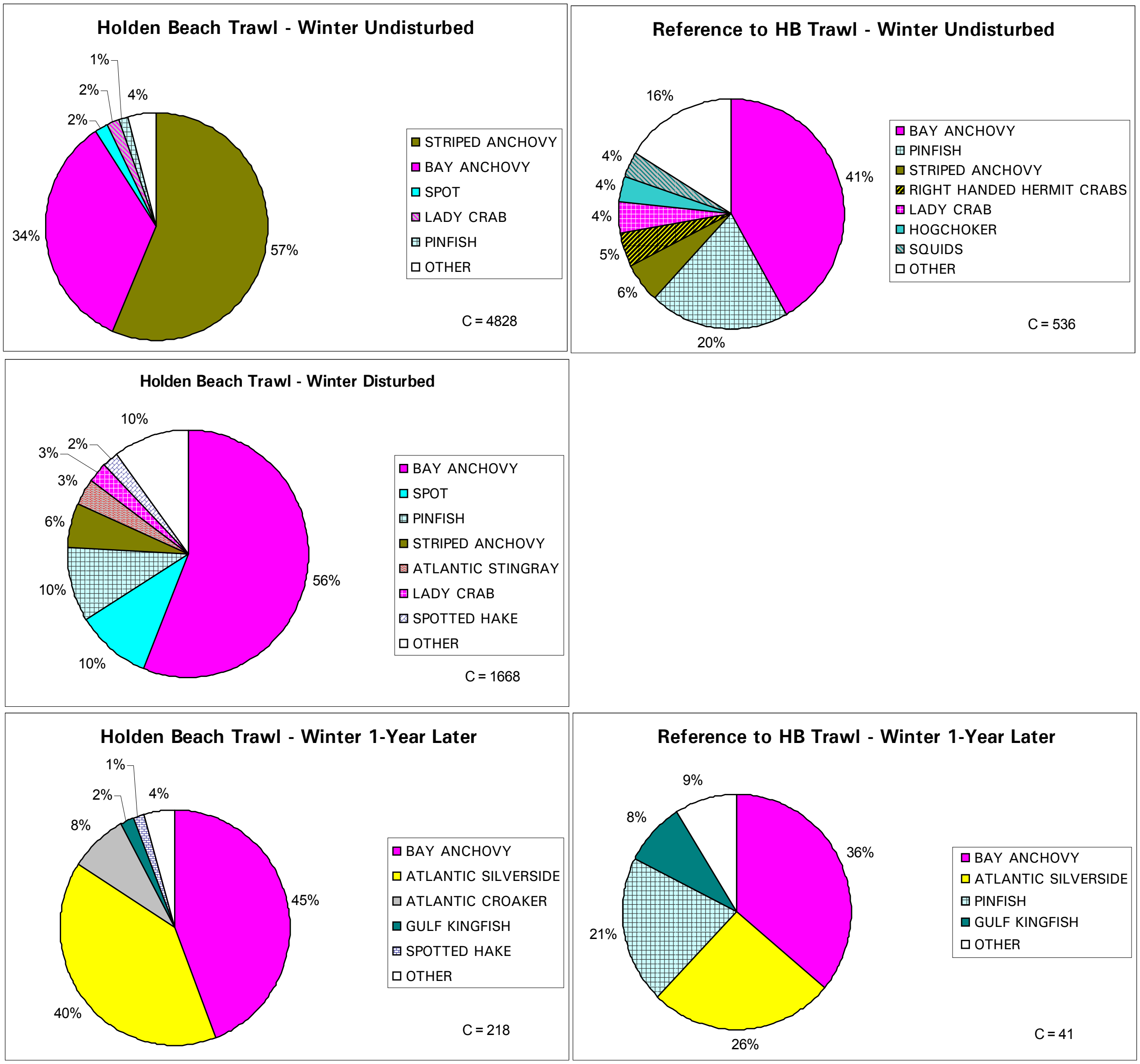


Figure TR-14. Species composition in trawl collections from Holden Beach and the reference beach before and after the disturbance and 1-year after sand placement. C = standardized total catch per effort.

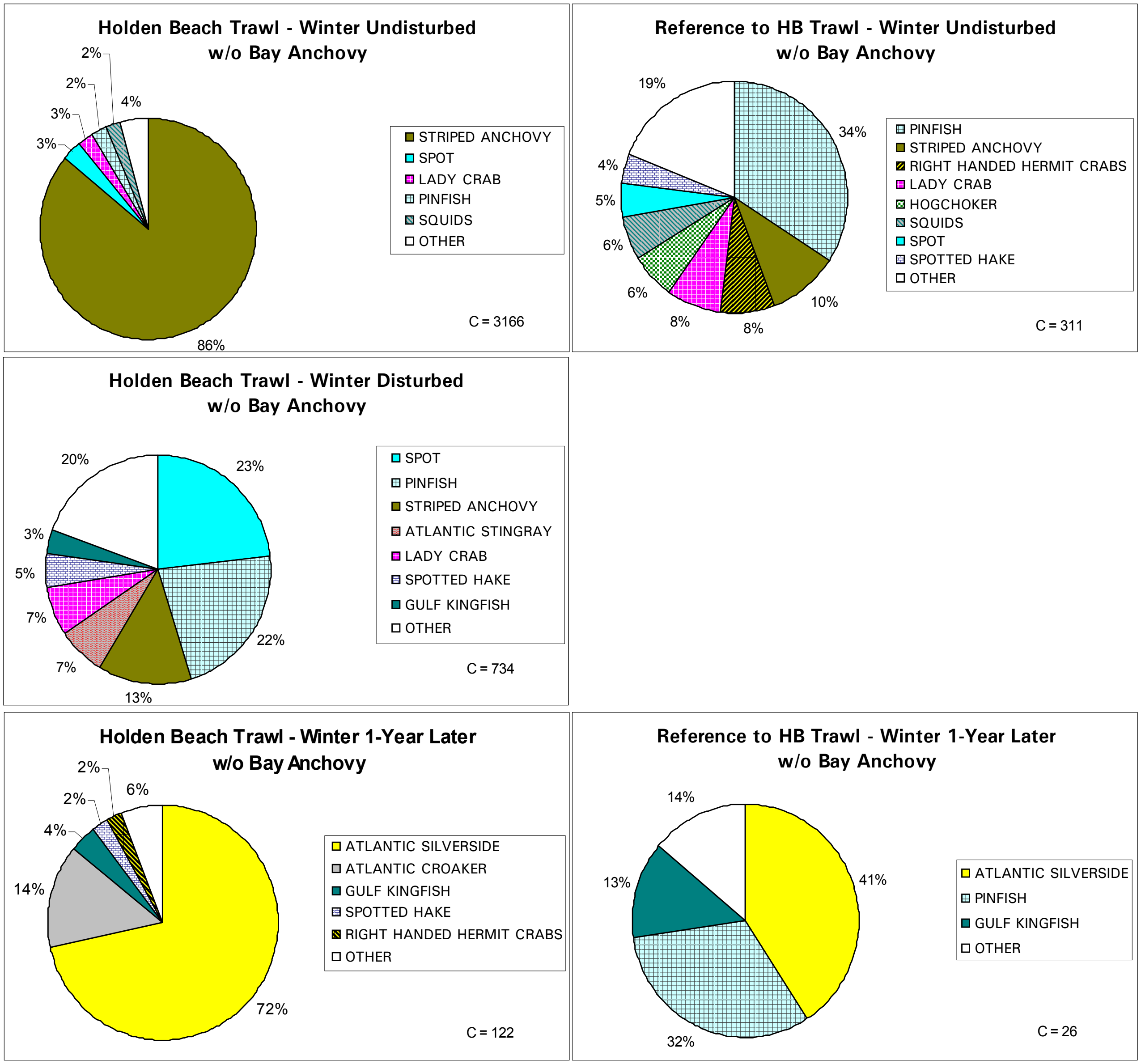


Figure TR-15. Species composition without bay anchovies in trawl collections from Holden Beach and the reference beach before and after the disturbance and 1-year after sand placement. C = standardized total catch per effort.

3.5 GILLNET SUMMARY

Because of the inherent mobility and migratory behavior exhibited by many adult and transient marine species, the primary goal of the gillnet survey was to document the occurrence and relative abundance of large mobile species utilizing the habitat just outside the surf zone. Due to the ephemeral nature of large pelagic fish species and the high variability in the gillnet catches, no statistical analyses were performed on these data to evaluate recovery from the beach nourishment project. Therefore, all second year survey data from all beaches were combined to present overall and seasonal changes in species composition and relative abundance of the major species collected.

Annual gillnet sampling at the subject beaches and the reference beach began in the spring of 2002 at Bald Head Island and followed the quarterly sampling schedule for the second year of the monitoring program at each beach. During each survey, nets were deployed at four stations at the subject beach and one station at the reference beach. The actual time each net was actively fishing was dependent upon season, and varied from 1.13 to 22.65 hr., with an average soak time of 7.5 hr. All gillnet catches were standardized to number caught per hour of soak time. For the entire second year of sampling gillnet catches averaged about 6 organisms per hour of soak time (Table GI-1). The second year collections were represented by total of 58 species, 47 of which were fish, including 11 sharks and 6 ray species. Ten species of invertebrates (7 crabs, 2 whelks, one shrimp), and one species of sea turtle (released alive) were also collected during the survey (Table GI-1).

Several recreational and commercially important species were collected throughout the survey. The most dominant species collected by the gillnets during the second year of monitoring were represented by sharks, herrings, bluefish, mackerel, and kingfish (Table GI-1). Individually, the Atlantic sharpnose shark was the most abundant species, representing 41% of the total catch during the entire survey (Figure GI-1). Seasonally, the Atlantic sharpnose shark dominated gillnet catches in the spring and summer while menhaden represented the majority of the catch in the fall and winter survey (Figure GI-1). One other herring species was present in relatively large numbers throughout the survey, the Atlantic thread herring. The Atlantic thread herring accounted for over 9% of the total survey catch (Figure GI-1). This species was most abundant in the spring and fall surveys.

Another abundant species was the blue fish (Table GI-1). The blue fish accounted for 8% of the total survey catch (Figure GI-1). This species exhibited peak dominance in the summer and fall when they accounted for 7 and 15% of the catches, respectively. Blue fish comprised only 5% of the total catch in the spring collections and none were taken in the winter gillnet sets.

A total of eleven different shark species were collected in the survey (Table GI-1). Many were collected in only one or two seasons with the exception being the bonnethead shark, which was collected in all seasons but winter. The most abundant shark in the survey was the Atlantic sharpnose shark, which comprised 88% of all shark species collected (Figure GI-1). It was very abundant in the spring and the summer surveys, but absent in fall and winter sampling events.

Nine species of drum (sciaenid) were present in the surf zone throughout the survey (Table GI-1). Over the entire second year survey the southern kingfish was the most abundant sciaenid (Figure GI-1). The southern kingfish was present in every season except winter, with the highest dominance in the summer when this fish is known to spawn in the surf zone (Murdy et. al. 1997; Figure GI-1; Table GI-1). Spot were also present during every season except winter, and most abundant in the summer (Table GI-1). Although the majority of individual drum species were limited in abundance, all drum species combined accounted for about 5% of the total catch.

As expected, most of the species collected by the gillnets outside the surf zone use the area on a seasonal or short-term basis. Large seasonal differences in species richness and species abundance were observed (Table GI-1). Only one species, Atlantic menhaden, out of the 47 finfish species collected in the gillnet survey were present in every season including winter. The highest species richness and abundance were encountered in the spring survey, with 47 species collected, including 18 species that were not present during any of the other seasons. Of those, most were highly migratory species including several sharks, rays, and the green sea turtle (Table GI-1). The summer season was the second most diverse season with 32 species, followed by the fall (17) and then winter (6).

Overall, the gillnet data indicates that species inhabiting the surf zone are highly seasonal with very few yearly residents. This represents a good baseline for documenting the seasonal occurrence of species just outside the surf zone. Although, direct impacts to these species from beach nourishment were not rigorously analyzed, it is important to note that many of the species collected in this survey were of commercial or recreational importance and no obvious differences in these communities were noted after the beach construction.

Table GI-1. Summary of species and percent occurrence for gillnet collections taken during the second year of monitoring at Brunswick County beaches.						
		% Occurrence				
Scienific Name	**Common Name**	**Total Year 2**	**Spring 02**	**Summer 02**	**Fall 02**	**Winter 03**
Alosa mediocris	Hickory shad	0.37	0.07			14.93
Alosa pseudoharengus	Alewife	0.62	0.77	0.11	1.25	
Alosa sapidissima	American shad	0.02	0.04			
Arenaeus cribrarius	Speckled swimming crab	0.17	0.21	0.22		
Bagre marinus	Gafftopsail catfish	0.01	0.02			
Bairdiella chrysoura	Silver perch	0.27	0.26	0.45		
Brevoortia tyrannus	Atlantic menhaden	22.42	7.42	11.67	64.44	78.53
Busycon carica	Knobbed whelk	0.03		0.08		
Busycotypus canaliculatus	Channeled whelk	0.09	0.02	0.24		
Callinectes sapidus	Blue crab	0.18	0.27			2.90
Caranx hippos	Crevalle jack	0.08	0.08	0.08	0.11	
Caranx latus	Horse-eye jack	0.18	0.43			
Carcharhinus brevipinna	Spinner shark	0.07		0.19		
Carcharhinus isodon	Finetooth shark	0.12	0.09	0.24		
Carcharhinus obscurus	Dusky shark	0.01	0.02			
Carcharhinus plumbeus	Sandbar shark	0.01	0.02			
Chaetodipterus faber	Atlantic spadefish	0.04	0.10			
Chelonia mydas	Green sea turtle	0.01	0.02			
Chloroscombrus chrysurus	Atlantic bumper	0.05	0.02	0.12		
Cynoscion nebulosus	Spotted seatrout	0.02				0.92
Cynoscion regalis	Weakfish	0.12	0.04	0.17	0.23	
Dasyatis americana	Southern stingray	0.25	0.60			
Dasyatis sabina	Atlantic stingray	0.02	0.04			
Elops saurus	Ladyfish	0.04	0.11			
Gymnura micrura	Smooth butterfly ray	0.05	0.05	0.08		
Leiostomus xanthurus	Spot	0.88	0.64	1.65	0.13	
Libinia dubia	Longnose spider crab	0.02	0.06			
Libinia emarginata	Portly spider crab	0.08	0.10			1.80
Limulus polyphemus	Horseshoe crab	0.05			0.24	
Lobotes surinamensis	Tripletail	0.07		0.21		
Menippe mercenaria	Florida stone crab	0.01	0.02			
Menticirrhus americanus	Southern kingfish	3.57	2.29	5.89	2.52	
Menticirrhus littoralis	Gulf kingfish	0.16	0.28		0.13	0.92
Micropogonias undulatus	Atlantic croaker	0.14	0.05	0.26	0.11	
Mugil cephalus	Striped mullet	0.15		0.43		
Mugil curema	White mullet	0.08		0.21		
Mustelus canis	Smooth dogfish	1.60	3.90			
Myliobatis freminvillei	Bullnose ray	0.26	0.57	0.08		
Odontaspis taurus	Sand tiger	0.02	0.04			
Oligoplites saurus	Leatherjack	0.02	0.04			
Opisthonema oglinum	Atlantic thread herring	9.32	18.07	0.60	8.04	
Ovalipes ocellatus	Lady crab	0.20	0.30	0.21		
Penaeus setiferus	Northern white shrimp	0.01	0.02			
Peprilus alepidotus	Harvestfish	0.15	0.02	0.41		
Peprilus triacanthus	Butterfish	0.10	0.04	0.24		
Pogonias cromis	Black drum	0.05		0.15		
Pomatomus saltatrix	Bluefish	7.56	4.92	6.79	14.95	
Rachycentron canadum	Cobia	0.05			0.23	
Raja eglanteria	Clearnose skate	0.09	0.21			
Rhinoptera bonasus	Cownose ray	1.22	0.29	3.02	0.11	
Rhizoprionodon terraenovae	Atlantic sharpnose shark	41.08	56.37	50.01		
Scomberomorus maculatus	Spanish mackerel	6.01	0.15	12.96	6.31	
Sphyraena barracuda	Great barracuda	0.07	0.16			
Sphyrna lewini	Scalloped hammerhead	0.20	0.04	0.51		

Table GI-1. (Continued)						
		% Occurrence				
Scienific Name	**Common Name**	**Total Year 2**	**Spring 02**	**Summer 02**	**Fall 02**	**Winter 03**
Sphyrna tiburo	Bonnethead	0.95	0.21	2.35	0.12	
Trachinotus carolinus	Florida pompano	0.50	0.51	0.24	0.95	
Trichiurus lepturus	Atlantic cutlassfish	0.05		0.15		
Trinectes maculatus	Hogchoker	0.02			0.11	
Mean Abundance (#/hr)		6	7	8	14	1
Total Number of Species		58	47	32	17	6

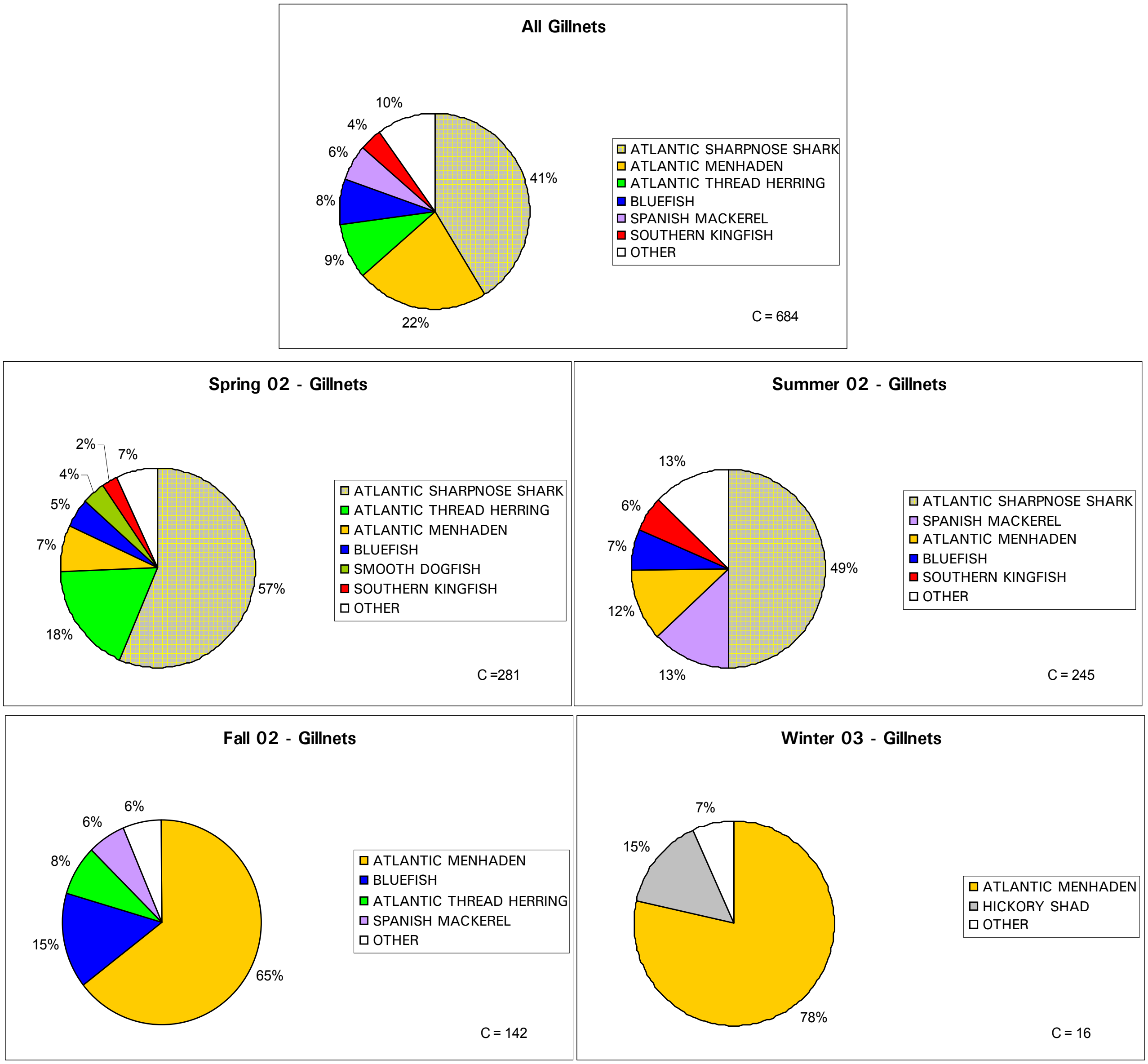


Figure GI-1. Species catch composition for the gillnet samples taken in the second year of monitoring at the Brunswick County beaches. C = standardized total catch per effort.

3.6 ICHTHYOPLANKTON SUMMARY

Annual ichthyoplankton sampling at the subject beaches and the reference beach began in the spring of 2002 at Bald Head Island and followed the routine sampling of the second year of quarterly monitoring at Caswell, Oak Island, and Holden Beach. As with the gillnet survey, the purpose of this survey was to document species occurrence and relative abundance of ichthyoplankton adjacent to the surf zone. During each ichthyoplankton survey, 2 replicate tows using a 550 μm bongo net were done at four stations at the subject beach and one station at the reference beach. All tows were combined for each beach and standardized to number caught per cubic meter. All the beach and reference data for year two were combined for each season of sampling and are presented in Table IC-1 and Figure IC-1.

During the second year of ichthyoplankton sampling, a total of 32 identifiable species within 7 different family groups were collected (Table IC-1). The most dominant were from the anchovy family, comprising 30% of the collection during the second year (Figure IC-1). Other dominant fish were the Atlantic silverside (26%), naked goby (9%), bluefish (8%), pinfish (7%), and the Atlantic croaker (4%).

During the spring survey, 16 fish taxa were collected (Table IC-1). The Atlantic silverside was the most prevalent species, representing 43% of the total species composition (Figure IC-1). Anchovies were the second most common species followed by drum species, bluefish and spotted hake. The highest species richness occurred during the summer survey with 22 fish taxa collected (Table IC-1). In this survey goby species dominated the catch along with anchovies (Figure IC-1). Sea trout and drums were also present in high numbers, representing 7% and 4% of the composition respectively. The season with the lowest species richness was the fall survey, which was dominated by bluefish and the planehead filefish (Figure IC-1). The winter survey was dominated by pinfish (37%), bluefish (29%), Atlantic croaker (18%), and lefteyed flounder (5%) (Figure IC-1).

The ichthyoplankton collected during this survey are indicative of ichthyoplankton assemblages found in the South Atlantic Bight (Able and Fahay 1998). Many of the species present in this survey are of ecological or socioieconomical importance. Again, as with the gillnet survey, these data represent good baseline information on seasonal occurrences of ichthyoplankton in the study area.

Table IC-1. Summary of species and per unit occurrence of ichthyoplankton tows taken during the second year of monitoring at Brunswick County beaches						
		% Occurrence				
Scientific Name	**Common Name**	**Total Year2**	**Spring 02**	**Summer 02**	**Fall 02**	**Winter 03**
Aluterus schoepfi	Orange filefish	0.02		0.08		
Anchoa spp.	Common anchovy	30.08	36.18	38.64		0.71
Anchoa hepsetus	Striped anchovy	0.02		0.08		
Anguilla rostrata	American Eel	0.90				4.83
Astroscopus guttatus	Northern stargazer	0.02				0.11
Bothidae	Lefteyed flounders	1.79	1.39			5.30
Brevoortia tyrannus	Atlantic menhaden	0.60	0.75	0.60		0.12
Carangidae	Jacks	0.14		0.60		
Chloroscombrus chrysurus	Atlantic bumper	0.08		0.35		
Cynoscion spp.	Sea trout	2.16	0.75	7.38		
Elops saurus	Ladyfish	0.11		0.47		
Gobiidae	True gobies	1.24		5.32		
Gobiosoma bosc	Naked goby	8.83	0.10	37.64		
Lagodon rhomboides	Pinfish	7.24	1.01			35.87
Larimus fasciatus	Banded drum	0.05		0.20		
Leiostomus xanthurus	Spot	0.43				2.31
Megalops atlanticus	Tarpon	0.04		0.15		
Menidia menidia	Atlantic silverside	25.85	43.62	0.53		2.62
Menticirrhus spp.	Kingfishes	0.02		0.08		
Micropogonias undulatus	Atlantic croaker	4.25	1.53			18.13
Monacanthus hispidus	Planehead filefish	1.09	1.16	1.42	35.65	
Osteichthyes spp.	Bony fishes	0.04		0.16		
Peprilus triacanthus	Butterfish	0.04	0.07			
Pomatomus saltatrix	Bluefish	7.95	3.90	0.37	64.35	29.33
Prionotus spp.	North American searobins	0.85	1.11	0.45		0.57
Sciaenidae	Drums	3.32	4.14	3.97		
Sphoeroides maculatus	Northern puffer	0.29	0.49			
Symphurus plagiusa	Blackcheek tonguefish	0.02				0.10
Syngnathus fuscus	Northern pipefish	0.09		0.41		
Trachinotus carolinus	Florida pompano	0.09	0.13	0.08		
Trinectes maculatus	Hogchoker	0.24		1.03		
Urophycis regia	Spotted hake	2.11	3.65			
Mean Average Abundance (#/cubic meters)		0.0185	0.0284	0.0160	0.0005	0.0093
Total Number of Taxa		32	16	22	2	12

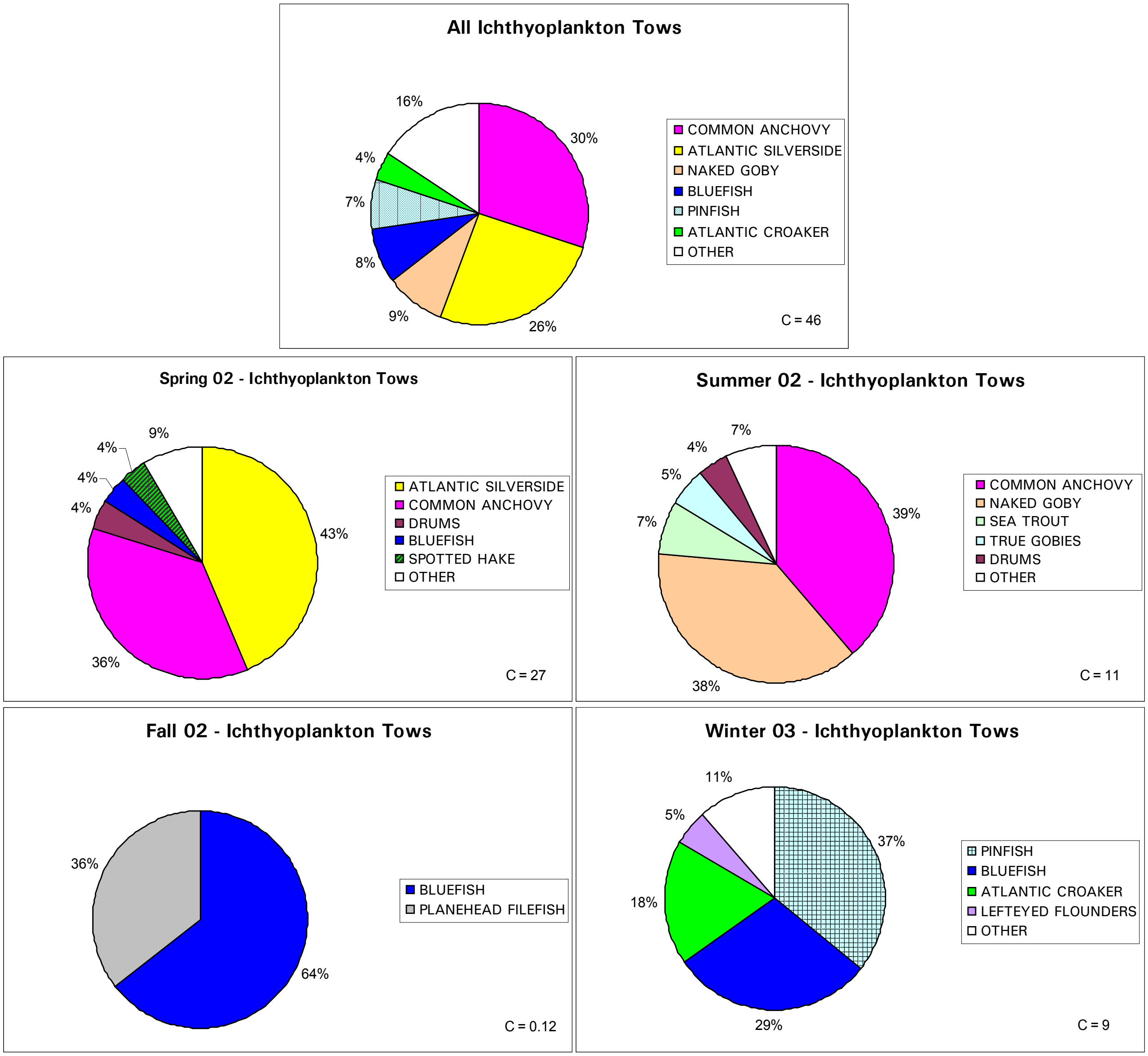


Figure IC-1. Species catch composition for the ichthyoplankton tows taken in the second year of monitoring at the Brunswick County beaches. C = standardized total catch per effort.

3.7 WATER QUALITY AND SEDIMENT CHARACTERISTICS

3.7.1 Water Quality

Water quality was monitored for seven months after the initial construction on Oak Island. In-situ YSI water quality meters were suspended from the Ocean Crest and Long Beach Island fishing piers at the same locations that were monitoring during the first year of the program. Both meters were maintained through November 2002. After this date the mooring system and YSI unit at the Ocean Crest pier failed and was not replaced. The Long Beach water quality meter was maintained until the last quarterly sampling event that occurred in January of 2003.

Ocean temperatures reflected expected seasonal changes where readings above 28 °C were observed from July through September gradually falling in the onset of fall (October 2002) to winter lows of about 10 °C (Figure WQ-1).

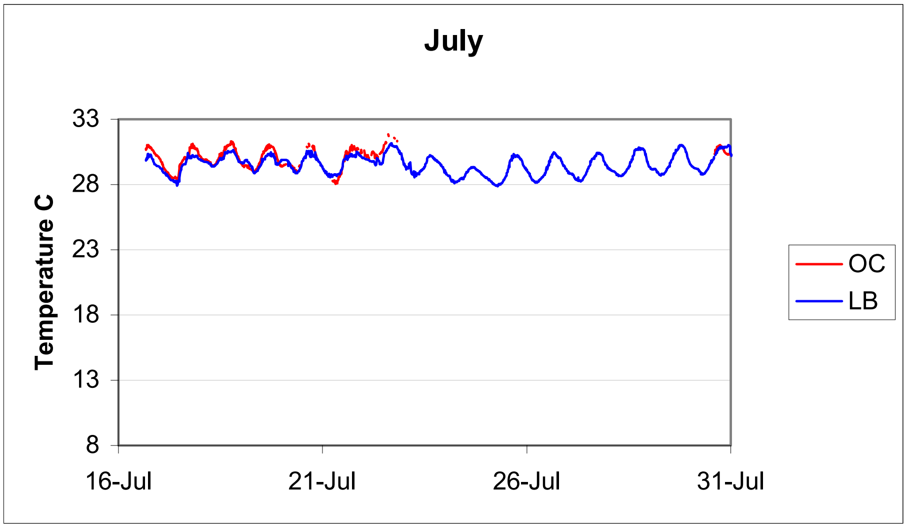
Oceans salinities varied little during the second year of monitoring and there were no observable differences in salinity between the two monitoring locations. Salinities were about 35 ppt throughout the entire monitoring period (Figure WQ-2).

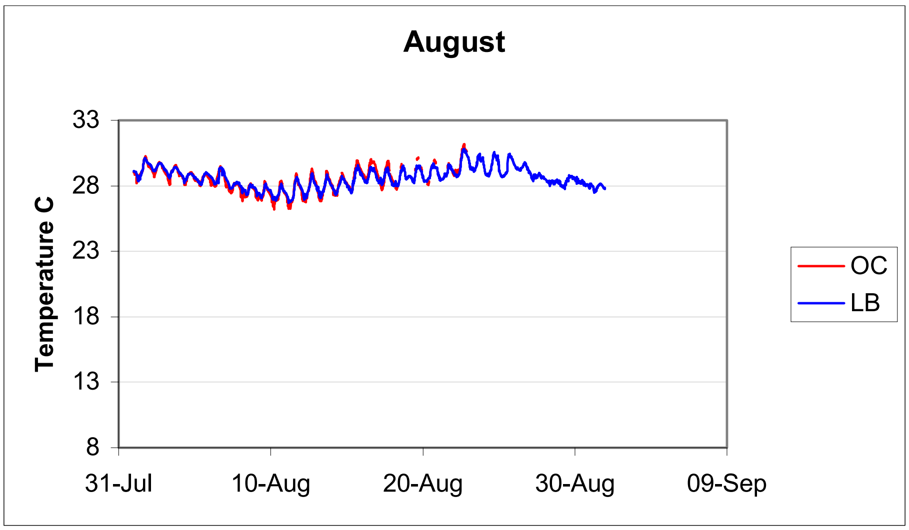
Dissolved oxygen levels were generally above 5 mg/L and averaged about 6 mg/L throughout the monitoring period (Figure WQ-3). Although the data were cleaned up to remove obviously erroneous data as a result of biofouling, electronic interferences, or other external factors, occasional very short-lived spikes below 5 mg/L were recorded.

Turbidity levels were typically below 100 mg/L with occasional spikes nearing the meter's 1,000 mg/L upper limit (Figure WQ-4). Because there was no beach replenishment activity conducted in the second year, the observed increases were most likely the result of storm related events and high surf conditions. Spikes in turbidity were commonly observed in the first four months of monitoring (July through October). Levels above 200 mg/L were rarely recorded in the subsequent months of November 2002 through January 2003. The long-term record of turbidity in the surf zone recorded in the second year of the program was very similar to the patterns observed during the construction year. Water quality monitoring and plume mapping during the beach construction suggested that turbidity plumes caused by the beach disposal operations on the beach face were small and short-lived (Versar 2002).

3.7.2 Sediment Grain Size Characteristics

As expected, sediment sized sand particles decreased in size from the wrack area outward to the deep habitat beyond the wave breakers. Coarse to very coarse sized sand particles were generally collected from the beach habitats and more medium to fine sized sand particles were collected from the deep habitat (Figures SD-1 to SD-5). Sediment grain size characteristics at the study beaches one-year post beach construction were consistent with those documented in Versar 2002 with one exception. During the first year of sampling, the deep habitat at Bald Head Island exhibited a higher level of silt/clay particles than other beaches (Versar 2002). By the second year of sampling (one-year later) the higher amount of silt/clay particles were not evident in the composite samples at Bald Head Island (Figure SD-1).





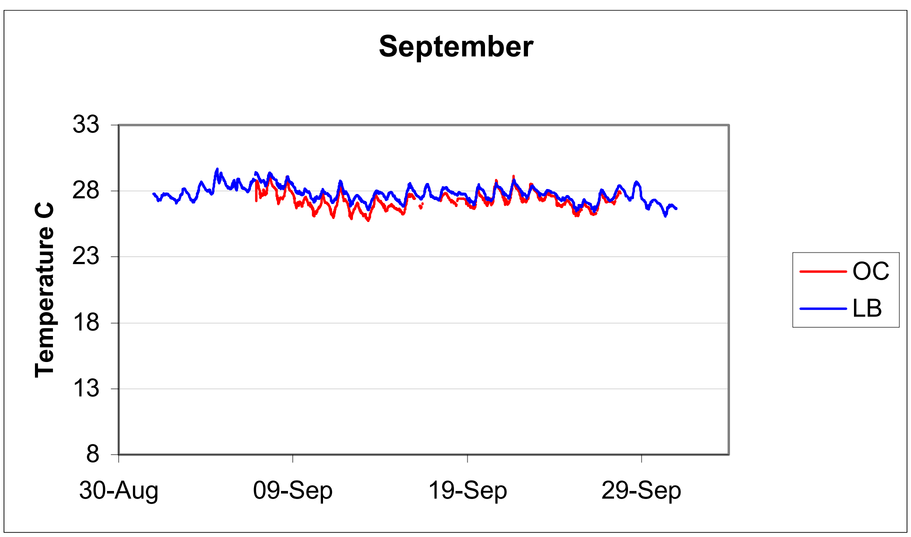


Figure WQ-1. Observed temperature (°C) at Ocean Crest and Long Beach piers on Oak Island, North Carolina during the second year of post construction monitoring conducted between July 2002 and Winter 2003. Data from Ocean Crest pier is represented in red and Long beach pier is represented in blue.

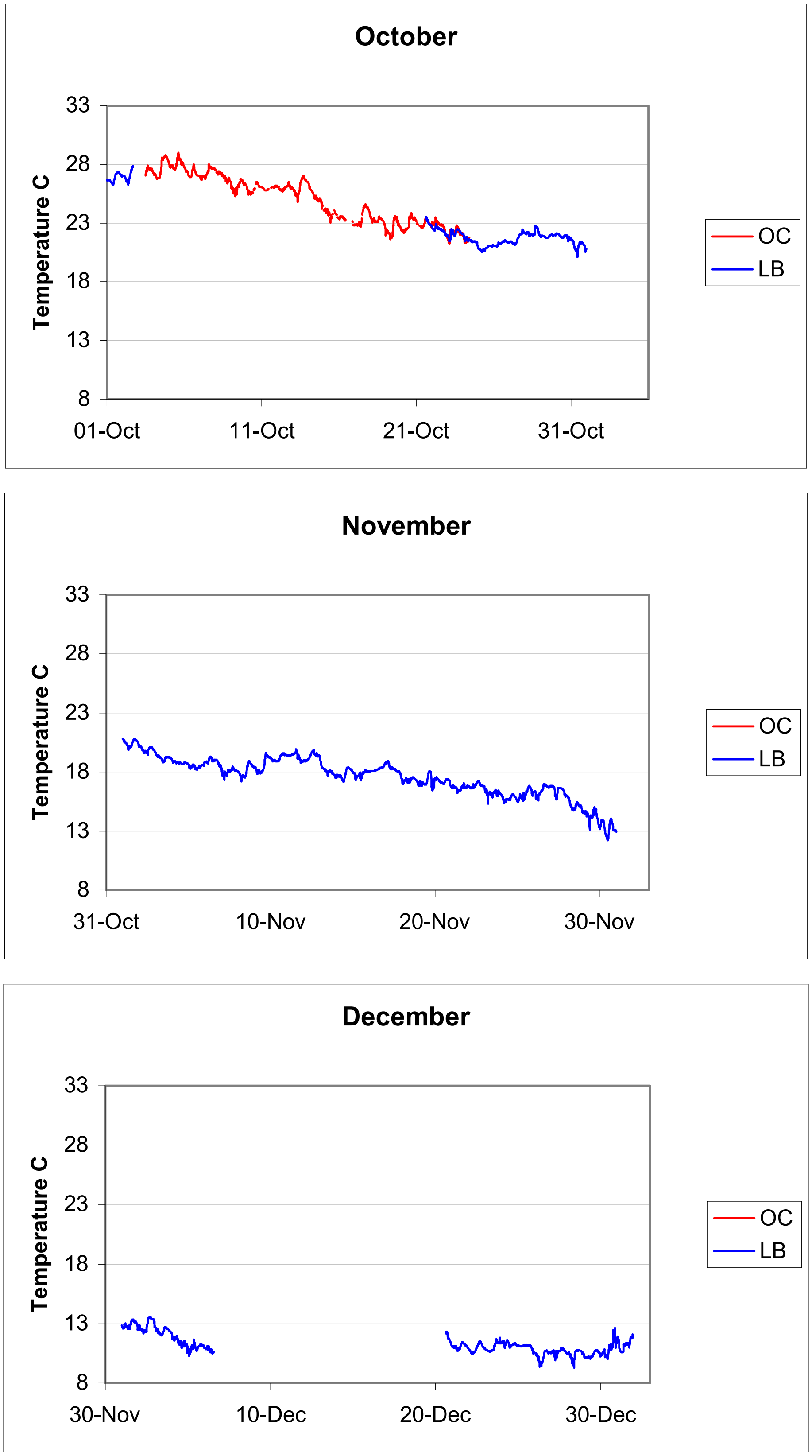


Figure WQ-1. (Continued)

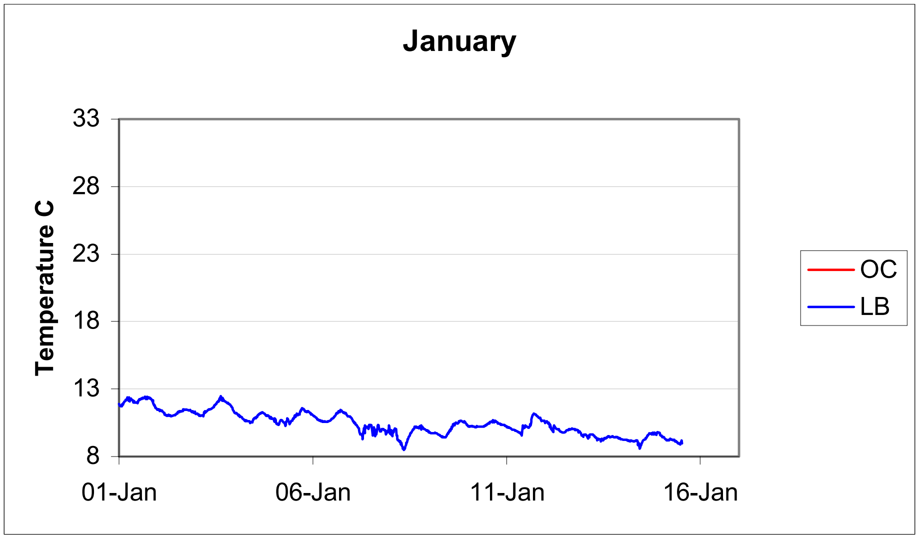


Figure WQ-1. (Continued)

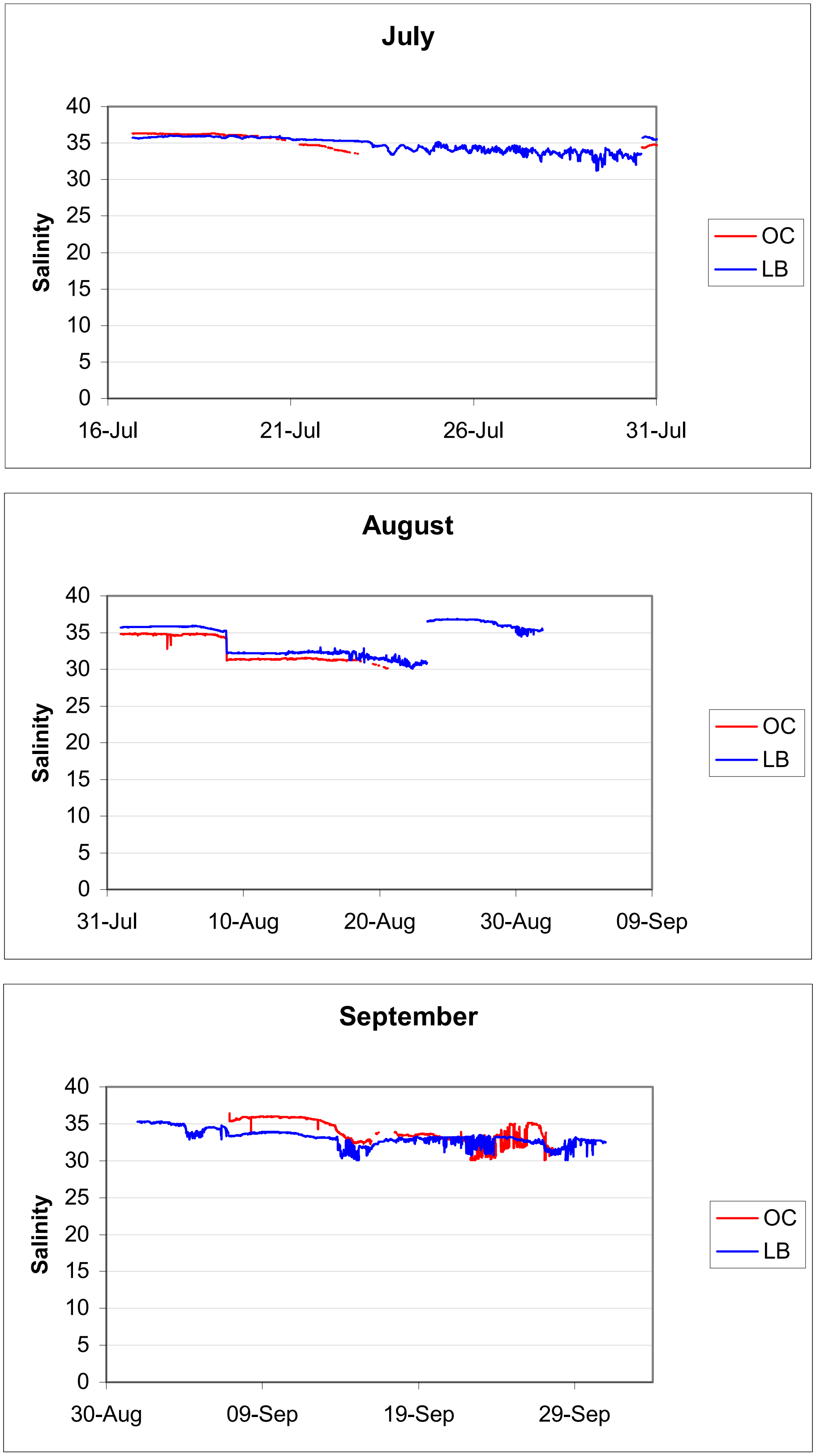
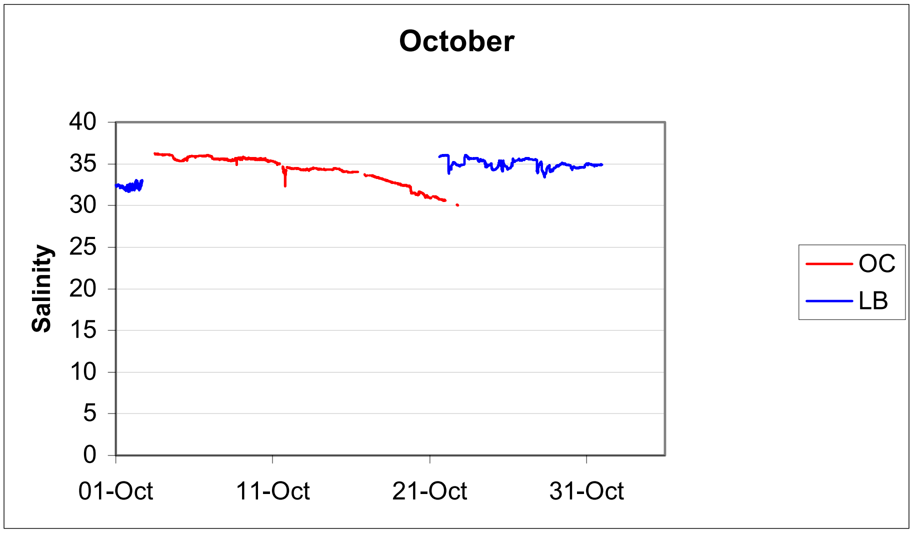
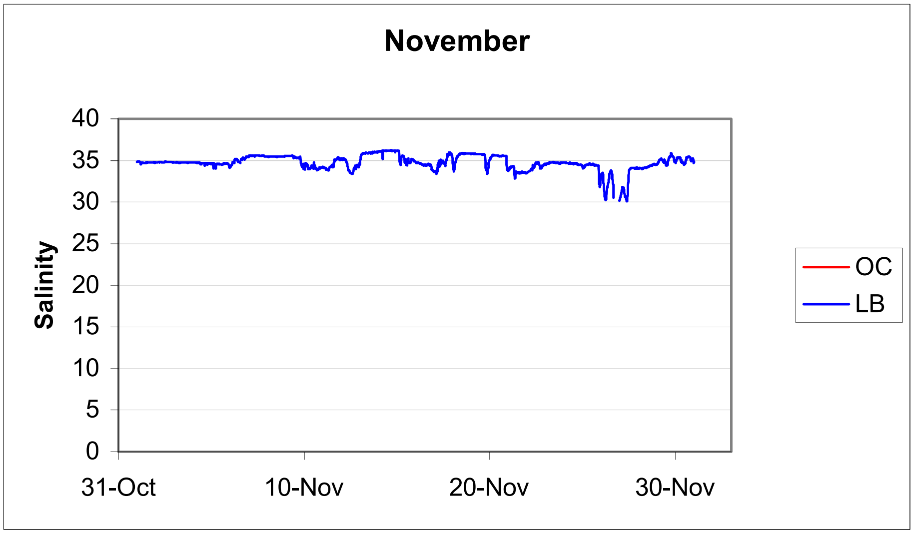


Figure WQ-2. Observed salinity (ppt) at Ocean Crest and Long Beach piers on Oak Island, North Carolina during the second year of post construction monitoring conducted between July 2002 and Winter 2003. Data from Ocean Crest pier is represented in red and Long beach pier is represented in blue.





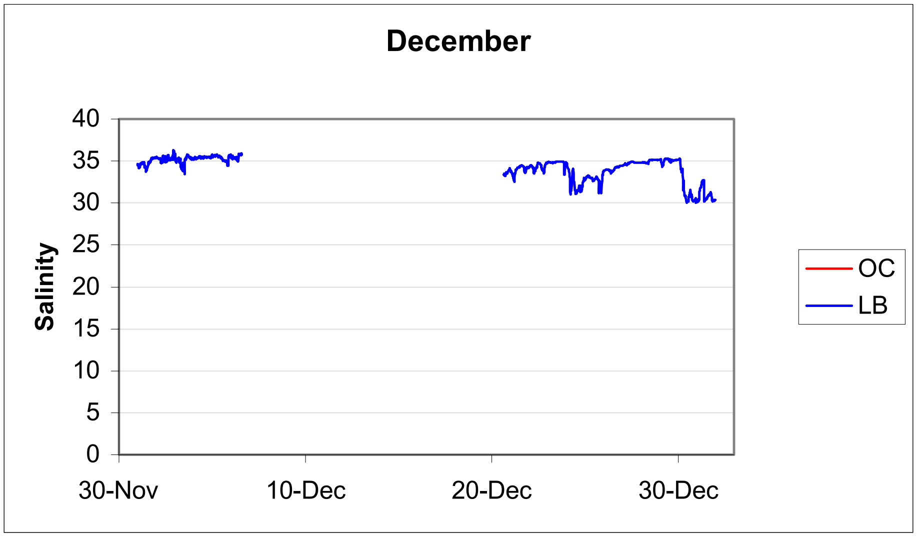


Figure WQ-2. (Continued)

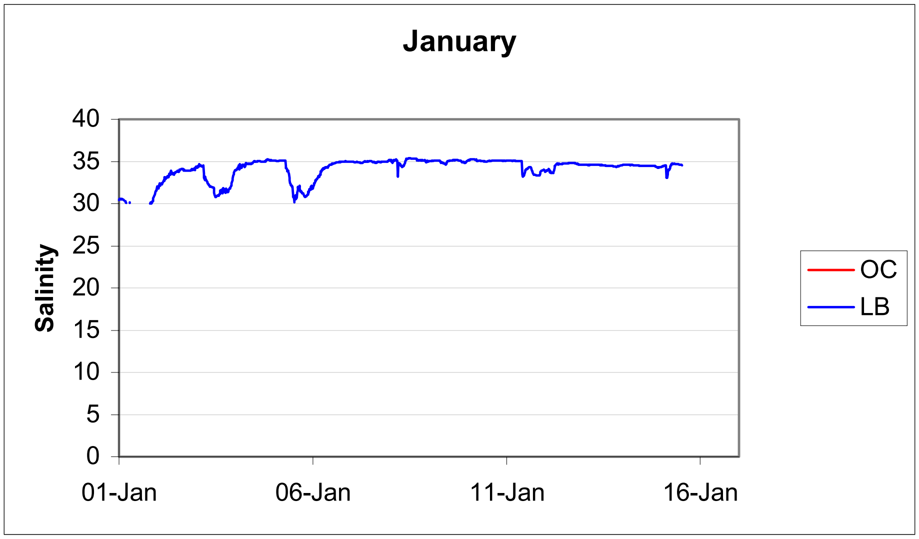


Figure WQ-2. (Continued)

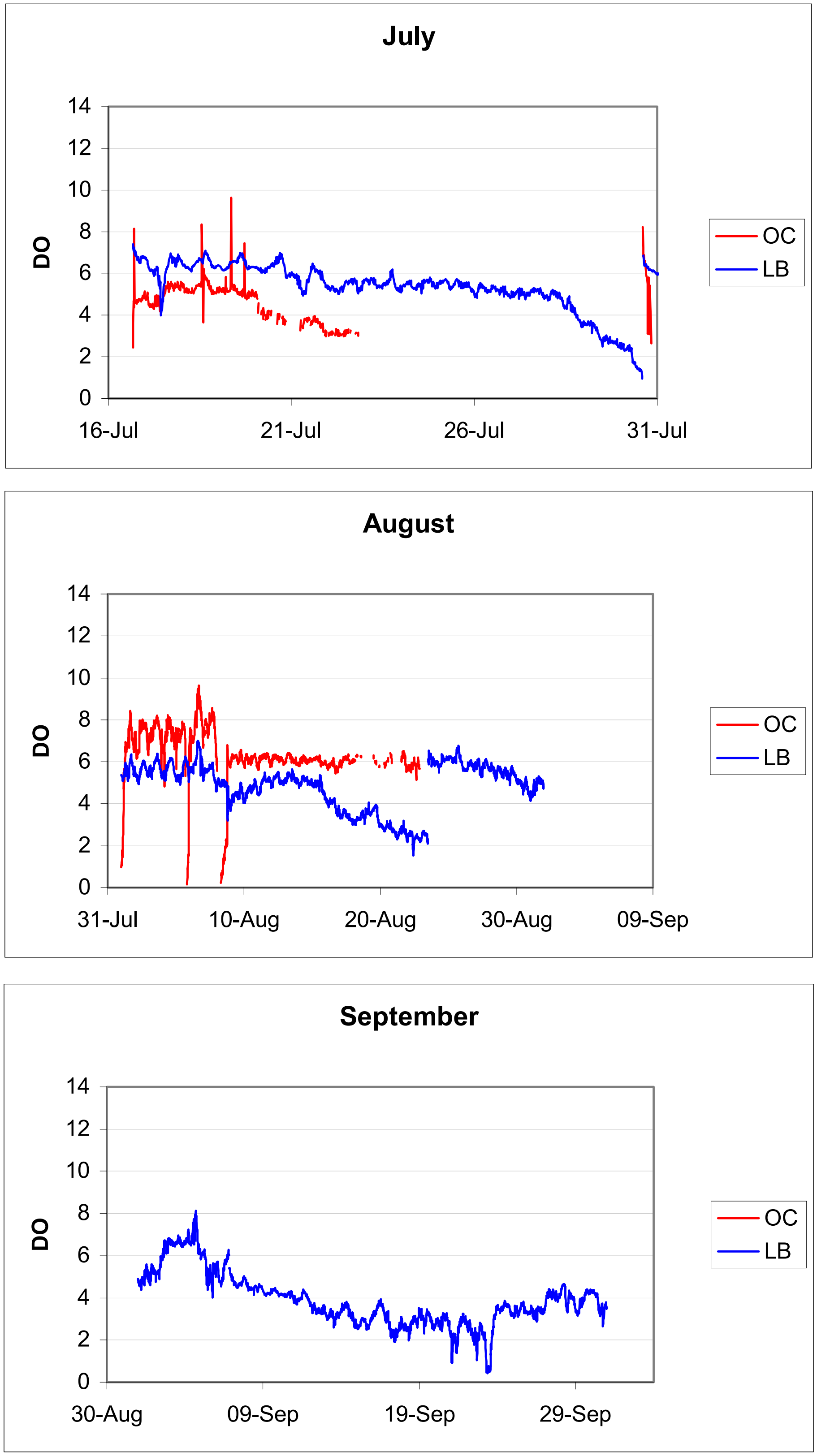
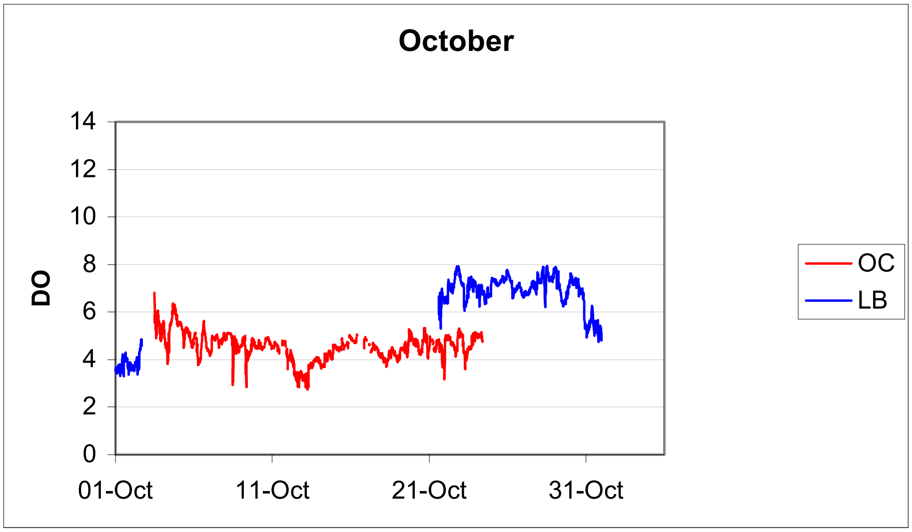
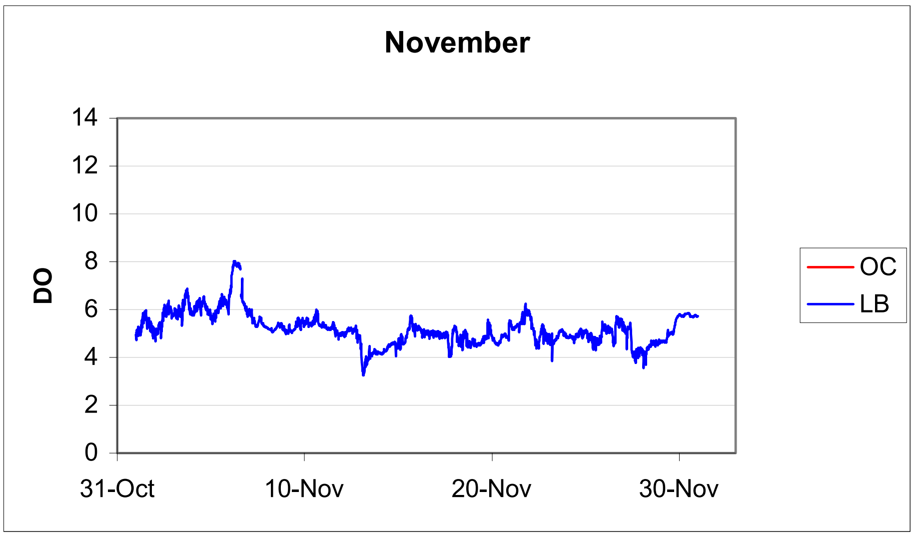


Figure WQ-3. Observed dissolved oxygen (mg/L) at Ocean Crest and Long Beach piers on Oak Island, North Carolina during the second year of post construction monitoring conducted between July 2002 and Winter 2003. Data from Ocean Crest pier is represented in red and Long beach pier is represented in blue.





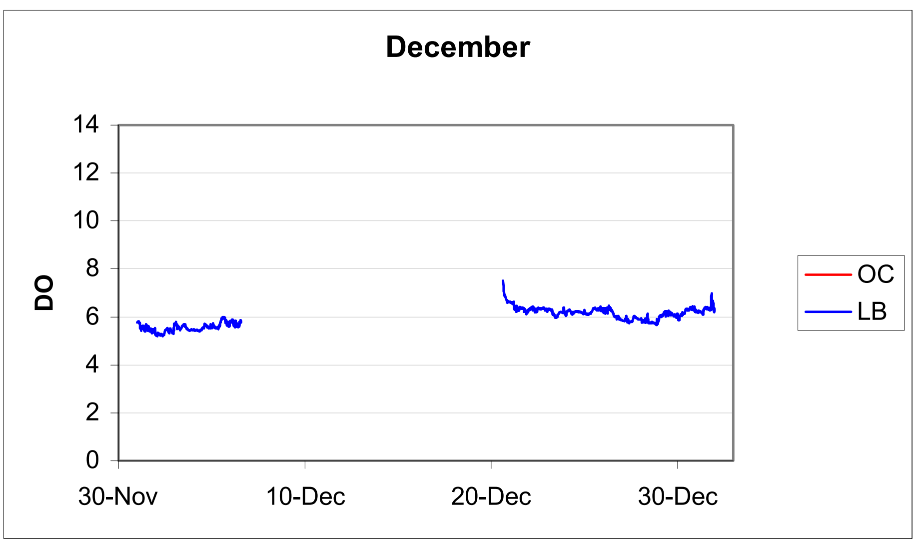


Figure WQ-3. (Continued)

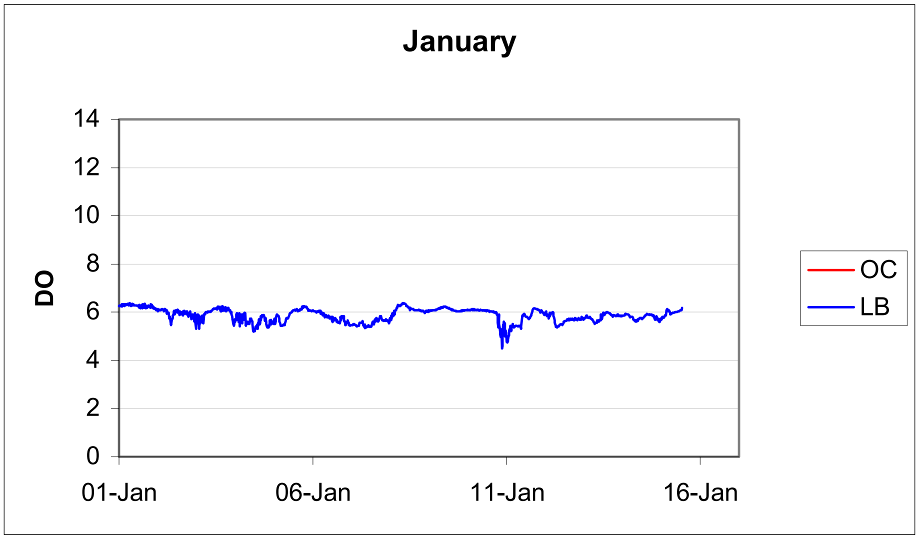


Figure WQ-3. (Continued)

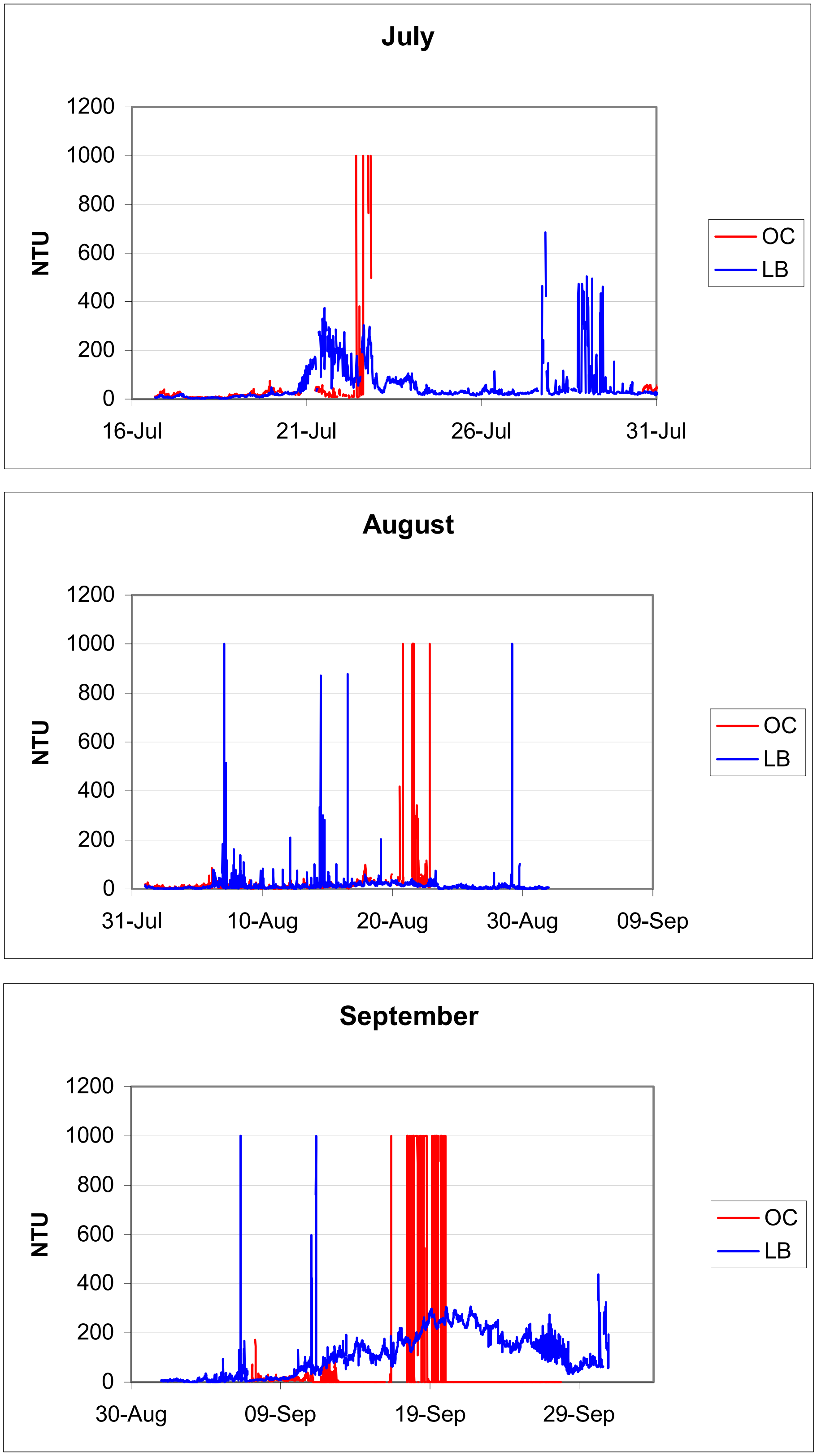


Figure WQ-4. Observed turbidities (NTUs) at Ocean Crest and Long Beach piers on Oak Island, North Carolina during the second year of post construction monitoring conducted between July 2002 and Winter 2003. Data from Ocean Crest pier is represented in red and Long beach pier is represented in blue.

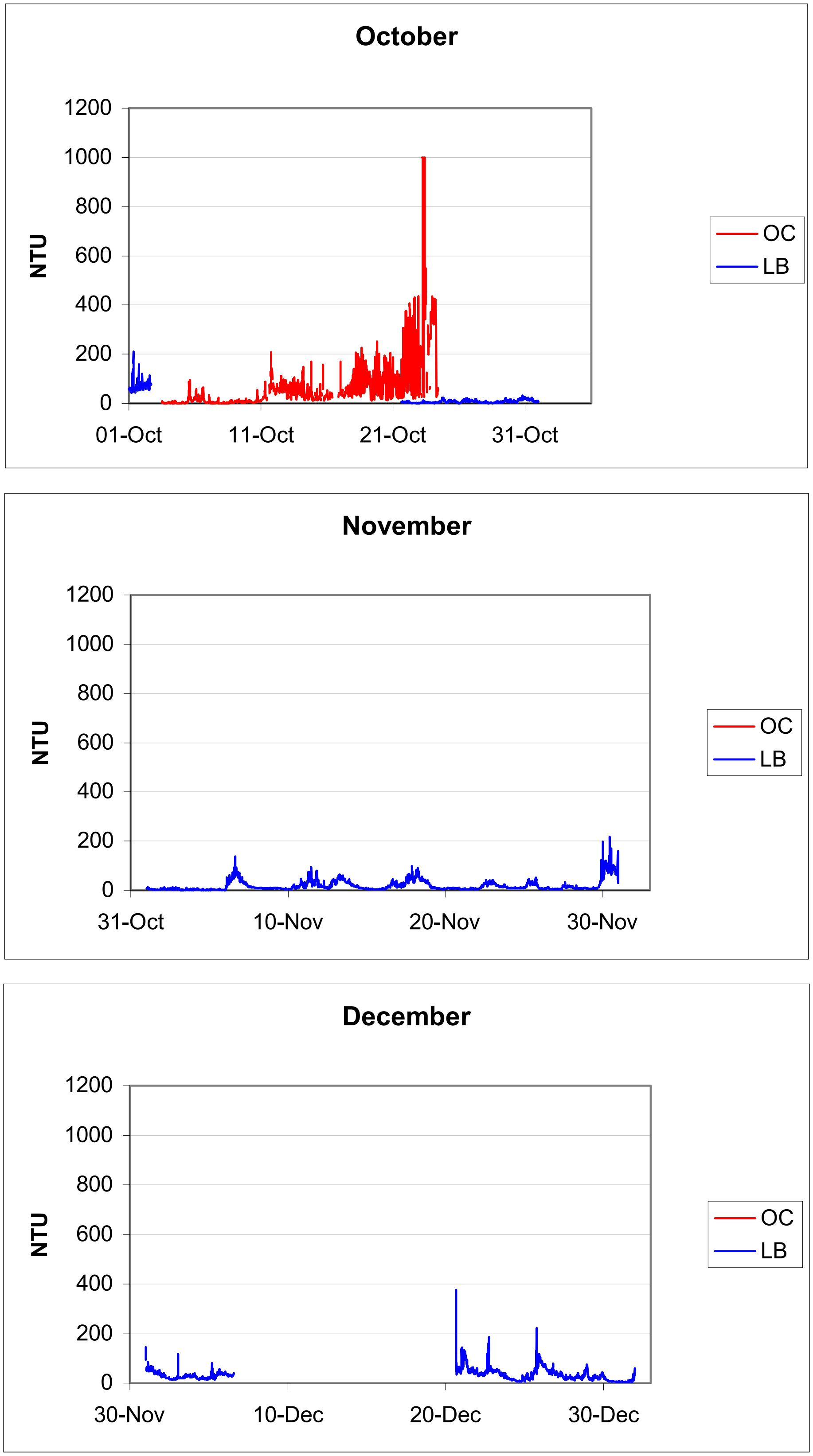


Figure WQ-4. (Continued)

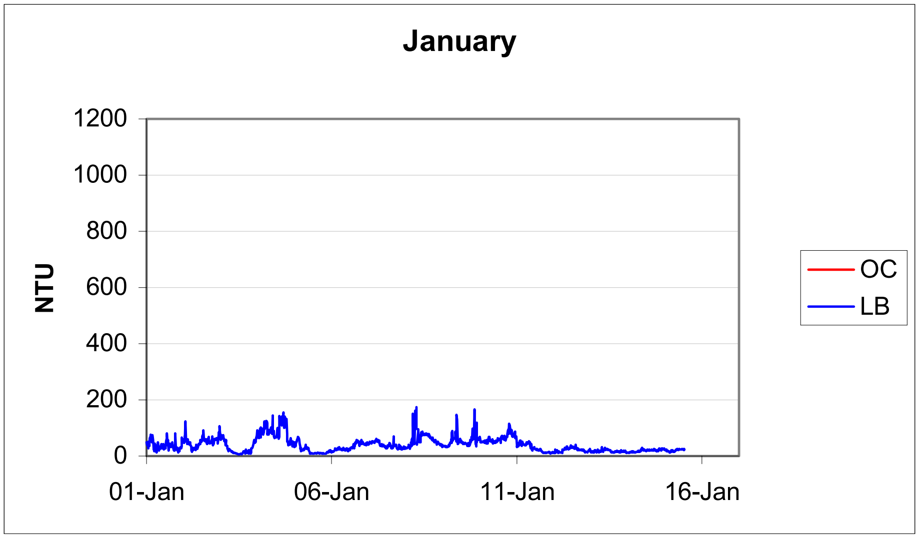


Figure WQ-4. (Continued)

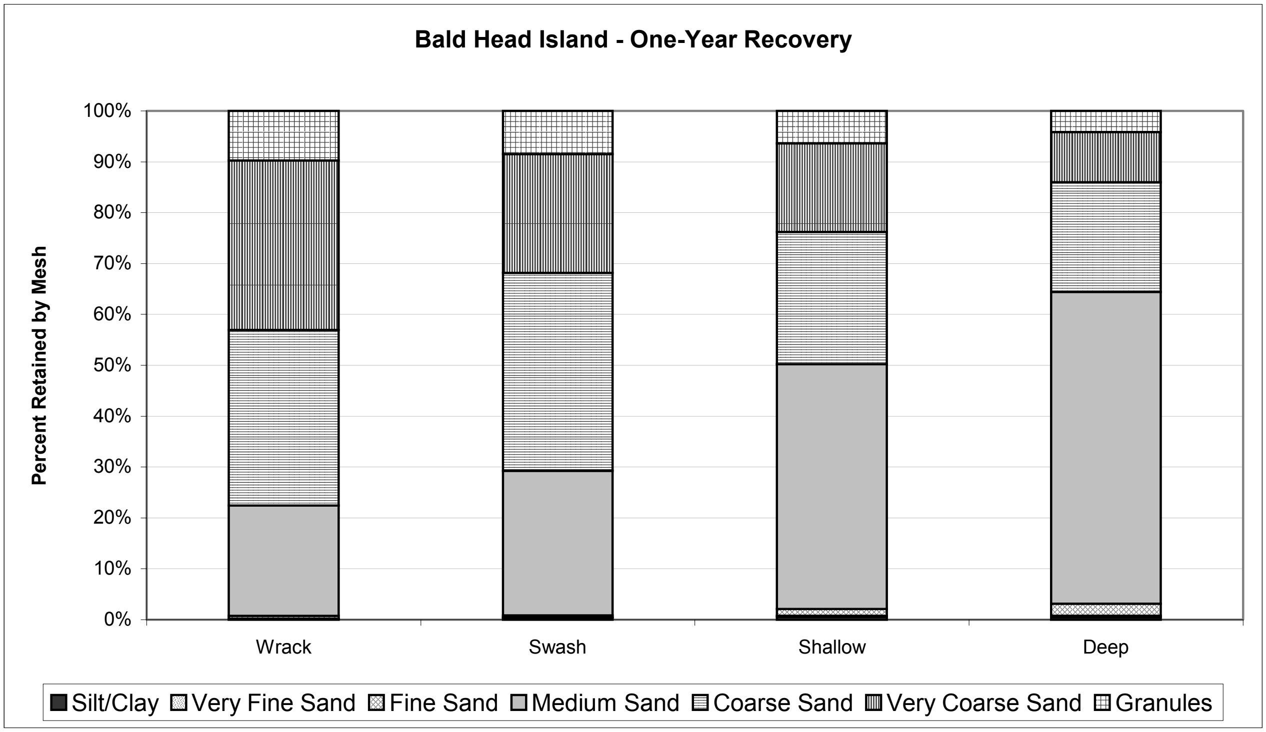


Figure SD-1. Sediment particle size percent distributions at the four sampled habitats at Bald Head Island, 1-year after sand placement.

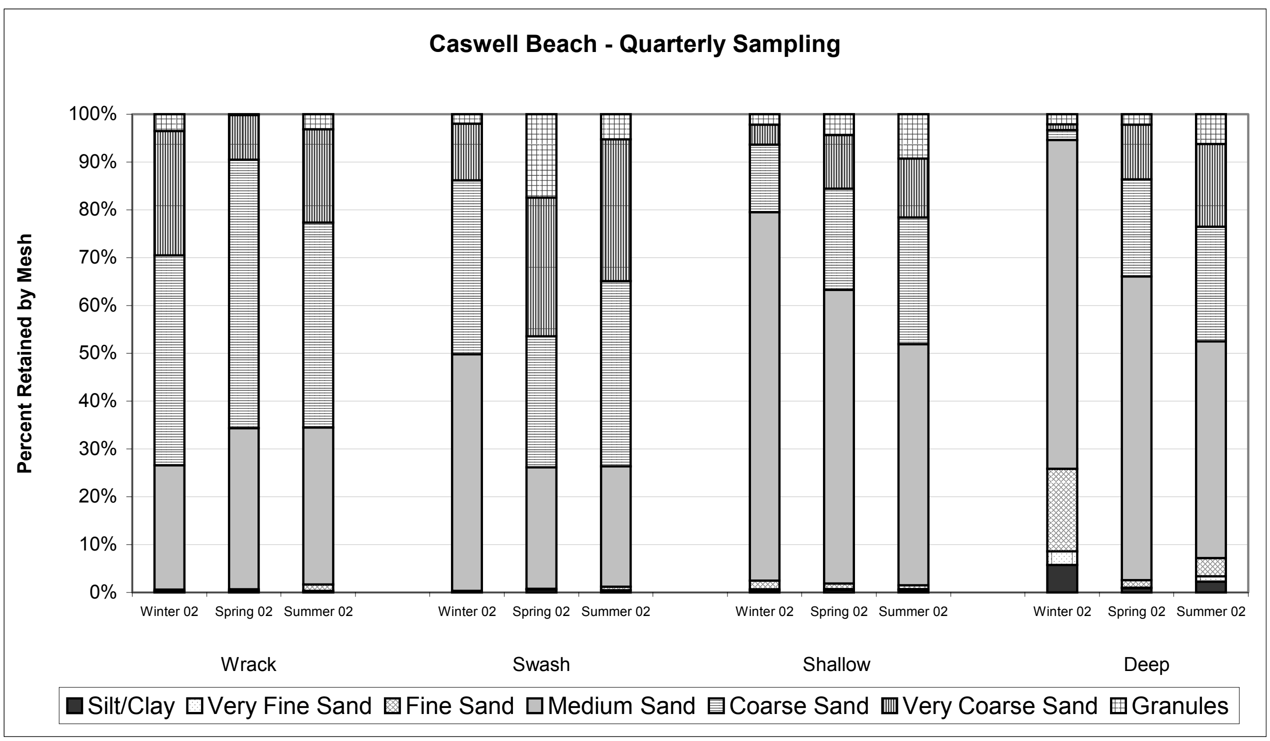


Figure SD-2. Sediment particle size percent distributions at the four sampled habitats at Caswell Beach for quarterly and 1-year post construction samples

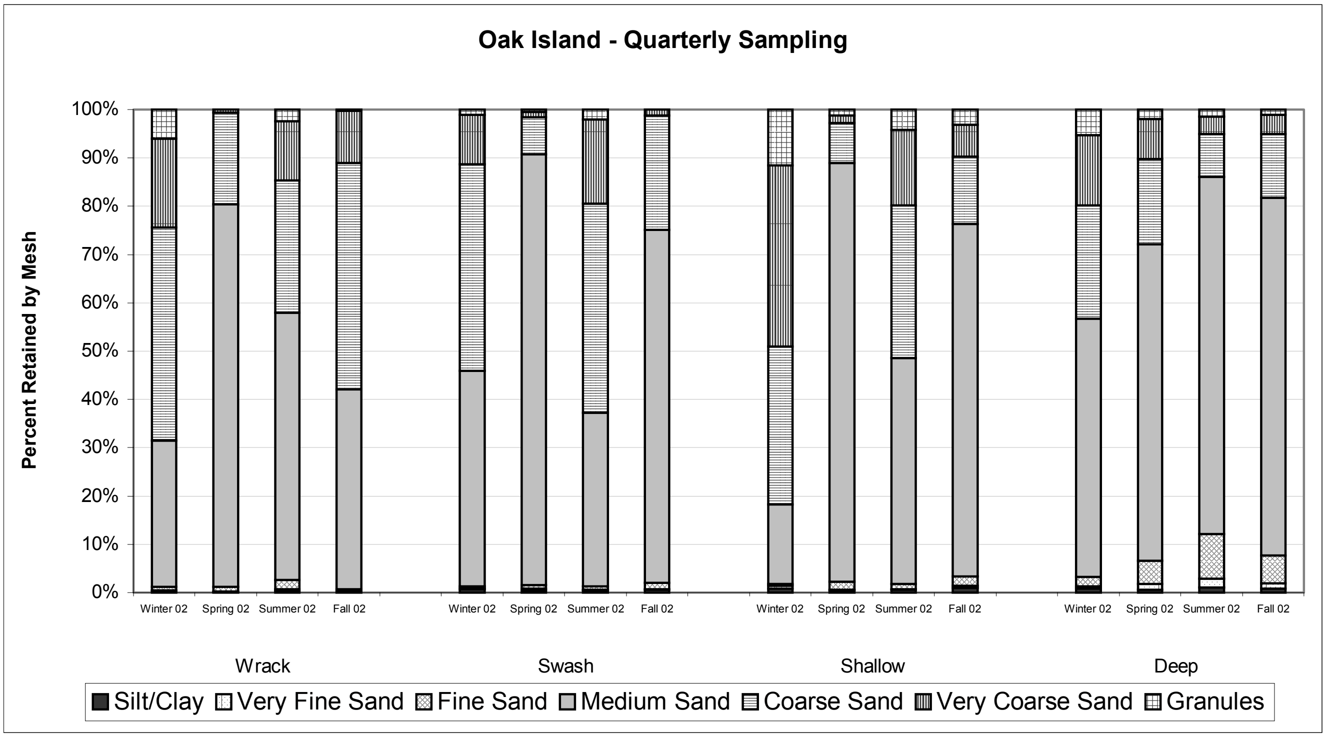


Figure SD-3. Sediment particle size percent distributions at the four sampled habitats at Oak Island for quarterly and 1-year post construction samples

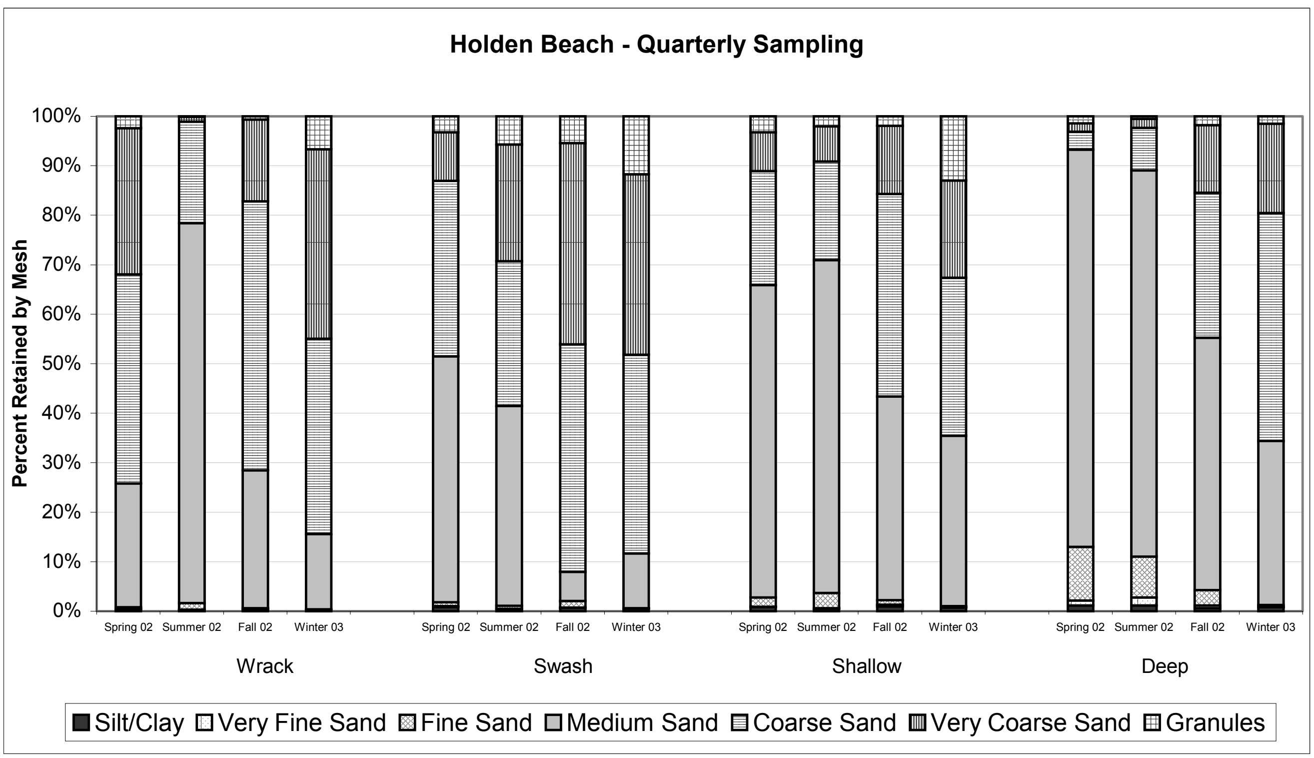


Figure SD-4. Sediment particle size percent distributions at the four sampled habitats at Holden Beach for quarterly and 1-year post construction samples

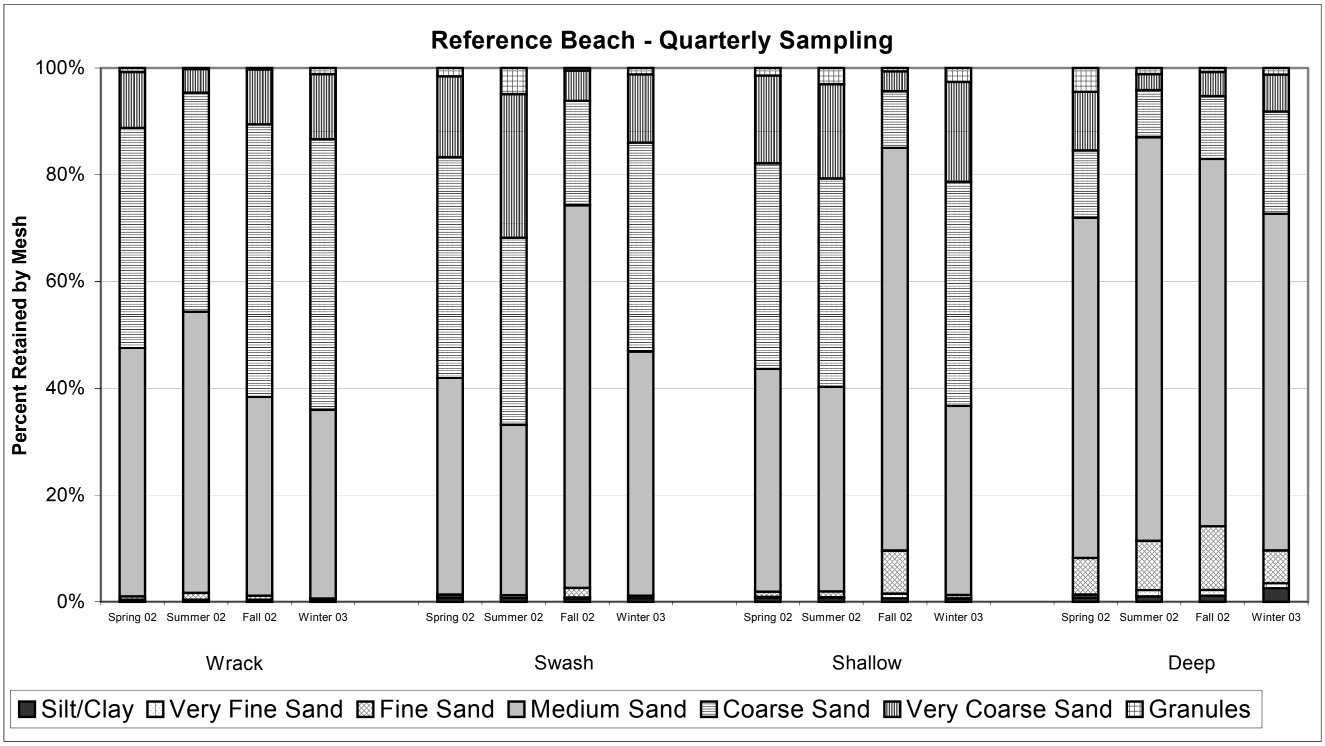


Figure SD-5. Sediment particle size percent distributions at the four sampled habitats at the reference beach for quarterly and 1-year post construction samples

4.0 DISCUSSION

Immediate impacts, defined for this report as the period between 0 to 8 weeks after sand placement, were documented for the swash and shallow habitat at the study beaches (Versar 2002). Some of these immediate impacts were still detected one-year after beach construction particularly at Caswell Beach which was reconstructed in the summer 2001. Immediate impacts in the wrack and deep habitats, however, were limited to the Bald Head Island that was reconstructed in the spring of 2001. The data suggest that the benthic communities in the wrack and deep habitats had recovered by one-year post construction. Since no quarterly sampling was conducted at Bald Head Island no estimate as to speed of recovery can be made for these habitats.

The most severe and widespread impacts of beach construction were detected in the swash habitat. The timing of beach construction did not appear to influence the immediate impact on the benthic community as all seasons displayed immediate impacts. However, the season when the beach was constructed or the way the beach was constructed (i.e., double impact at Caswell Beach) may have affected the recovery rate of the benthic community.

Sampling immediately after sand placement revealed much lower populations of bean clams (*Donax variabilis*) at all four beaches, but the most severe impact was detected in spring (Bald Head Island) and summer (Caswell Beach). At Bald Head Island, *Donax* abundances decreased by 2 orders of magnitude from undisturbed conditions and remained at this low level one-year later. *Emerita* mole crabs decreased by 1 order of magnitude immediately after sand placement and remained that way one-year later. Quarterly sampling was not conducted at this beach so impacts in other seasons could not be determined. Other researchers (Reilly and Bellis 1978, 1983, Van Dolah et al. 1992, and Jutte et al. 1999b) found similar declines in *Donax* abundances immediately after sand placement in the spring but found that clam populations had recovered by the following year.

At Caswell Beach, an immediate impact of sand placement conducted in the summer was detected for *Donax* clam populations. Clam abundances decreased by about 10 fold from about 500/m^2 to around 30/m^2 immediately after and stayed around 60/m^2 by one-year after. Quarterly sampling at this beach also showed much reduced numbers of clams at the study beach when compared to the reference beach. Immediate impacts on clam populations have been documented by other studies with beach replenishment activities occurring in the summer (Jutte et al. 1999, Van Dolah et al. 1992) but again the clam populations were found to have recovered by 6 months. The double impact that occurred at Caswell Beach most likely caused a disruption in recruitment ability of *Donax* clams that persisted up to a year after the placement effects. If the impact was restricted to one placement event in the summer then it could be expected that the clam population would have been able to recover within a year. Oak Island clam populations (the season with the second highest numbers of clams) also displayed a significant decrease in clam populations immediately after beach reconstruction but abundances had recovered within a year of the impact.

Based on past research, Hackney et al. 1996 suggested that the best time for beach nourishment activities to limit impacts on mole crabs would be during winter and early spring (see also Peterson et al. 2000). Our results, however, found significant immediate impacts on mole crab abundances in the winter and spring. The low numbers of crabs present in these seasons and the low standard error about the mean most likely added to the significant depression exhibited immediately after sand placement. None of the impacts detected in the winter and spring were apparent one-year later. No immediate impact or long-term impact on crab abundances was detected in the summer and fall when impacts would be expected (Hackney et al. 1996).

In the shallow habitat, the only immediate and long-lasting impact detected was at Caswell Beach, the area that had two nourishment cycles conducted within the same season. At this beach, *Donax variabilis* again was the most affected species. The recruitment period for this species of clam occurs in the early to mid summer (Hackney et al. 1996). The fact that the clam's abundance had not recovered one-year later as other researchers found (Jutte et al. 1999b, Van Dolah et al. 1992) is likely due to the double impact conducted at this beach which disrupted the clam's recruitment ability.

Impacts in the deep habitat were minimal with the exception of a large decrease in polychaete abundances at Bald Head Island. This decrease was due to a large decrease in *Scolelepis squamata* polychaete abundances documented in the results section. Abundance of this polychaete one-year after sand placement was similar to reference conditions both before and after the impact. Therefore the decrease in total abundance that was detected in this habitat was more likely caused by the large natural variation in polychaete abundances rather than sand placement. Again other researchers found little to no short or long-term impacts from sand placement in these subtidal areas (Reilly and Bellis 1978, 1983, Van Dolah et al. 1992, and Jutte et al. 1999a,b).

The fish community sampled with both seines and trawls exhibited similar trends in species composition and abundance at all of the study beaches; however, there was a general tendency of lower diversity at the reference beach. This pattern of lower diversity and abundance at the reference beach was also observed during the first year of the study (Versar 2002). The difference displayed at the reference beach may be attributable to its distance from the mouth of the Cape Fear River. Similar patterns of large numbers of schooling fish such as bay anchovies were displayed in both years of the study. The presence of these fish constrained the ability to detect impacts from beach nourishment activities.

Beach reconstruction activities could impact fish communities in several ways. The most direct effect would be altering the abundance or distribution of fish and nekton during or immediately after the disturbance. Few impacts from the beach reconstruction were detected from the first year of trawl and seine data, indicating limited immediate impacts on surf zone fish communities at any study beach or season during the nourishment activities and up to 8 weeks beyond the disturbance. A potential indirect impact would be the alteration or decimation of the benthic community, which serve as important prey for fish communities, or the alteration of the feeding grounds, which could impact fish feeding habits. If immediate impacts detected in the benthic population were to impact the fish community's feeding behavior, impacts on the fish community could take a longer period of time to be displayed in the data (i.e., quarterly or yearly). Annual and quarterly beach seine and trawl sampling for long-term impacts on the surf zone fish and nekton communities exhibited no significant depressions in abundance and diversity one-year after the initial beach construction. When significant differences where observed between undisturbed and recovery collections, either an enhancement was indicated or seasonal differences between the subject beach and the reference beach were inconsistent.

Few studies on beach nourishment impacts on fish communities within the surf zone have been conducted along the east coast of the U.S. Most of the studies conducted on fish impacts have dealt with impacts at the borrow site. A large and comprehensive study conducted along the coast of north New Jersey (USACE 2001) examined impacts to fish communities along the reconstructed beach. Results from the current study of Brunswick County, NC were similar to those documented from New Jersey. The New Jersey study found some changes in fish abundance during beach reconstruction but these changes were either considered short-term responses or were thought to be due to natural variability. No long-term impacts from the beach nourishment activities in New Jersey were detected which are comparable to the current study.

Because of the inherent mobility and migratory behavior exhibited by many adult and transient marine species, the primary goal of the gillnet survey was to document the occurrence and relative abundance of large mobile species utilizing the habitat just outside the surf zone. Additionally, as with the gillnet survey, the premise of ichthyoplankton survey was only to document species occurrence and relative abundance of ichthyoplankton adjacent to the surf zone. Large changes in species composition in both the gillnet and ichthyoplankton surveys were documented in the quarterly and yearly data obtained from the reference data. Since large changes in community composition are displayed naturally within the two community types, the changes displayed within the data collected for these two surveys could not be attributable to beach construction impacts. Other researchers have had the same results when attempting to examine beach construction impacts on surf zone ichthyoplankton or on large fish species utilizing offshore habitats (USACE 2001). They concluded that with the high natural variability in communities, only catastrophic events could be detected in the data. No such catastrophic events were displayed during the current study.

Benthic community composition can be affected by changes in sediment type that may occur from beach reconstruction events. Sediment analyses conducted during both years of the current study found that, with the single exception of spring samples collected from the first year at Bald Head Island, the sand being placed on the study beaches did not alter the sediment characteristics of the beaches. During one exception when a high silt content was present in samples taken at Bald Head Island immediately after the beach construction activities, a corresponding decrease in the number of polychaetes was documented in the deep habitat. However, with the addition of a second year of data, the decrease in polychaetes displayed immediately after sand placement may be more attributable to a natural decline expected after such a large peak displayed in the pre-construction data than by a beach construction impact. The sediment composition did not display the high silt content one-year after beach construction and the number of poly-chaetes were not significantly different one-year after placement based on the ANOVA test.

Beach construction did not appear to be responsible for any changes in water quality parameters, such as dissolved oxygen, salinity or pH, that would have conse-quences to biota. However, the single major water quality parameter that was clearly affected during sand placement activities was turbidity (Versar 2002). Observed spikes in turbidity at the fixed stations did occur when sand placement was occurring in close proximity to the monitoring stations, but was also observed during other periods, most likely in response to off-shore storms, winds, and tidal cycles. Observed increases in turbidity detected during the second year were probably due to storm events and high surf conditions. Plume mapping conducted during the first year of study confirmed that the turbidity plume associated with sand placement tended to remain close to shore, with its direction of displacement being associated with tide stage and currents (Versar 2002). These data suggested that turbidity plumes caused by the beach disposal operations on the beach face were small and short-lived.

5.0 REFERENCES

Able, K.W. and M.P. Fahay. 1998. *The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight*. Rutgers University Press, New Brunswick, NJ.

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

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

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

Jutte, P.C., R.F. Van Dolah, and M.V. Levisen. 1999a. An environmental monitoring study of the Myrtle Beach Renourishment Project: Intertidal benthic community assessment of Phase I. – Cherry Grove to North Myrtle Beach. Final Report. Prepared by the Marine Resources Division, South Carolina Department of Natural Resources for U.S. Army Corps of Engineers, Charleston, SC.

Jutte, P.C., R.F. Van Dolah, and M.V. Levisen. 1999b. An environmental monitoring study of the Myrtle Beach Renourishment Project: Intertidal benthic community assessment of Phase II. – Myrtle Beach. Supplemental Report. Prepared by the Marine Resources Division, South Carolina Department of Natural Resources for U.S. Army Corps of Engineers, Charleston, SC.

Krebs, C.J. 1978. *Ecology: The Experimental Analysis of Distribution and Abundance.* New York: Harper & Row.

Murdy, E.O., R.S. Birdsong, and J.A. Musick. 1997. *Fishes of the Chesapeake Bay*. Smithsonian Institution Press, Washington DC.

Nelson, W.G. 1993. Beach restoration in the southeastern US: Environmental effects and biological monitoring. Ocean & Coastal Management 19:157-182.

Peterson, C.H., D.H.M. Hickerson, and G.G. Johnson. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. Journal of Coastal Research 16:368-378.

Reilly, F.J. and V.J. Bellis. 1978. A study of the ecological impact of beach nourishment with dredged material on the intertidal zone. East Carolina University Institute for Coastal and Marine Resources, Technical Report No. 4, Greenville, North Carolina.

Reilly, F.J. and V.J. Bellis. 1983. The ecological impact of beach nourishment with dredged materials on the intertidal zone at Bogue Banks, North Carolina. Miscellaneous Report 83-3. U.S. Army Engineer Coastal Engineering Research Center, Fort Belvoir, VA.

Shannon, C.E. and W. Weaver. 1949. *The Mathematical Theory of Communication.* Urbana: University of Illinois Press.

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

Van Dolah, R.F., P.A. Wendt, R.M. Martore, M.V. Levisen, and W.A. Rhoumillat. 1992. Final Report for a physical and biological monitoring study of the Hilton Head Beach Nourishment Project. Prepared by the Marine Resources Division, South Carolina Department of Natural Resources for Town of Hilton Head Island and South Carolina Coastal Council. 159 pp.

Van Dolah, R.F., R.M. Martore, A.E. Lynch, P.A. Wendt, M.V. Levisen, D.J. Whitaker, and W.D. Anderson. 1994. Final Report. Environmental Evaluation of the Folly Beach Nourishment Project. Prepared by the Marine Resources Division, South Carolina Department of Natural Resources for U.S. Army Corps of Engineers, Charleston, SC. 101 pp. & appendices.

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

APPENDIX A

ABUNDANCE OF *DONAX VARIABILIS* AND *EMERITA TALPOIDA* IN THE SWASH HABITAT

Table A-1. Mean total abundance of *Donax variabilis* and *Emerita talpoida* at each study and reference beach.

Study Beach/Season	Taxon Name	Undisturbed	Disturbed	1-Year Later	Reference Undisturbed	Reference 1-Year Later
Bald Head Island/Spring	*Emerita talpoida*	8.6	0.0	0.0	11.3	13.8
Caswell Beach/Summer	*Emerita talpoida*	0.0	88.8	30.0	188.8	20
Oak Island/Fall	*Emerita talpoida*	154	12.0	330.0	51.7	210.0
Holden Beach/Winter	*Emerita talpoida*	50.9	12.0	0.0	3.8	5.0
Bald Head Island/Spring	*Donax variabilis*	101.9	0.0	0.0	87.5	175
Caswell Beach/Summer	*Donax variabilis*	491.4	32.8	67.5	320.0	355.0
Oak Island/Fall	*Donax variabilis*	90.9	8.0	75.0	378.3	310.0
Holden Beach/Winter	*Donax variabilis*	121.8	4.0	0.0	16.0	10.0

APPENDIX B

BENTHIC DATA FOR THE SHALLOW HABITAT

Table B-1. Mean abundance of benthic taxa at Bald Head Island and the reference beach shallow habitat

Major Taxonomic Group	Taxon Name	Bald Head Island			Reference	
		Undisturbed	Disturbed	Spring 1-Year Later	Undisturbed	1-Year Later
Polychaeta	*Scolelepis squamata*	813.3	1056.4	570.0	2222.5	4537.5
	Eteone heteropoda	1.0	0.0	0.0	73.8	30.0
	Paraonis fulgens	0.0	0.0	5.0	7.5	43.8
	Mediomastus spp.	0.0	0.0	27.5	0.0	3.8
	Sabellaria vulgaris	1.9	7.3	2.5	0.0	1.3
	Mediomastus ambiseta	0.0	0.0	12.5	0.0	0.0
	Spiophanes bombyx	6.7	1.8	0.0	0.0	0.0
	Oligochaeta	0.0	1.8	2.5	1.3	0.0
	Polygordius spp.	1.0	3.6	0.0	0.0	0.0
	Proceraea cornuta	0.0	0.0	0.0	0.0	3.8
	Nereididae	0.0	3.6	0.0	0.0	0.0
	Onuphis eremita	0.0	0.0	2.5	0.0	0.0
	Streblospio benedicti	0.0	0.0	2.5	0.0	0.0
	Carazziella hobsonae	0.0	1.8	0.0	0.0	0.0
	Ampharetidae	0.0	1.8	0.0	0.0	0.0
	Nephtyidae	0.0	0.0	0.0	0.0	1.3
	Glyceridae	0.0	0.0	0.0	1.3	0.0
	Dispio uncinata	0.0	0.0	0.0	0.0	1.3
	Heteromastus filiformis	0.0	0.0	0.0	0.0	1.3
Crustacea : Amphipoda	*Amphiporeia virginiana*	128.6	3.6	85.0	450.0	52.5
	Parahaustorius longimerus	205.7	0.0	30.0	46.3	251.3
	Acanthohaustorius similis	34.3	0.0	15.0	10.0	70.0
	Acanthohaustorius millsi	24.8	0.0	0.0	5.0	0.0
	Protohaustorius cf. *deichmannae*	0.0	0.0	0.0	0.0	17.5
	Monocorophium tuberculatum	0.0	0.0	2.5	0.0	0.0
	Bathyporeia quoddyensis	0.0	0.0	0.0	0.0	2.5
	Batea catharinensis	0.0	0.0	0.0	0.0	1.3
	Casco bigelowi	0.0	0.0	0.0	1.3	0.0
Crustacea : Cirripedia	*Balanus* spp.	4.8	0.0	0.0	0.0	0.0
Crustacea : Cumacea	*Mancocuma stellifera*	17.1	0.0	65.0	3.8	2.5
	Cyclaspis varians	0.0	0.0	5.0	0.0	3.8
	Oxyurostylis smithi	0.0	0.0	2.5	0.0	0.0
Crustacea : Decapoda	*Emerita talpoida*	0.0	0.0	2.5	1.3	1.3
	Pagurus longicarpus	4.8	0.0	0.0	0.0	0.0
	Pinnotheridae	1.0	1.8	0.0	0.0	0.0
Crustacea : Isopoda	*Chiridotea caeca*	0.0	0.0	0.0	11.3	11.3
	Ancinus depressus	0.0	0.0	2.5	0.0	1.3
Crustacea : Mysidacea	*Bowmaniella* spp.	11.4	0.0	25.0	2.5	16.3
	Americamysis spp.	1.0	0.0	0.0	2.5	0.0
Mollusca : Bivalvia	*Donax variabilis*	55.2	0.0	12.5	16.3	2610.0
	Crassinella spp.	2.9	5.5	2.5	3.8	2.5
	Spisula solidissima	1.0	3.6	0.0	2.5	0.0
	Anadara spp.	0.0	0.0	0.0	1.3	0.0
	Mytilus edulis	0.0	0.0	0.0	1.3	0.0
	Mercenaria mercenaria	0.0	0.0	0.0	1.3	0.0
Mollusca : Gastropoda	Gastropoda	0.0	1.8	0.0	0.0	0.0
Miscellaneous	Nemertina	7.6	7.3	157.5	26.3	31.3
	Turbellaria	1.9	20.0	0.0	25.0	2.5
	Phoronis spp.	0.0	0.0	2.5	0.0	0.0
	Hirudinea	0.0	0.0	0.0	1.3	0.0
Total Mean Abundance		1325.7	1121.8	1035.0	2918.7	7701.2
Total Mean Biomass		0.49	0.32	0.27	0.91	1.38
Total Number of Species		20	15	22	24	25
Total Mean Number of Species		5.05	2.27	7.13	6.06	8.06
Shannon Wiener Diversity		1.51	0.73	1.83	1.06	0.88

Table B-2. Mean abundance of benthic taxa at Caswell Beach and the reference beach shallow habitat

		Caswell Beach			Reference	
Major Taxonomic Group	Taxon Name	Undisturbed	Disturbed	Summer 1-Year Later	Undisturbed	1-Year Later
Polychaeta	*Scolelepis squamata*	460.0	65.6	47.5	262.5	40.0
	Paraonis fulgens	5.7	12.0	0.0	20.0	28.3
	Polygordius spp.	0.0	0.0	0.0	0.0	48.3
	Spiophanes bombyx	0.0	0.0	0.0	0.0	21.7
	Proceraea cornuta	0.0	0.0	0.0	0.0	11.7
	Nephtys bucera	2.9	1.6	0.0	0.0	1.7
	Mediomastus ambiseta	2.9	0.0	0.0	1.3	0.0
	Syllidae	0.0	0.0	0.0	0.0	1.7
	Mediomastus spp.	0.0	0.0	0.0	0.0	1.7
	Lumbrineridae	0.0	0.8	0.0	0.0	0.0
	Scoletoma fragilis	0.0	0.8	0.0	0.0	0.0
	Polydora spp.	0.0	0.8	0.0	0.0	0.0
Crustacea : Amphipoda	*Parahaustorius longimerus*	142.9	38.4	10.0	21.3	113.3
	Amphiporeia virginiana	71.4	27.2	2.5	45.0	8.3
	Protohaustorius cf. *deichmannae*	25.7	54.4	0.0	7.5	0.0
	Acanthohaustorius similis	0.0	3.2	0.0	1.3	33.3
	Bathyporeia quoddyensis	0.0	0.0	0.0	0.0	20.0
	Bathyporeia parkeri	14.3	1.6	0.0	1.3	0.0
	Acanthohaustorius millsi	0.0	0.8	0.0	11.3	0.0
	Microprotopus raneyi	2.9	0.8	0.0	0.0	5.0
	Cerapus tubularis	0.0	0.0	0.0	0.0	1.7
	Ampelisca abdita	0.0	0.8	0.0	0.0	0.0
	Atylus cf. *minikoi*	0.0	0.8	0.0	0.0	0.0
Crustacea : Cirripedia	*Balanus* spp.	0.0	0.0	0.0	1.3	0.0
Crustacea : Cumacea	*Balanus balanoides*	0.0	0.8	0.0	0.0	0.0
	Oxyurostylis smithi	2.9	0.0	0.0	0.0	0.0
	Campylaspis affinis	2.9	0.0	0.0	0.0	0.0
	Cyclaspis varians	0.0	0.8	0.0	0.0	0.0
Crustacea : Decapoda	Pinnotheridae	14.3	4.8	0.0	40.0	3.3
	Emerita talpoida	0.0	27.2	2.5	16.3	8.3
	Ogyrides alphaerostris	11.4	0.0	0.0	0.0	0.0
	Pagurus longicarpus	2.9	0.8	2.5	0.0	0.0
	Ogyrides spp.	0.0	0.0	0.0	0.0	1.7
Crustacea : Isopoda	*Chiridotea caeca*	22.9	8.0	0.0	0.0	5.0
	Ancinus depressus	0.0	0.8	0.0	11.3	3.3
	Chiridotea tuftsi	0.0	0.0	0.0	1.3	0.0
Crustacea : Mysidacea	*Bowmaniella* spp.	45.7	176.8	7.5	28.8	55.0
Mollusca : Bivalvia	*Donax variabilis*	1174.3	63.2	37.5	1157.5	613.3
	Crassinella spp.	0.0	1.6	2.5	1.3	3.3
	Mytilidae	0.0	0.0	0.0	1.3	0.0
Miscellaneous	Nemertina	48.6	30.4	180.0	35.0	103.3
	Turbellaria	94.3	2.4	0.0	0.0	0.0
	Oligochaeta	11.4	0.8	0.0	1.3	0.0
Total Mean Abundance		2160.0	528.0	292.5	1666.2	1133.3
Total Mean Biomass		0.78	0.21	0.45	1.51	0.68
Total Number of Species		20	28	9	20	23
Total Mean Number of Species		9.71	5.20	3.63	6.13	7.00
Shannon Wiener Diversity		1.84	1.70	1.25	1.35	1.68

Table B-3. Mean abundance of benthic taxa at Oak Island and the reference beach shallow habitat

		Oak Island			Reference	
Major Taxonomic Group	Taxon Name	Undisturbed	Disturbed	Fall 1-Year Later	Undisturbed	1-Year Later
Polychaeta	*Scolelepis squamata*	100.0	68.0	10.0	97.5	20.0
	Paraonis fulgens	0.0	8.0	0.0	1.3	5.0
	Onuphis eremita	0.0	0.0	0.0	0.0	5.0
	Sabellaria vulgaris	0.0	0.0	0.0	3.8	0.0
	Mediomastus spp.	0.0	0.0	2.5	0.0	0.0
	Nephtys bucera	0.0	0.0	2.5	0.0	0.0
	Polydora spp.	0.0	0.0	0.0	2.5	0.0
	Scoletoma impatiens	0.0	0.0	2.5	0.0	0.0
	Microphthalmus aberrans	1.8	0.0	0.0	0.0	0.0
Crustacea : Amphipoda	*Parahaustorius longimerus*	29.1	0.0	120.0	95.0	175.0
	Acanthohaustorius similis	3.6	20.0	52.5	6.3	295.0
	Protohaustorius cf. *deichmannae*	78.2	16.0	5.0	68.8	15.0
	Bathyporeia quoddyensis	0.0	0.0	0.0	0.0	30.0
	Amphiporeia virginiana	9.1	4.0	0.0	7.5	0.0
	Bathyporeia parkeri	3.6	0.0	0.0	13.8	0.0
	Microprotopus raneyi	0.0	0.0	0.0	5.0	0.0
	Atylus cf. *minikoi*	0.0	0.0	0.0	3.8	0.0
	Haustorius canadensis	3.6	0.0	0.0	0.0	0.0
	Hemiaegina minuta	1.8	0.0	0.0	0.0	0.0
	Cerapus tubularis	0.0	0.0	0.0	1.3	0.0
Crustacea : Decapoda	*Emerita talpoida*	1.8	0.0	5.0	1.3	5.0
	Ogyrides spp.	0.0	0.0	5.0	0.0	5.0
	Pagurus longicarpus	0.0	0.0	0.0	0.0	5.0
Crustacea : Isopoda	*Ancinus depressus*	9.1	0.0	30.0	2.5	60.0
	Chiridotea caeca	0.0	0.0	0.0	0.0	5.0
Crustacea : Mysidacea	*Bowmaniella* spp.	12.7	44.0	45.0	160.0	15.0
Mollusca : Bivalvia	*Donax variabilis*	58.2	16.0	110.0	101.3	365.0
	Crassinella spp.	0.0	4.0	0.0	0.0	0.0
	Mytilidae	0.0	0.0	0.0	1.3	0.0
	Spisula solidissima	0.0	0.0	0.0	1.3	0.0
Miscellaneous	Nemertina	1.8	0.0	15.0	1.3	15.0
	Turbellaria	0.0	0.0	5.0	1.3	15.0
	Renilla reniformis	0.0	0.0	0.0	2.5	0.0
	Mellita quinquiesperforata	0.0	0.0	0.0	1.3	0.0
Total Mean Abundance		314.5	180.0	410.0	580.0	1035.0
Total Mean Biomass		0.13	0.10	0.14	0.61	0.29
Total Number of Species		14	8	14	22	16
Total Mean Number of Species		3.82	3.20	4.63	5.56	8.25
Shannon Wiener Diversity		1.48	1.12	1.19	1.83	2.27

Table B-4. Mean abundance of benthic taxa at Holden Beach and the reference beach shallow habitat

		Holden Beach			Reference	
Major Taxonomic Group	**Taxon Name**	**Undisturbed**	**Disturbed**	**Winter 1-Year Later**	**Undisturbed**	**1-Year Later**
Polychaeta	*Scolelepis squamata*	16.4	0.0	0.0	0.0	26.3
	Paraonis fulgens	14.5	4.0	0.0	0.0	5.0
	Mediomastus ambiseta	0.0	0.0	0.0	5.0	0.0
	Leitoscoloplos spp.	0.0	4.0	0.0	0.0	0.0
	Magelona papillicornis	0.0	4.0	0.0	0.0	0.0
	Spiophanes bombyx	0.0	0.0	0.0	2.5	0.0
	Spionidae	1.8	0.0	0.0	0.0	0.0
	Sabellaria vulgaris	0.0	0.0	0.0	0.0	1.3
Crustacea : Amphipoda	*Parahaustorius longimerus*	236.4	52.0	0.0	0.0	41.3
	Protohaustorius cf. *deichmannae*	192.7	4.0	0.0	0.0	8.8
	Amphiporeia virginiana	16.4	16.0	5.0	0.0	28.8
	Acanthohaustorius millsi	18.2	4.0	0.0	0.0	7.5
	Acanthohaustorius similis	5.5	4.0	2.5	7.5	1.3
	Americhelidium americanum	1.8	0.0	0.0	0.0	0.0
	Bathyporeia parkeri	1.8	0.0	0.0	0.0	0.0
	Cerapus tubularis	1.8	0.0	0.0	0.0	0.0
	Microprotopus raneyi	0.0	0.0	0.0	0.0	1.3
	Rhepoxynius epistomus	0.0	0.0	0.0	0.0	1.3
Crustacea : Decapoda	*Emerita talpoida*	0.0	0.0	17.5	12.5	1.3
	Pagurus longicarpus	1.8	0.0	0.0	0.0	0.0
Crustacea : Mysidacea	*Bowmaniella* spp.	3.6	0.0	0.0	0.0	1.3
Mollusca : Bivalvia	*Donax variabilis*	105.5	56.0	0.0	82.5	67.5
	Crassinella spp.	1.8	0.0	0.0	0.0	0.0
	Spisula solidissima	0.0	0.0	0.0	0.0	1.3
Miscellaneous	Nemertina	3.6	0.0	50.0	40.0	5.0
	Turbellaria	1.8	0.0	10.0	2.5	0.0
	Oligochaeta	0.0	0.0	0.0	2.5	0.0
	Renilla reniformis	0.0	0.0	0.0	0.0	1.3
	Mellita quinquiesperforata	0.0	0.0	0.0	0.0	1.3
Total Mean Abundance		625.4	148.0	85.0	155.0	201.2
Total Mean Biomass		0.33	0.10	0.13	0.44	1.06
Total Number of Species		17	9	5	8	17
Total Mean Number of Species		5.18	3.60	1.50	3.93	2.63
Shannon Wiener Diversity		1.66	1.47	0.48	1.62	1.12

APPENDIX C

BENTHIC DATA FOR THE DEEP HABITAT

Table C-1. Mean abundance of benthic taxa at Bald Head Island and the reference beach deep habitat

Major Taxonomic Group	Taxon Name	Bald Head Island Undisturbed	Bald Head Island Disturbed	Bald Head Island Spring 1-Year Later	Reference Undisturbed	Reference 1-Year Later
Polychaeta	*Scolelepis squamata*	8103.4	475.4	288.4	83.1	2364.3
	Paraonis fulgens	13.1	15.2	2.8	262.8	283.4
	Spiophanes bombyx	86.9	15.2	1.4	43.3	16.3
	Travisia spp.	12.5	57.8	0.0	0.0	0.7
	Nephtyidae	2.3	0.0	1.4	33.4	6.4
	Eteone heteropoda	11.4	0.9	0.0	0.7	14.2
	Glycera spp.	13.1	7.6	0.0	0.7	2.1
	Leitoscoloplos spp.	0.0	0.0	0.0	14.9	8.5
	Magelona papillicornis	4.5	0.9	1.4	7.8	5.7
	Glycera dibranchiata	9.7	4.7	0.0	0.0	1.4
	Streptosyllis pettiboneae	0.0	10.4	0.0	0.0	0.0
	Dispio uncinata	0.6	0.0	0.0	6.4	2.8
	Eurysyllis lamelligera	0.6	6.6	0.0	0.0	0.0
	Parapionosyllis longicirrata	0.0	4.7	0.0	0.0	0.0
	Nephtys bucera	0.0	1.9	0.0	0.0	1.4
	Mediomastus spp.	0.0	0.0	2.8	0.0	0.0
	Syllides verrilli	0.0	0.0	0.0	0.0	2.1
	Scoletoma impatiens	0.0	0.0	0.0	2.1	0.0
	Streblospio benedicti	0.0	0.0	0.0	2.1	0.0
	Microphthalmus aberrans	0.0	0.0	0.0	1.4	0.0
	Prionospio perkinsi	0.0	0.0	1.4	0.0	0.0
	Sabellaria vulgaris	1.1	0.0	0.0	0.0	0.0
	Phyllodoce arenae	0.0	0.9	0.0	0.0	0.0
	Parapionosyllis spp.	0.0	0.9	0.0	0.0	0.0
	Paraprionospio pinnata	0.0	0.9	0.0	0.0	0.0
	Cossuridae	0.0	0.9	0.0	0.0	0.0
	Maldanidae	0.0	0.9	0.0	0.0	0.0
	Sabellides spp.	0.0	0.9	0.0	0.0	0.0
	Terebellidae	0.0	0.9	0.0	0.0	0.0
	Bhawania heteroseta	0.0	0.0	0.0	0.0	0.7
	Onuphis eremita	0.0	0.0	0.0	0.7	0.0
	Lumbrineridae	0.0	0.0	0.0	0.7	0.0
	Scoletoma fragilis	0.0	0.0	0.0	0.0	0.7
	Opheliidae	0.0	0.0	0.0	0.7	0.0
	Armandia agilis	0.0	0.0	0.0	0.0	0.7
	Capitellidae	0.0	0.0	0.0	0.0	0.7
	Mediomastus ambiseta	0.0	0.0	0.0	0.7	0.0
	Ampharete spp.	0.0	0.0	0.0	0.0	0.7
	Arabella iricolor	0.6	0.0	0.0	0.0	0.0
Crustacea: Amphipoda	*Protohaustorius* cf. *deichmannae*	1014.2	118.4	305.4	3887.1	2975.1
	Acanthohaustorius similis	516.5	32.2	214.5	1068.2	839.5
	Bathyporeia quoddyensis	0.0	0.0	2.8	1054.0	0.0
	Parahaustorius longimerus	105.1	7.6	529.8	19.9	262.1
	Bathyporeia parkeri	0.6	1.9	0.0	32.0	433.9
	Rhepoxynius epistomus	13.1	0.0	1.4	87.4	18.5
	Eudevenopus honduranus	49.4	6.6	2.8	3.6	0.7
	Acanthohaustorius millsi	19.3	10.4	0.0	0.7	2.8
	Americhelidium americanum	5.1	0.9	0.0	12.1	2.8
	Ameroculodes species complex	0.6	1.9	0.0	2.1	0.7
	Atylus cf. *minikoi*	0.0	0.0	1.4	0.7	0.0
	Caprellidae	0.0	0.0	1.4	0.7	0.0
	Cerapus tubularis	0.0	0.0	1.4	0.0	0.0
	Monocorophium tuberculatum	0.0	0.0	1.4	0.0	0.0
	Microprotopus raneyi	0.0	0.0	0.0	1.4	0.0
	Amphiporeia virginiana	0.6	0.0	0.0	0.7	0.0
	Leptocheirus pinguis	0.0	0.0	0.0	0.7	0.0
	Batea catharinensis	0.0	0.0	0.0	0.7	0.0
	Paraphoxus spp.	0.6	0.0	0.0	0.0	0.0

Table C-1. (Continued)

Major Taxonomic Group	Taxon Name	Bald Head Island			Reference	
		Undisturbed	Disturbed	Spring 1-Year Later	Undisturbed	1-Year Later
Crustacea : Cirripedia	*Balanus* spp.	0.6	0.0	0.0	0.0	0.0
Crustacea : Cumacea	*Mancocuma stellifera*	46.6	2.8	163.4	60.4	34.1
	Oxyurostylis smithi	15.9	40.7	1.4	16.3	14.9
	Cyclaspis varians	4.0	3.8	0.0	49.0	2.1
Crustacea : Decapoda	*Pagurus longicarpus*	14.8	16.1	1.4	3.6	2.1
	Pinnotheridae	0.0	0.0	1.4	3.6	0.7
	Ovalipes stephensoni	1.1	0.0	0.0	0.0	1.4
	Pinnixa cristata	0.0	0.0	0.0	1.4	0.0
	Pagurus spp.	0.0	0.0	0.0	0.7	0.0
Crustacea : Isopoda	*Chiridotea caeca*	51.1	1.9	0.0	46.9	75.3
	Ancinus depressus	2.8	3.8	1.4	12.8	2.1
Crustacea : Mysidacea	*Bowmaniella* spp.	1.1	0.0	116.5	80.3	8.5
	Mysidae	0.0	0.0	0.0	0.7	0.0
Crustacea : Tanaidacea	*Tanaissus psammophilus*	13.1	21.8	0.0	0.0	0.0
Mollusca : Bivalvia	*Donax variabilis*	2.8	0.0	2.8	298.3	0.0
	Crassinella spp.	0.0	23.7	0.0	0.0	7.8
	Spisula solidissima	1.1	2.8	0.0	1.4	19.2
	Tellina agilis	0.6	0.9	0.0	5.7	4.3
	Ensis directus	0.0	0.9	0.0	7.8	1.4
	Tellina spp.	0.0	0.0	0.0	0.0	4.3
	Mulinia lateralis	0.0	0.0	0.0	2.8	0.0
	Gemma gemma	0.0	0.0	0.0	1.4	0.0
	Zirfaea crispata	0.0	0.9	0.0	0.0	0.0
	Mytilidae	0.6	0.0	0.0	0.0	0.0
	Astarte spp.	0.6	0.0	0.0	0.0	0.0
	Corbula contracta	0.6	0.0	0.0	0.0	0.0
Mollusca : Gastropoda	*Nassarius acutus*	0.0	0.0	0.0	2.1	0.0
	Crepidula maculosa	1.1	0.0	0.0	0.7	0.0
	Olivella spp.	0.0	0.0	0.0	1.4	0.0
	Nudibranchia	0.0	0.0	0.0	0.7	0.0
Miscellaneous	Nemertina	18.2	9.5	4.3	34.1	19.2
	Oligochaeta	0.6	11.4	4.3	2.8	0.0
	Turbellaria	0.0	0.0	0.0	12.8	0.0
	Mellita quinquiesperforata	1.7	0.0	0.0	0.0	0.0
	Anthozoa	0.0	0.0	0.0	0.0	0.7
	Hemichordata	0.0	0.0	0.0	0.7	0.0
	Sipuncula	0.0	0.0	0.0	0.0	0.7
	Branchiostoma caribaeum	0.6	0.0	0.0	0.0	0.0
Total Mean Abundance		10164.1	928.9	1659.0	7281.9	7448.1
Total Mean Biomass		2.06	0.52	0.37	0.08	1.17
Total Number of Species		45	41	26	57	45
Total Mean Number of Species		12.60	10.00	8.63	19.44	15.25
Shannon Wiener Diversity		1.27	2.16	2.19	2.26	2.04

Table C-2. Mean abundance of benthic taxa at Caswell Beach and the reference beach deep habitat

Major Taxonomic Group	Taxon Name	Caswell Beach Undisturbed	Caswell Beach Disturbed	Caswell Beach Summer 1-Year Later	Reference Undisturbed	Reference 1-Year Later
Polychaeta	*Amastigos caperatus*	0.0	290.0	0.0	80.3	0.0
	Paraonis fulgens	0.0	1.4	17.0	72.4	233.9
	Scolelepis squamata	55.2	14.1	42.6	36.2	81.4
	Tharyx sp. A Morris	9.7	170.5	0.0	6.4	0.0
	Magelona papillicornis	55.2	35.5	9.9	30.5	22.7
	Mediomastus ambiseta	0.0	68.2	0.0	0.0	0.0
	Dispio uncinata	0.0	0.0	28.4	8.5	19.9
	Nephtys bucera	3.2	33.2	2.8	11.4	1.9
	Spiophanes bombyx	3.2	42.7	0.0	4.3	0.0
	Sabellaria vulgaris	1.6	28.6	5.7	0.0	5.7
	Leitoscoloplos spp.	0.0	5.9	0.0	28.4	6.6
	Onuphis eremita	6.5	12.3	0.0	12.1	0.0
	Mediomastus spp.	0.0	16.8	0.0	0.0	0.0
	Brania wellfleetensis	0.0	9.1	0.0	5.0	0.0
	Nephtyidae	8.1	2.3	0.0	0.7	1.9
	Glycera dibranchiata	1.6	7.7	0.0	3.6	0.0
	Streblospio benedicti	0.0	8.6	0.0	0.0	0.0
	Prionospio spp.	0.0	3.2	0.0	4.3	0.0
	Glycera spp.	0.0	7.3	0.0	0.0	0.0
	Scoletoma impatiens	0.0	0.0	7.1	0.0	0.0
	Mediomastus californiensis	0.0	6.4	0.0	0.0	0.0
	Dipolydora socialis	0.0	5.9	0.0	0.0	0.0
	Lumbrineridae	0.0	0.0	2.8	0.0	0.9
	Goniadides carolinae	0.0	2.3	0.0	0.0	0.0
	Owenia fusiformis	0.0	1.8	0.0	0.0	0.0
	Armandia maculata	1.6	0.0	0.0	0.0	0.0
	Scoletoma fragilis	0.0	0.0	0.0	1.4	0.0
	Scoletoma spp.	0.0	0.0	0.0	1.4	0.0
	Chaetopteridae	0.0	1.4	0.0	0.0	0.0
	Drilonereis longa	0.0	1.4	0.0	0.0	0.0
	Notomastus lobatus	0.0	1.4	0.0	0.0	0.0
	Streptosyllis pettiboneae	0.0	1.4	0.0	0.0	0.0
	Travisia spp.	0.0	0.5	0.0	0.7	0.0
	Diopatra cuprea	0.0	0.9	0.0	0.0	0.0
	Paraprionospio pinnata	0.0	0.9	0.0	0.0	0.0
	Microphthalmus aberrans	0.0	0.0	0.0	0.7	0.0
	Ophelina acuminata	0.0	0.0	0.0	0.7	0.0
	Anaitides longipes	0.0	0.5	0.0	0.0	0.0
	Phyllodoce arenae	0.0	0.5	0.0	0.0	0.0
	Spiochaetopterus costarum	0.0	0.5	0.0	0.0	0.0
Crustacea : Amphipoda	*Protohaustorius* cf. *deichmannae*	1305.2	145.9	2521.3	1188.2	1411.0
	Acanthohaustorius similis	48.7	2.3	98.0	218.7	446.0
	Rhepoxynius epistomus	16.2	29.1	1.4	175.4	60.6
	Bathyporeia parkeri	0.0	0.5	0.0	145.6	0.0
	Parahaustorius longimerus	0.0	0.0	142.0	0.0	3.8
	Bathyporeia quoddyensis	0.0	0.0	2.8	0.0	133.5
	Americhelidium americanum	4.9	13.2	0.0	11.4	1.9
	Eudevenopus honduranus	0.0	0.9	0.0	23.4	0.9
	Microprotopus raneyi	0.0	15.0	9.9	0.0	0.0
	Atylus cf. *minikoi*	0.0	0.5	8.5	0.0	0.0
	Tiron spiniferum	6.5	1.4	0.0	0.7	0.0
	Leptocheirus pinguis	0.0	0.0	5.7	0.0	0.0
	Cerapus tubularis	0.0	0.5	2.8	0.0	0.0
	Monocorophium spp.	0.0	3.2	0.0	0.0	0.0
	Batea catharinensis	0.0	2.3	0.0	0.7	0.0
	Monocorophium tuberculatum	0.0	0.0	1.4	0.0	0.0
	Protohaustorius spp.	0.0	0.0	0.0	1.4	0.0
	Paraphoxus spp.	0.0	0.9	0.0	0.0	0.0
Crustacea : Cirripedia	*Balanus* spp.	0.0	3.2	0.0	0.0	0.0

Table C-2. (Continued)						
		Caswell Beach			Reference	
Major Taxonomic Group	Taxon Name	Undisturbed	Disturbed	Summer 1 Year Later	Undisturbed	1 Year Later
Crustacea : Cumacea	*Cyclaspis varians*	13.0	7.3	4.3	2.8	10.4
	Mancocuma stellifera	4.9	1.4	1.4	0.7	0.0
	Oxyurostylis smithi	0.0	0.5	0.0	1.4	0.9
Crustacea : Decapoda	*Ogyrides* spp.	6.5	1.4	34.1	4.3	18.9
	Pinnotheridae	3.2	10.9	11.4	7.1	2.8
	Pagurus longicarpus	1.6	10.9	2.8	0.7	2.8
	Thalassinidea	3.2	5.9	0.0	4.3	0.0
	Emerita talpoida	0.0	0.0	5.7	0.7	0.0
	Acetes americanus carolinae	0.0	0.5	0.0	1.4	0.0
	Pagurus spp.	0.0	0.0	1.4	0.0	0.0
	Pinnixa cristata	0.0	0.5	0.0	0.7	0.0
	Callinectes sapidus	0.0	0.0	0.0	0.0	0.9
	Persephona mediterranea	0.0	0.0	0.0	0.7	0.0
	Pagurus pollicaris	0.0	0.5	0.0	0.0	0.0
	Trachypenaeus constrictus	0.0	0.5	0.0	0.0	0.0
Crustacea : Isopoda	*Chiridotea caeca*	9.7	7.7	35.5	39.8	28.4
	Ancinus depressus	3.2	3.2	19.9	2.1	3.8
	Edotea spp.	3.2	0.0	0.0	0.0	0.0
Crustacea : Mysidacea	*Bowmaniella* spp.	14.6	12.7	108.0	22.0	86.2
	Mysidae	3.2	19.1	0.0	2.1	0.0
Crustacea : Stomatopoda	*Squilla empusa*	0.0	0.0	0.0	0.7	0.0
Crustacea : Tanaidacea	*Tanaissus psammophilus*	0.0	2.3	0.0	5.7	0.0
Mollusca : Bivalvia	*Donax variabilis*	51.9	0.5	98.0	34.8	257.6
	Tellina agilis	0.0	37.7	0.0	24.1	0.0
	Tellina spp.	40.6	5.9	0.0	0.0	0.0
	Petricola pholadiformis	0.0	40.5	0.0	0.0	0.0
	Spisula solidissima	6.5	20.0	5.7	1.4	0.0
	Tellina iris	13.0	5.5	0.0	2.8	0.0
	Crassinella spp.	0.0	7.3	0.0	1.4	0.0
	Zirfaea crispata	0.0	4.1	0.0	0.0	0.0
	Corbula contracta	3.2	0.0	0.0	0.0	0.0
	Mulinia lateralis	0.0	2.7	0.0	0.0	0.0
	Mytilidae	0.0	0.0	1.4	0.0	0.0
	Arcidae	0.0	1.4	0.0	0.0	0.0
	Ensis directus	0.0	0.5	0.0	0.0	0.0
	Nucula proxima	0.0	0.5	0.0	0.0	0.0
Mollusca : Gastropoda	*Nassarius acutus*	3.2	20.9	0.0	20.6	3.8
	Crepidula maculosa	0.0	32.3	0.0	0.0	0.0
	Gastropoda	3.2	0.9	0.0	0.0	0.0
	Polinices duplicatus	0.0	0.9	1.4	0.0	0.0
	Nassarius trivittatus	0.0	0.0	0.0	2.1	0.0
	Terebra dislocata	0.0	0.9	0.0	0.0	0.9
	Olivella spp.	0.0	0.0	0.0	1.4	0.0
	Turbonilla spp.	0.0	0.0	0.0	0.7	0.0
	Columbellidae	0.0	0.5	0.0	0.0	0.0
	Crepidula spp.	0.0	0.5	0.0	0.0	0.0
Miscellaneous	Nemertina	19.5	21.8	19.9	14.9	23.7
	Turbellaria	9.7	4.1	0.0	5.7	0.9
	Ophiuroidea	1.6	7.3	2.8	0.0	0.0
	Oligochaeta	0.0	4.1	0.0	0.7	0.0
	Echinoidea	0.0	0.0	0.0	3.6	0.0
	Renilla reniformis	0.0	0.0	2.8	0.0	0.0
	Mellita quinquiesperforata	0.0	0.5	0.0	0.0	1.9
	Holothuroidea	1.6	0.5	0.0	0.0	0.0
	Echinodermata	0.0	0.0	0.0	0.7	0.0
	Anthozoa	0.0	0.5	0.0	0.0	0.0
Total Mean Abundance		1748.3	1308.1	3267.0	2286.9	2876.8
Total Mean Biomass		0.86	1.71	1.09	1.83	2.41
Total Number of Species		22	47	20	33	15
Total Mean Number of Species		14.43	17.96	14.75	17.25	15.25
Shannon Wiener Diversity		1.63	3.00	2.00	2.44	2.41

Table C-3. Mean abundance of benthic taxa at Oak Island and the reference beach deep habitat

Major Taxonomic Group	Taxon Name	Oak Island			Reference	
		Undisturbed	Disturbed	Fall 1-Year Later	Undisturbed	1-Year Later
Polychaeta	*Scolelepis squamata*	10.3	13.6	17.0	22.0	62.5
	Leitoscoloplos spp.	35.1	0.0	0.0	38.4	2.8
	Magelona papillicornis	36.2	2.3	0.0	9.2	0.0
	Paraonis fulgens	18.6	0.0	0.0	19.9	2.8
	Onuphis eremita	23.8	0.0	0.0	5.7	0.0
	Spiophanes bombyx	0.0	2.3	0.0	7.8	0.0
	Dispio uncinata	2.1	0.0	5.7	0.0	0.0
	Prionospio spp.	4.1	0.0	0.0	0.0	0.0
	Nephtys bucera	3.1	0.0	0.0	0.7	0.0
	Scoletoma impatiens	0.0	0.0	2.8	0.0	0.0
	Nereis lamellosa	0.0	2.3	0.0	0.0	0.0
	Sabellaria vulgaris	0.0	2.3	0.0	0.0	0.0
	Tharyx sp. A Morris	1.0	0.0	0.0	0.0	0.0
	Armandia agilis	1.0	0.0	0.0	0.0	0.0
	Amastigos caperatus	1.0	0.0	0.0	0.0	0.0
	Ampharete americana	1.0	0.0	0.0	0.0	0.0
Crustacea : Amphipoda	*Protohaustorius* cf. *deichmannae*	672.5	652.3	44.0	1804.0	88.1
	Acanthohaustorius similis	178.7	177.3	48.3	436.8	76.7
	Protohaustorius spp.	95.0	259.1	0.0	253.6	0.0
	Bathyporeia parkeri	12.4	36.4	0.0	476.6	0.0
	Parahaustorius longimerus	0.0	0.0	112.2	0.0	45.5
	Rhepoxynius epistomus	28.9	11.4	0.0	41.9	0.0
	Bathyporeia quoddyensis	0.0	0.0	2.8	0.0	45.5
	Americhelidium americanum	19.6	13.6	0.0	11.4	0.0
	Microprotopus raneyi	0.0	0.0	0.0	0.0	5.7
	Acanthohaustorius spp.	5.2	0.0	0.0	0.0	0.0
	Ameroculodes species complex	1.0	0.0	0.0	0.7	0.0
	Tiron spiniferum	0.0	0.0	0.0	1.4	0.0
	Atylus cf. *minikoi*	1.0	0.0	0.0	0.0	0.0
	Eudevenopus honduranus	0.0	0.0	0.0	0.7	0.0
Crustacea : Cumacea	*Cyclaspis varians*	7.2	4.5	0.0	7.8	0.0
	Oxyurostylis smithi	2.1	2.3	0.0	2.8	0.0
	Mancocuma stellifera	0.0	0.0	0.0	3.6	0.0
Crustacea : Decapoda	*Pagurus longicarpus*	2.1	2.3	2.8	0.7	5.7
	Ogyrides spp.	0.0	0.0	5.7	0.0	2.8
	Pinnotheridae	3.1	0.0	2.8	2.1	0.0
	Emerita talpoida	0.0	0.0	1.4	0.0	0.0
	Pinnixa cristata	1.0	0.0	0.0	0.0	0.0
Crustacea : Isopoda	*Chiridotea caeca*	25.8	18.2	0.0	14.2	2.8
	Ancinus depressus	4.1	9.1	11.4	7.1	11.4
	Edotea spp.	1.0	0.0	0.0	0.7	2.8
Crustacea : Mysidacea	*Bowmaniella* spp.	6.2	4.5	21.3	7.1	39.8
	Mysidae	17.6	4.5	0.0	6.4	0.0
Crustacea : Tanaidacea	*Tanaissus psammophilus*	0.0	2.3	0.0	1.4	0.0
Mollusca : Bivalvia	*Donax variabilis*	15.5	22.7	434.7	19.2	704.5
	Tellina agilis	15.5	2.3	0.0	4.3	0.0
	Strigilla mirabilis	0.0	2.3	0.0	0.0	0.0
	Tellina iris	2.1	0.0	0.0	0.0	0.0
	Crassinella spp.	0.0	0.0	0.0	1.4	0.0
	Spisula solidissima	1.0	0.0	0.0	0.0	0.0
Mollusca : Gastropoda	*Crepidula convexa*	0.0	4.5	0.0	0.0	0.0
	Nassarius acutus	0.0	2.3	0.0	0.0	0.0
	Olivella spp.	0.0	0.0	0.0	0.7	0.0
Miscellaneous	Nemertina	9.3	2.3	0.0	10.7	8.5
	Turbellaria	4.1	2.3	2.8	16.3	2.8
	Echinoidea	14.5	2.3	0.0	3.6	0.0
	Renilla reniformis	6.2	0.0	0.0	7.1	2.8
	Mellita quinquiesperforata	0.0	0.0	0.0	0.7	0.0

Table C-3. (Continued)						
		Oak Island			Reference	
				Fall		
Major Taxonomic Group	Taxon Name	Undisturbed	Disturbed	1-Year Later	Undisturbed	1-Year Later
Total Mean Abundance		1290.2	1261.3	715.9	3248.5	1113.6
Total Mean Biomass		0.68	0.86	0.20	0.86	0.25
Total Number of Species		39	27	15	36	18
Total Mean Number of Species		13.91	10.80	7.12	14.20	10.75
Shannon Wiener Diversity		2.37	2.08	1.78	1.95	1.98

Table C-4. Mean abundance of benthic taxa at Holden Beach and the reference beach deep habitat

Major Taxonomic Group	Taxon Name	Holden Beach Undisturbed	Holden Beach Disturbed	Holden Beach Winter 1 Year Later	Reference Undisturbed	Reference 1 Year Later
Polychaeta	*Scolelepis squamata*	51.7	38.6	21.3	92.3	8.5
	Spiophanes bombyx	64.0	31.8	12.8	10.7	15.6
	Paraonis fulgens	31.0	27.3	4.3	7.1	7.1
	Magelona papillicornis	28.9	36.4	0.0	3.6	0.0
	Leitoscoloplos spp.	14.5	18.2	0.0	32.7	0.0
	Onuphis eremita	5.2	15.9	0.0	1.4	0.0
	Dispio uncinata	2.1	6.8	1.4	3.6	0.0
	Mediomastus ambiseta	0.0	2.3	0.0	0.7	4.3
	Nephtys bucera	3.1	2.3	0.0	1.4	0.0
	Armandia agilis	4.1	0.0	0.0	0.0	0.0
	Asabellides oculata	1.0	0.0	1.4	0.7	0.0
	Dipolydora socialis	0.0	0.0	0.0	0.0	2.8
	Orbiniidae	0.0	2.3	0.0	0.0	0.0
	Prionospio steenstrupi	0.0	2.3	0.0	0.0	0.0
	Apoprionospio pygmaea	0.0	2.3	0.0	0.0	0.0
	Capitellidae	0.0	2.3	0.0	0.0	0.0
	Sabellaria vulgaris	0.0	2.3	0.0	0.0	0.0
	Eteone heteropoda	2.1	0.0	0.0	0.0	0.0
	Paraprionospio pinnata	1.0	0.0	0.0	0.0	0.0
	Psammodrilus balanoglossoides	1.0	0.0	0.0	0.0	0.0
	Polygordius spp.	1.0	0.0	0.0	0.0	0.0
	Glycera spp.	0.0	0.0	0.0	0.7	0.0
	Maldanidae	0.0	0.0	0.0	0.7	0.0
Crustacea : Amphipoda	*Protohaustorius* cf. *deichmannae*	2064.0	1963.6	1.4	1442.5	0.0
	Acanthohaustorius similis	411.2	359.1	8.5	556.1	15.6
	Bathyporeia parkeri	314.0	102.3	0.0	301.8	0.0
	Protohaustorius spp.	463.8	0.0	0.0	120.7	0.0
	Parahaustorius longimerus	65.1	147.7	14.2	191.8	22.7
	Rhepoxynius epistomus	68.2	75.0	0.0	10.7	0.0
	Americhelidium americanum	26.9	0.0	0.0	7.1	0.0
	Acanthohaustorius millsi	3.1	4.5	0.0	0.7	0.0
	Amphiporeia virginiana	0.0	0.0	0.0	0.7	5.7
	Ameroculodes species complex	0.0	2.3	0.0	3.6	0.0
	Eudevenopus honduranus	2.1	2.3	0.0	0.0	0.0
	Microprotopus raneyi	1.0	2.3	0.0	0.7	0.0
	Corophiidae	0.0	2.3	0.0	0.0	0.0
	Tiron spiniferum	0.0	0.0	0.0	1.4	0.0
Crustacea : Cumacea	*Cyclaspis varians*	4.1	4.5	0.0	2.8	0.0
	Mancocuma stellifera	2.1	2.3	1.4	4.3	0.0
	Oxyurostylis smithi	3.1	4.5	0.0	0.7	0.0
Crustacea : Decapoda	*Emerita talpoida*	0.0	0.0	4.3	0.0	2.8
	Pagurus longicarpus	4.1	0.0	0.0	0.0	0.0
	Pinnotheridae	0.0	2.3	0.0	0.7	0.0
Crustacea : Isopoda	*Chiridotea caeca*	14.5	6.8	0.0	5.7	0.0
	Ancinus depressus	0.0	2.3	0.0	3.6	0.0
	Edotea spp.	0.0	2.3	0.0	0.0	0.0
Crustacea : Mysidacea	Mysidae	10.3	0.0	0.0	0.7	0.0
	Bowmaniella spp.	0.0	0.0	0.0	0.7	0.0
Crustacea : Tanaidacea	*Tanaissus psammophilus*	0.0	0.0	0.0	3.6	0.0
Mollusca : Bivalvia	*Donax variabilis*	19.6	4.5	32.7	46.9	61.1
	Tellina agilis	17.6	36.4	0.0	0.0	0.0
	Tellina spp.	8.3	15.9	0.0	0.0	0.0
	Ensis directus	0.0	0.0	2.8	0.0	0.0
	Spisula solidissima	2.1	0.0	0.0	0.0	0.0
	Crassinella spp.	0.0	0.0	0.0	0.7	0.0
	Mulinia lateralis	0.0	0.0	0.0	0.7	0.0
Mollusca : Gastropoda	*Nassarius acutus*	0.0	2.3	0.0	0.0	0.0
	Terebra dislocata	0.0	2.3	0.0	0.0	0.0
	Polinices duplicatus	1.0	0.0	0.0	0.0	0.0

Table C-4. (Continued)

Major Taxonomic Group	Taxon Name	Holden Beach Undisturbed	Holden Beach Disturbed	Holden Beach Winter 1 Year Later	Reference Undisturbed	Reference 1 Year Later
Miscellaneous	Nemertina	10.3	11.4	0.0	23.4	1.4
	Turbellaria	12.4	2.3	0.0	1.4	0.0
	Echinoidea	11.4	0.0	0.0	2.1	0.0
	Mellita quinquiesperforata	3.1	4.5	0.0	1.4	0.0
	Hemichordata	0.0	2.3	0.0	0.0	0.0
	Renilla reniformis	2.1	0.0	0.0	0.0	0.0
Total Mean Abundance		3756.1	2959.0	106.5	2892.7	147.7
Total Mean Biomass		1.15	0.90	0.15	1.14	0.12
Total Number of Species		40	40	12	40	11
Total Mean Number of Species		16.18	17.80	4.13	11.81	4.13
Shannon Wiener Diversity		2.13	1.80	1.68	1.96	1.55

APPENDIX D

SEINE FISH SPECIES DATA

Table D-1. Total seine catch (% occurrence) by beach

		% Occurrence				
Scienific Name	**Common Name**	**Total**	**Bald Head Island (Spring)**	**Caswell Beach (Summer)**	**Oak Island (Fall)**	**Holden Beach (Winter)**
Alosa aestivalis	Blueback herring	1.36	0.14	1.96	1.73	
Alosa pseudoharengus	Alewife	0.10		1.96		
Alosa sapidissima	American shad	0.03			0.05	
Anchoa hepsetus	Striped anchovy	0.14			0.19	
Anchoa mitchilli	Bay anchovy	47.35	0.14		66.99	
Arenaeus cribrarius	Speckled swimming crab	2.24	6.10	3.27	0.86	
Bairdiella chrysoura	Silver perch	0.07			0.10	
Brevoortia tyrannus	Atlantic menhaden	0.03			0.05	
Carangidae	Jacks	0.07	0.28			
Caranx hippos	Crevalle jack	0.61			0.86	
Chaetodipterus faber	Atlantic spadefish	0.03			0.05	
Chilomycterus schoepfi	Striped burrfish	0.17	0.71			
Chloroscombrus chrysurus	Atlantic bumper	3.02	2.55	46.41		
Dasyatis americana	Southern stingray	0.14			0.19	
Dasyatis sabina	Atlantic stingray	0.07			0.10	
Elops saurus	Ladyfish	0.20			0.29	
Emerita talpoida	Atlantic sand crab	0.03			0.05	
Gymnura micrura	Smooth butterfly ray	0.03			0.05	
Lagodon rhomboides	Pinfish	0.27			0.38	
Leiostomus xanthurus	Spot	14.02			19.85	
Libinia dubia	Longnose spider crab	0.68	2.70		0.05	
Membras martinica	Rough silverside	1.19			1.68	
Menidia menidia	Atlantic silverside	0.78			1.11	
Menticirrhus americanus	Southern kingfish	0.34	0.43	2.61	0.14	
Menticirrhus littoralis	Gulf kingfish	5.67	13.48	7.19	2.64	85.71
Monacanthus hispidus	Planehead filefish	0.81	3.12		0.10	
Mugil cephalus	Striped mullet	0.14			0.19	
Mugil curema	White mullet	8.25	34.33	0.65		
Opisthonema oglinum	Atlantic thread herring	0.44	0.57	1.31	0.34	
Paguridae	Right-handed hermit crabs	0.14	0.14	0.65	0.10	
Paralichthys dentatus	Summer flounder	0.14		1.96	0.05	
Paralichthys lethostigma	Southern flounder	0.03			0.05	
Peprilus triacanthus	Butterfish	0.27			0.38	
Pomatomus saltatrix	Bluefish	0.17	0.28		0.14	
Portunus sayi	Sargassum swimming crab	0.10	0.43			
Scomberomorus maculatus	Spanish mackerel	0.14	0.57			
Scophthalmus aquosus	Windowpane	0.41		3.92	0.29	
Selene setapinnis	Atlantic moonfish	0.03			0.05	
Selene vomer	Lookdown	0.10	0.28		0.05	
Sphoeroides maculatus	Northern puffer	0.07	0.14		0.05	
Strongylura marina	Atlantic needlefish	0.03		0.65		
Syngnathus floridae	dusky pipefish	0.07	0.28			
Syngnathus fuscus	Northern pipefish	0.03	0.14			
Trachinotus carolinus	Florida pompano	9.78	32.91	25.49	0.82	
Trachinotus falcatus	Permit	0.03		0.65		
Trachinotus goodie	Palometa	0.07		1.31		
Xanthidae	Mud crabs	0.10	0.28			14.29
Mean Total Abundance (#/haul)		32	23.5	15.3	57.8	0.4
Total Number of Taxa		47	22	15	34	2

Table D-2. Total seine catch (% occurrence) for Bald Head Island

Scientific Name	Common Name	Spring % Bald Head Island Undisturbed			Reference Undisturbed	
		Undisturbed	Disturbed	1-Year Later	Undisturbed	1-Year Later
Alosa aestivalis	Blueback herring	0.02	0.03		0.06	
Alosa mediocris	Hickory shad		0.03		0.12	
Alosa sapidissima	American shad			0.05		
Anchoa hepsetus	Striped anchovy	1.31	0.25		1.08	
Anchoa mitchilli	Bay anchovy	28.35	93.71	73.36	92.83	
Arenaeus cribrarius	Speckled swimming crab			0.43		21.43
Bairdiella chrysoura	Silver perch	0.12	0.89	0.11		
Bivalvia	Clams				0.03	
Brevoortia tyrannus	Atlantic menhaden	0.20	0.28	0.05	0.35	
Callinectes similis	Lesser blue crab	0.05				
Caranx hippos	Crevalle jack			0.64		
Cephalopoda	Squids	0.17	0.14			
Clupea harengus harengus	Atlantic herring	0.02				
Dasyatis sabina	Atlantic stingray			0.05		
Elops saurus	Ladyfish		0.06			
Fundulus majalis	Striped killifish				0.23	
Lagodon rhomboides	Pinfish			0.05		
Leiostomus xanthurus	Spot	0.59	1.61	21.62	0.84	3.57
Membras martinica	Rough silverside	59.62	0.22	1.87	0.73	
Menidia menidia	Atlantic silverside	6.94	1.61	0.96	0.44	17.86
Menticirrhus littoralis	Gulf kingfish	0.07	0.19	0.05		14.29
Menticirrhus saxatilis	Northern kingfish	0.30			0.12	
Micropogonias undulatus	Atlantic croaker	0.05			0.32	
Monacanthus hispidus	Planehead filefish	0.17	0.03	0.11	0.03	
Mugil cephalus	Striped mullet	0.02	0.11			
Opisthonema oglinum	Atlantic thread herring				0.03	
Ovalipes ocellatus	Lady crab	1.61		0.05	0.23	
Ovalipes stephensoni	Coarsehand lady crab	0.02	0.03			
Paguridae	Right-handed hermit crabs	0.05				
Paralichthys lethostigma	Southern flounder	0.02				3.57
Peprilus triacanthus	Butterfish			0.16	0.26	
Pomatomus saltatrix	Bluefish	0.02	0.00	0.27	0.03	
Scophthalmus aquosus	Windowpane	0.10		0.11	0.20	
Selene setapinnis	Atlantic moonfish			0.05		
Sphoeroides maculatus	Northern puffer	0.02				
Stomatopoda	Mantis shrimp	0.05	0.03			
Syngnathus fuscus	Northern pipefish				0.03	
Trachinotus carolinus	Florida pompano	0.07	0.80		2.04	39.29
Mean Total Abundance (#/haul)		184	361	234	343	4
Total Number of Taxa		25	18	18	20	6

Table D-3. Total seine catch (% occurrence) for Caswell Beach						
		Summer %				
		Caswell Beach			**Reference**	
Scientific Name	**Common Name**	**Undisturbed**	**Disturbed**	**1-Year Later**	**Undisturbed**	**1-Year Later**
Alosa aestivalis	Blueback herring	0.38	0.46			
Anchoa hepsetus	Striped anchovy	0.38	2.63			
Anchoa mitchilli	Bay anchovy		0.04		0.53	
Arenaeus cribrarius	Speckled swimming crab	1.54	5.56	5.66	0.53	3.38
Astroscopus guttatus	Northern stargazer		0.08			
Brevoortia tyrannus	Atlantic menhaden	0.77	0.67			
Callinectes similis	Lesser blue crab		0.13			
Carangidae	Jacks			3.77		
Caranx hippos	Crevalle jack	0.19	0.08			
Chilomycterus schoepfi	Striped burrfish	0.19	0.08			
Chloroscombrus chrysurus	Atlantic bumper	4.61	38.43		0.53	
Cynoscion nebulosus	Spotted seatrout		0.04			
Dasyatis americana	Southern stingray	7.68	1.04			
Dasyatis sabina	Atlantic stingray	0.19	0.13			
Dasyatis say	Bluntnose stingray		0.92			
Elops saurus	Ladyfish	0.38	0.88			
Gymnura micrura	Smooth butterfly ray		0.25			
Lagodon rhomboides	Pinfish	0.19	0.04			
Larimus fasciatus	Banded drum		0.04			
Leiostomus xanthurus	Spot	2.30	0.42		0.53	
Libinia dubia	Longnose spider crab		0.21			
Membras martinica	Rough silverside	0.19				
Menticirrhus americanus	Southern kingfish		0.88			
Menticirrhus littoralis	Gulf kingfish	22.26	11.11	60.38	19.05	11.11
Menticirrhus saxatilis	Northern kingfish		0.04			
Micropogonias undulatus	Atlantic croaker		0.08			
Mugil cephalus	Striped mullet	0.19	0.58			
Mugil curema	White mullet	4.41	2.51	1.89	1.06	54.11
Opisthonema oglinum	Atlantic thread herring		13.95			0.97
Orthopristis chrysoptera	Pigfish		0.04			
Ovalipes ocellatus	Lady crab		0.13			
Paguridae	Right-handed hermit crabs		0.08			
Paralichthys dentatus	Summer flounder		0.17			
Paralichthys lethostigma	Southern flounder	0.19				
Pomatomus saltatrix	Bluefish	0.96	0.29			0.48
Portunus sayi	Sargassum swimming crab		0.04			
Sciaenops ocellatus	Red drum		0.25			
Scomberomorus maculatus	Spanish mackerel	0.19	0.79			
Strongylura marina	Atlantic needlefish	0.19	2.84			
Trachinotus carolinus	Florida pompano	52.59	14.04	28.30	77.78	29.47
Trinectes maculatus	Hogchoker		0.04			
Xanthidae	Mud crabs					0.48
Mean Total Abundance (#/haul)		87	92	7	24	35
Total Number of Taxa		21	38	5	7	7

Table D-4. Total seine catch (% occurrence) for Caswell Beach quarterly sampling

		Fall 01		Winter 02		Spring 02		Summer 02	
Scientific Name	**Common Name**	**Caswell Beach**	**Reference**	**Caswell Beach**	**Reference**	**Caswell Beach**	**Reference**	**Caswell Beach**	**Reference**
Alosa aestivalis	Blueback herring					26.17			
Alosa sapidissima	American shad			8.74					
Anchoa hepsetus	Striped anchovy	0.55				3.74			
Anchoa mitchilli	Bay anchovy	1.09				16.82			
Archosargus probatocephalus	Sheepshead	0.55							
Arenaeus cribrarius	Speckled swimming crab	5.46		2.91		3.74	21.43	5.66	3.38
Carangidae	Jacks							3.77	
Caranx hippos	Crevalle jack					5.61			
Cephalopoda	Squids	2.73							
Chaetodipterus faber	Atlantic spadefish					0.93			
Chloroscombrus chrysurus	Atlantic bumper	22.40							
Dasyatis americana	Southern stingray					2.80			
Dasyatis sabina	Atlantic stingray					0.93			
Elops saurus	Ladyfish	1.09				2.80			
Lagodon rhomboides	Pinfish	1.09		49.51	8.11	6.54			
Leiostomus xanthurus	Spot	4.37		14.56		3.74	3.57		
Libinia dubia	Longnose spider crab					0.93			
Membras martinica	Rough silverside	0.55							
Menidia menidia	Atlantic silverside						17.86		
Menticirrhus americanus	Southern kingfish	2.19				1.87			
Menticirrhus littoralis	Gulf kingfish	6.56	76.47	13.59	78.38	1.87	14.29	60.38	11.11
Menticirrhus saxatilis	Northern kingfish	0.55							
Mugil cephalus	Striped mullet	15.30	2.94		2.70	0.93			
Mugil curema	White mullet	21.31	5.88	0.97				1.89	54.11
Opisthonema oglinum	Atlantic thread herring					6.54			0.97
Paguridae	Right-handed hermit crabs				2.70	0.93			
Paralichthys dentatus	Summer flounder	1.09							
Paralichthys lethostigma	Southern flounder						3.57		
Peprilus triacanthus	Butterfish					4.67			
Pogonias cromis	Black drum	8.20		1.94	5.41				
Pomatomus saltatrix	Bluefish	0.55				2.80			0.48
Prionotus carolinus	Northern searobin				2.70				
Scophthalmus aquosus	Windowpane	0.55							
Selene vomer	Lookdown	1.64							
Strongylura marina	Atlantic needlefish			2.91					
Trachinotus carolinus	Florida pompano	2.19	14.71			5.61	39.29	28.30	29.47
Urophycis regia	Spotted hake			4.85					
Xanthidae	Mud crabs								0.48
Mean Total Abundance (#/haul)		23	9	13	5	13	4	7	35
Total Number of Taxa		21	4	9	6	20	6	5	7

Table D-5. Total seine catch (% occurrence) for Oak Island						
		Fall %				
		Oak Island			Reference	
Scientific Name	**Common Name**	**Undisturbed**	**Disturbed**	**1-Year Later**	**Undisturbed**	**1-Year Later**
Alosa aestivalis	Blueback herring			1.50		5.00
Alosa pseudoharengus	Alewife					15.00
Anchoa hepsetus	Striped anchovy	0.30				
Arenaeus cribrarius	Speckled swimming crab	15.32	7.19	3.76		
Astroscopus guttatus	Northern stargazer	0.30	0.72			
Bairdiella chrysoura	Silver perch	2.10	0.72			
Chloroscombrus chrysurus	Atlantic bumper	0.90	2.16	53.38		
Crangon septemspinosa	Sand shrimp	0.30				
Echinoidea	Heart urchins	0.30				
Elops saurus	Ladyfish	0.60	0.72			
Leiostomus xanthurus	Spot	0.90	2.16			
Menticirrhus americanus	Southern kingfish	0.60		3.01		
Menticirrhus littoralis	Gulf kingfish	54.05	78.42	7.52	84.00	5.00
Mugil cephalus	Striped mullet	0.90				
Mugil curema	White mullet	0.60	3.60			5.00
Opisthonema oglinum	Atlantic thread herring					10.00
Paguridae	Right-handed hermit crabs					5.00
Paralichthys dentatus	Summer flounder	0.30		1.50		5.00
Paralichthys lethostigma	Southern flounder					
Pogonias cromis	Black drum		0.72			
Prionotus carolinus	Northern searobin	0.30				
Scophthalmus aquosus	Windowpane	2.40		3.76		5.00
Selene vomer	Lookdown	0.60				
Strongylura marina	Atlantic needlefish		0.72	0.75		
Trachinotus carolinus	Florida pompano	15.02	2.16	22.56	16.00	45.00
Trachinotus falcatus	Permit	0.30		0.75		
Trachinotus goodie	Palometa			1.50		
Trinectes maculatus	Hogchoker	3.90	0.72			
Mean Total Abundance (#/haul)		28	17	17	8	10
Total Number of Taxa		20	12	11	2	9

Table D-6. Total seine catch (% occurrence) for Oak Island quarterly sampling									
		Winter 02		**Spring 02**		**Summer 02**		**Fall 02**	
Scientific Name	**Common Name**	**Oak Island**	**Reference**	**Oak Island**	**Reference**	**Oak Island**	**Reference**	**Oak Island**	**Reference**
Alosa aestivalis	Blueback herring					0.35		1.50	5.00
Alosa pseudoharengus	Alewife								15.00
Anchoa mitchilli	Bay anchovy			1.52		0.35			
Arenaeus cribrarius	Speckled swimming crab				21.43	10.73	3.38	3.76	
Chilomycterus schoepfi	Striped burrfish					1.73			
Chloroscombrus chrysurus	Atlantic bumper					3.11		53.38	
Dasyatis americana	Southern stingray			1.52					
Elops saurus	Ladyfish			3.03					
Gymnura micrura	Smooth butterfly ray			1.52					
Leiostomus xanthurus	Spot			4.55	3.57				
Libinia dubia	Longnose spider crab					6.57			
Menidia menidia	Atlantic silverside				17.86				
Menticirrhus americanus	Southern kingfish			1.52		0.69		3.01	
Menticirrhus littoralis	Gulf kingfish	83.33	100.00	72.73	14.29	12.46	11.11	7.52	5.00
Monacanthus hispidus	Planehead filefish					7.61			
Mugil cephalus	Striped mullet			4.55					
Mugil curema	White mullet					2.42	54.11		5.00
Opisthonema oglinum	Atlantic thread herring						0.97		10.00
Paguridae	Right-handed hermit crabs					0.35			5.00
Paralichthys dentatus	Summer flounder			1.52				1.50	5.00
Paralichthys lethostigma	Southern flounder				3.57				
Pomatomus saltatrix	Bluefish					0.35	0.48		
Portunus sayi	Sargassum swimming crab					1.04			
Scomberomorus maculatus	Spanish mackerel				0.00				
Scophthalmus aquosus	Windowpane			6.06				3.76	5.00
Selene vomer	Lookdown					0.69			
Sphoeroides maculatus	Northern puffer			1.52		0.35			
Strongylura marina	Atlantic needlefish							0.75	
Syngnathus floridae	dusky pipefish					0.69			
Syngnathus fuscus	Northern pipefish					0.35			
Trachinotus carolinus	Florida pompano				39.29	49.83	29.47	22.56	45.00
Trachinotus falcatus	Permit							0.75	
Trachinotus goodie	Palometa							1.50	
Xanthidae	Mud crabs	16.67				0.35	0.48		
Mean Total Abundance (#/haul)		1	0.25	8	4	36	35	17	10
Total Number of Taxa		2	1	11	7	19	7	11	9

Table D-7. Total seine catch (% occurrence) for Holden Beach						
		Winter %				
		Holden Beach			Reference	
Scientific Name	**Common Name**	**Undisturbed**	**Disturbed**	**1-Year Later**	**Undisturbed**	**1-Year Later**
Alosa sapidissima	American shad	2.22	10.00			
Elops saurus	Ladyfish	4.44	22.50			
Lagodon rhomboides	Pinfish		12.50		5.88	
Leiostomus xanthurus	Spot	6.67	5.00			
Menticirrhus americanus	Southern kingfish		2.50			
Menticirrhus littoralis	Gulf kingfish	33.33	35.00		70.59	100.00
Mugil cephalus	Striped mullet				5.88	
Mugil curema	White mullet	46.67			7.84	
Paralichthys dentatus	Summer flounder	2.22				
Persephona mediterranea	Mottled purse crab		2.50			
Pogonias cromis	Black drum	2.22			3.92	
Prionotus carolinus	Northern searobin				1.96	
Scophthalmus aquosus	Windowpane		7.50			
Stomatopoda	Mantis shrimp		2.50			
Trachinotus carolinus	Florida pompano	2.22			3.92	
Mean Total Abundance (#/haul)		4.50	1.82	0	6.38	0.25
Total Number of Taxa		8	9	0	7	1

Table D-8. Total seine catch (% occurrence) for Holden Beach quarterly sampling

Scientific Name	Common Name	Spring 02		Summer 02		Fall 02		Winter 03	
		Holden Beach	Reference	Holden Beach	Reference	Holden Beach	Reference	Holden Beach	Reference
Alosa aestivalis	Blueback herring	42.86				1.00	5.00		
Alosa pseudoharengus	Alewife						15.00		
Anchoa hepsetus	Striped anchovy					27.00			
Anchoa mitchilli	Bay anchovy	14.29							
Arenaeus cribrarius	Speckled swimming crab		21.43	1.28	3.38	1.00			
Chloroscombrus chrysurus	Atlantic bumper			5.77					
Dasyatis americana	Southern stingray			0.00					
Emerita talpoida	Atlantic sand crab	14.29							
Leiostomus xanthurus	Spot		3.57						
Menidia menidia	Atlantic silverside		17.86						
Menticirrhus americanus	Southern kingfish			0.64		2.00			
Menticirrhus littoralis	Gulf kingfish		14.29	2.56	11.11	24.00	5.00		100.00
Mugil curema	White mullet			78.21	54.11	5.00	5.00		
Opisthonema oglinum	Atlantic thread herring			1.28	0.97	1.00	10.00		
Paguridae	Right-handed hermit crabs	14.29				2.00	5.00		
Paralichthys dentatus	Summer flounder						5.00		
Paralichthys lethostigma	Southern flounder		3.57						
Pomatomus saltatrix	Bluefish				0.48				
Scomberomorus maculatus	Spanish mackerel			2.56					
Scophthalmus aquosus	Windowpane						5.00		
Selene vomer	Lookdown	14.29							
Strongylura marina	Atlantic needlefish					3.00			
Trachinotus carolinus	Florida pompano		39.29	7.69	29.47	34.00	45.00		
Xanthidae	Mud crabs				0.48				
Mean Total Abundance (#/haul)		1	4	20	35	13	10	0	0.25
Total Number of Taxa		5	6	9	7	10	9	0	1

APPENDIX E

TRAWL FISH SPECIES DATA

Table E-1. Total trawl catch (% occurrence) by season						
		% Occurrence				
Scienific Name	**Common Name**	**Total 02**	**Spring 02**	**Summer 02**	**Fall 02**	**Winter 02**
Alosa aestivalis	Blue back herring	0.22		0.34		
Alosa pseudoharengus	Alewife	0.02				0.88
Alosa sapidissima	American shad					
Anchoa hepsetus	Striped anchovy	17.56	3.79	25.22	13.74	
Anchoa mitchilli	Bay anchovy	65.14	71.19	62.55		55.94
Archosargus probatocephalus	Sheepshead					
Arenaeus cribrarius	Speckled swimming crab	0.56	0.22	0.75	1.08	
Asteroidea	Star drum	0.27				
Astroscopus guttatus	Northern stargazer	0.01			1.08	0.15
Astroscopus y-graecum	Southern stargazer					
Bairdiella chrysoura	Silver perch	0.06		0.01		
Bivalvia	Clams	0.00		0.00		
Brevoortia tyrannus	Atlantic menhaden	0.05	0.08	0.00	2.63	0.46
Busycon carica	Knobbed whelk	0.02	0.06	0.01		
Busycotypus canaliculatus	Channeled whelk	0.00			1.06	
Callinectes danae	Dana swimming crab	0.00	0.01			
Callinectes sapidus	Blue crab	0.19	0.01	0.00		
Callinectes similis	Lesser blue crab	0.08	0.21	0.01		
Cancer irroratus	Atlantic rock crab					
Caranx hippos	Crevalle jack	0.00		0.01		
Centropristis striata	Black sea bass	0.01	0.02			
Cephalopoda	Squids	1.33	0.75	1.66		0.59
Chaetodipterus faber	Atlantic spadefish					
Chasmodes bosquianus	Striped blenny					
Chilomycterus schoepfi	Striped burrfish	0.01	0.02	0.01		
Chloroscombrus chrysurus	Atlantic bumper	1.75		2.71	2.24	
Citharichthys spilopterus	Bay whiff	0.04	0.12			
Crangon septemspinosa	Sand shrimp	0.23	0.69	0.01		
Cynoscion regalis	Weakfish	0.14	0.26	0.08		0.39
Dasyatis americana	Southern stingray	0.10	0.16	0.07		0.17
Dasyatis sabina	Atlantic stingray	0.02	0.05			
Dasyatis say	Bluntnose stingray	0.00	0.01			
Echinoidea	Heart urchins	0.04	0.01	0.05		0.17
Etropus microstomus	Smallmouth flounder	0.04	0.03	0.05	0.60	
Eucinostomus argenteus	Spotfin mojarra					
Eucinostomus gula	Silver jenny	0.01		0.00		
Gymnura	Butterfly rays	0.01	1.67			
Gymnura altavela	Spiny butterfly ray					
Gymnura micrura	Smooth butterfly ray	0.24	0.34	0.17	6.28	
Hepatus epheliticus	Calico box crab	0.00		0.00		
Hyporhamphus unifasciatus	Silverstripe halfbeak	0.00	0.18			
Hypsoblennius hentzi	Feather blenny	0.00	0.01			
Lagodon rhomboides	Pinfish	0.38	0.21	0.03		14.09
Larimus fasciatus	Banded drum	0.81	0.78	0.85	2.75	
Leiostomus xanthurus	Spot	0.94	2.75	0.04		0.39
Libinia dubia	Longnose spider crab	0.62	1.37	0.26	1.24	
Libinia emarginata	Portly spider crab	0.03	0.08	0.00		
Limulus polyphemus	Horseshoe crab	0.00	0.01			
Membras martinica	Rough silverside					
Menidia menidia	Atlantic silverside	0.26				12.40
Menippe mercenaria	Florida stone crab	0.01	0.04			
Menticirrhus americanus	Southern kingfish	2.43	1.94	2.56	58.99	0.69

Table E-1. (Continued)						
		% Occurrence				
Scienific Name	**Common Name**	**Total 02**	**Spring 02**	**Summer 02**	**Fall 02**	**Winter 02**
Menticirrhus littoralis	Gulf kingfish	0.06	0.05	0.03		1.21
Menticirrhus saxatilis	Northern kingfish	0.00				0.15
Micropogonias undulatus	Atlantic croaker	0.22	0.51			2.19
Monacanthus hispidus	Planehead filefish	0.06	0.14	0.02	1.18	0.16
Mugil curema	White mullet					
Mustelus canis	Smooth dogfish	0.01	0.02			
Myliobatis freminvillei	Bullnose ray	0.01	0.02			
Narcine brasiliensis	Lesser electric ray					
Ophidion marginatum	Striped cusk eel	0.08	0.25			
Opisthonema oglinum	Atlantic thread herring	0.20	0.06	0.23		1.66
Opsanus tau	Oyster toadfish	0.01	0.02			
Orthopristis chrysoptera	Pigfish					
Ovalipes ocellatus	Lady crab	0.59	1.65	0.03	1.06	1.15
Ovalipes stephensoni	Coarsehand lady crab	0.17	0.49	0.01		
Paguridae	Right handed hermit crabs	1.40	3.90	0.16		0.34
Paralichthys dentatus	Summer flounder	0.04	0.06	0.02		0.39
Paralichthys lethostigma	Southern flounder	0.01	0.04			
Paralichthys oblongus	Fourspot flounder	0.06	0.15	0.01		
Penaeus aztecus	Brown shrimp	0.17	0.49	0.01		
Penaeus setiferus	Northern white shrimp	0.13	0.04	0.04		4.17
Peprilus alepidotus	Harvestfish	0.01	0.01	0.00		
Peprilus triacanthus	Butterfish	0.55		0.01		
Persephona mediterranea	Mottled purse crab	0.01	0.01	0.01		
Polinices spp	Moon snails					
Pomatomus saltatrix	Bluefish	0.00	0.59			
Portunus gibbesii	Iridescent swimming crab	0.04	0.08	0.03		
Portunus sayi	Sargassum swimming crab	0.06	0.16	0.02		
Prionotus carolinus	Northern searobin	0.47	0.81	0.30	2.24	0.24
Prionotus evolans	Striped searobin	0.07	0.08	0.07		
Prionotus scitulus	Leopard searobin					
Prionotus tribulus	Bighead searobin	0.11	0.29	0.02		
Raja eglanteria	Clearnose skate	0.03	0.09		1.38	0.14
Renilla mulleri	Sea pansy	0.00				0.17
Rhizoprionodon terraenovae	Atlantic sharpnose shark	0.02	0.03	0.02		
Scomberomorus maculatus	Spanish mackerel					
Scophthalmus aquosus	Windowpane	0.18	0.54	0.00		
Selar crumenophthalmus	Bigeye scad	0.00	0.01			
Selene setapinnis	Atlantic moonfish	0.02	0.01	0.02		
Selene vomer	Lookdown	0.03		0.05		
Serranidae	Groupers					
Sphoeroides maculatus	Northern puffer	0.07	0.17	0.01		
Sphyraena barracuda	Great barracuda	0.03		0.04		
Sphyraena guachancho	Guaguanche	0.00	0.01			
Stellifer lanceolatus	Starfishes		0.35	0.24		
Stenotomus chrysops	Scup	0.01		0.01		
Stomatopoda	Mantis shrimp	0.02	0.03	0.01		
Symphurus plagiusa	Blackcheek tonguefish	0.01	0.03			
Syngnathus floridae	Dusky pipefish	0.00	0.01			
Syngnathus fuscus	Northern pipefish	0.02	0.05			
Synodus foetens	Inshore lizardfish	0.05	0.07	0.04	0.04	
Trachinotus carolinus	Florida pompano	0.02		0.03		
Trichiurus lepturus	Atlantic cutlassfish	0.01	0.02			

Table E-1. (Continued)							
		% Occurrence					
Scienific Name	**Common Name**	**Total 02**	**Spring 02**	**Summer 02**	**Fall 02**	**Winter 02**
Trinectes maculatus	Hogchoker	1.03	1.01	1.06	2.42	0.17
Upeneus parvus	Dwarf goatfish					
Urophycis chuss	Red hake	0.02				0.72
Urophycis regia	Spotted hake	0.17	0.47			0.52
Xanthidae	Mud crabs	0.06	0.15	0.00		0.29
Average Abundance (#/500m)		342	312	809	8	26
Total Number of Taxa		91	72	59	17	28

Table E-2. Total trawl catch (% occurrence) for Bald Head Island						
		Spring %				
		Bald Head Island			Reference	
Scientific Name	Common Name	Undisturbed	Disturbed	1-Year Later	Undisturbed	1-Year Later
Anchoa hepsetus	Striped anchovy	0.54	1.19	10.66	7.81	2.92
Anchoa mitchilli	Bay anchovy	39.97	34.68	29.13	42.79	89.30
Archosargus probatocephalus	Sheepshead	0.02				
Arenaeus cribrarius	Speckled swimming crab			0.14		0.02
Astroscopus y-graecum	Southern stargazer	0.02				
Bivalvia	Clams	0.02				
Brevoortia tyrannus	Atlantic menhaden	0.07	1.97	1.11	0.14	
Callinectes sapidus	Blue crab			0.13	0.08	0.02
Callinectes similis	Lesser blue crab	0.76	0.44		1.18	0.02
Centropristis striata	Black sea bass			0.25		
Cephalopoda	Squids	2.24	2.91	0.25	1.93	0.71
Chilomycterus schoepfi	Striped burrfish	0.02				0.04
Chloroscombrus chrysurus	Atlantic bumper					
Citharichthys spilopterus	Bay whiff	0.16	0.13	0.29		0.05
Crangon septemspinosa	Sand shrimp	0.35	3.54			
Cynoscion regalis	Weakfish	0.04			0.08	
Dasyatis americana	Southern stingray	0.04	0.21			0.02
Dasyatis sabina	Atlantic stingray	0.12	0.28	0.31		0.02
Dasyatis say	Bluntnose stingray			0.16		
Echinoidea	Heart urchins	11.83	0.45		2.30	
Gymnura spp.	Butter rays	4.32	7.20	12.61	17.29	0.85
Gymnura altavela	Spiny butterfly ray	0.02				
Gymnura micrura	Smooth butterfly ray	0.38			0.23	0.06
Hepatus epheliticus	Calico box crab	0.09	0.08		0.14	
Hyporhamphus unifasciatus	Silverstripe halfbeak	0.22	0.07	0.12	0.21	
Lagodon rhomboides	Pinfish	0.48		0.63		0.02
Larimus fasciatus	Banded drum	0.39	0.15			0.12
Leiostomus xanthurus	Spot	1.13	0.54	23.67	1.42	0.82
Libinia dubia	Longnose spider crab			0.62	2.36	0.87
Libinia emarginata	Portly spider crab	0.73	0.11	0.12	0.06	0.13
Limulus polyphemus	Horseshoe crab					0.02
Menticirrhus americanus	Southern kingfish			0.41		0.18
Menticirrhus littoralis	Gulf kingfish	1.17	0.09	0.76		
Menticirrhus saxatilis	Northern kingfish	0.13	0.49		0.08	
Micropogonias undulatus	Atlantic croaker	1.71	0.16		3.37	
Monacanthus hispidus	Planehead filefish	0.03	1.18	0.30	0.81	0.16
Mustelus canis	Smooth dogfish					0.06
Myliobatis freminvillei	Bullnose ray			0.37		
Narcine brasiliensis	Lesser electric ray	0.02				
Ophidion marginatum	Striped cusk eel	0.02	2.24			0.20
Opisthonema oglinum	Atlantic thread herring	0.06	0.09	0.63		
Ovalipes ocellatus	Lady crab	3.12	1.78	6.23	2.81	0.33
Ovalipes stephensoni	Coarsehand lady crab	11.88	25.64	6.48	2.57	0.06
Paguridae	Right handed hermit crabs	1.56	0.83	1.42	0.56	0.33
Paralichthys dentatus	Summer flounder	0.10	0.46			
Paralichthys lethostigma	Southern flounder		0.20			
Paralichthys oblongus	Fourspot flounder	0.06		0.47		0.13
Penaeus aztecus	Brown shrimp	0.02		0.13		
Penaeus setiferus	Northern white shrimp	0.34	0.37		0.34	
Peprilus alepidotus	Harvestfish	0.02	0.32			
Peprilus triacanthus	Butterfish					
Persephona mediterranea	Mottled purse crab	0.25	1.00		0.11	
Polinices spp.	Moon snails	0.02				
Pomatomus saltatrix	Bluefish		0.08			
Portunus gibbesii	Iridescent swimming crab	0.06			0.68	0.04
Prionotus carolinus	Northern searobin	0.04	0.09	1.05		0.52

Table E-2. (Continued)						
		Spring %				
		Bald Head Island			Reference	
Scientific Name	Common Name	Undisturbed	Disturbed	1-Year Later	Undisturbed	1-Year Later
Prionotus evolans	Striped searobin	0.02				
Prionotus tribulus	Bighead searobin	0.82	1.39	0.34	0.10	0.02
Raja eglanteria	Clearnose skate	0.88	0.97	0.29	0.13	0.06
Rhizoprionodon terraenovae	Atlantic sharpnose shark		0.43		0.19	0.02
Scomberomorus maculatus	Spanish mackerel					
Scophthalmus aquosus	Windowpane	4.32	5.08	0.57	5.86	0.43
Selar crumenophthalmus	Bigeye scad					0.02
Serranidae	Groupers	0.05	0.10			
Sphoeroides maculatus	Northern puffer	0.02				0.04
Stomatopoda	Mantis shrimp		1.29			
Symphurus plagiusa	Blackcheek tonguefish	0.06				
Syngnathus floridae	Dusky pipefish	0.02				
Syngnathus fuscus	Northern pipefish	0.16	0.11		0.23	
Synodus foetens	Inshore lizardfish					0.13
Trichiurus lepturus	Atlantic cutlassfish	0.15	0.07		0.17	0.02
Trinectes maculatus	Hogchoker	1.06	0.98		0.65	0.17
Urophycis regia	Spotted hake	7.87	0.62	0.37	3.28	1.01
Xanthidae	Mud crabs					0.09
Mean Total Abundance (#/500m)		204	95	95	119	657
Total Number of Taxa		55	42	31	32	39

Table E-3. Total trawl catch (% occurrence) for Caswell Beach						
		Summer %				
		Caswell Beach			Reference	
Scientific Name	Common Name	Undisturbed	Disturbed	1-Year Later	Undisturbed	1-Year Later
Alosa aestivalis	Blue back herring					0.07
Anchoa hepsetus	Striped anchovy	3.56	3.56	6.09	48.83	21.69
Anchoa mitchilli	Bay anchovy	28.48	65.12	74.03	23.05	70.30
Arenaeus cribrarius	Speckled swimming crab	0.09	0.01	1.70	0.10	0.39
Asteroidea	Star drum				0.03	
Bairdiella chrysoura	Silver perch			0.02		
Bivalvia	Clams		0.01			
Brevoortia tyrannus	Atlantic menhaden	0.04	0.01		0.19	0.01
Busycon carica	Knobbed whelk			0.02		
Busycotypus canaliculatus	Channeled whelk	0.04	0.05			
Callinectes similis	Lesser blue crab	1.19	0.21	0.02	0.35	0.02
Cancer irroratus	Atlantic rock crab				0.03	
Centropristis striata	Black sea bass		0.00			
Cephalopoda	Squids	16.30	4.43	1.23	7.32	2.02
Chaetodipterus faber	Atlantic spadefish		0.01			
Chilomycterus schoepfi	Striped burrfish	0.08				0.03
Chloroscombrus chrysurus	Atlantic bumper	3.85	2.50	6.76	10.24	0.69
Citharichthys spilopterus	Bay whiff				0.11	
Cynoscion regalis	Weakfish	2.70	2.46	0.10	1.43	0.02
Dasyatis americana	Southern stingray	0.04	0.00			0.10
Dasyatis sabina	Atlantic stingray	0.04	0.01			
Dasyatis say	Bluntnose stingray		0.01			
Echinoidea	Heart urchins		0.14	0.02	0.57	0.03
Etropus microstomus	Smallmouth flounder		0.00	0.12		0.04
Gymnura spp.	Butter rays	0.05	0.01			
Gymnura micrura	Smooth butterfly ray	0.18	0.12	0.13	0.05	0.13
Hepatus epheliticus	Calico box crab	0.09				0.02
Hyporhamphus unifasciatus	Silverstripe halfbeak		0.02			
Lagodon rhomboides	Pinfish			0.06	0.09	0.01
Larimus fasciatus	Banded drum	0.45	0.91	2.43	1.01	0.37
Leiostomus xanthurus	Spot	0.34	0.04	0.04	0.09	0.01
Libinia dubia	Longnose spider crab	2.26	0.24	0.12	0.16	0.19
Libinia emarginata	Portly spider crab					0.02
Membras martinica	Rough silverside		0.03			
Menippe mercenaria	Florida stone crab	0.12				
Menticirrhus americanus	Southern kingfish	1.84	1.05	5.50	0.73	2.05
Menticirrhus littoralis	Gulf kingfish					0.03
Menticirrhus saxatilis	Northern kingfish		0.02			
Micropogonias undulatus	Atlantic croaker	11.68	1.15	0.00	0.18	
Monacanthus hispidus	Planehead filefish		0.01			
Ophidion marginatum	Striped cusk eel				0.05	
Opisthonema oglinum	Atlantic thread herring		0.08	0.35	1.50	0.26
Orthopristis chrysoptera	Pigfish		0.01			
Ovalipes ocellatus	Lady crab	0.48	0.25	0.04	0.85	0.03
Ovalipes stephensoni	Coarsehand lady crab					0.01
Paguridae	Right handed hermit crabs	0.47	0.10	0.29	0.09	0.08
Paralichthys dentatus	Summer flounder	0.08	0.02		0.12	
Paralichthys lethostigma	Southern flounder	0.09	0.00			
Paralichthys oblongus	Fourspot flounder					0.03
Penaeus aztecus	Brown shrimp	7.94	1.17		0.89	0.02
Penaeus setiferus	Northern white shrimp		0.08	0.02		
Peprilus alepidotus	Harvestfish		0.08		0.06	
Peprilus triacanthus	Butterfish			0.06		
Persephona mediterranea	Mottled purse crab	0.05	0.01			
Polinices spp.	Moon snails	0.08				
Pomatomus saltatrix	Bluefish	0.12	0.01			

Table E-3. (Continued)						
		Summer %				
		Caswell Beach			Reference	
Scientific Name	**Common Name**	**Undisturbed**	**Disturbed**	**1-Year Later**	**Undisturbed**	**1-Year Later**
Portunus gibbesii	Iridescent swimming crab	0.17	0.07	0.02	0.19	0.05
Portunus sayi	Sargassum swimming crab		0.01	0.04		
Prionotus carolinus	Northern searobin	0.04	0.00		0.05	0.64
Prionotus evolans	Striped searobin	0.12	0.03		0.05	0.19
Prionotus scitulus	Leopard searobin		0.00		0.05	
Prionotus tribulus	Bighead searobin			0.04		0.03
Raja eglanteria	Clearnose skate				0.11	
Rhizoprionodon terraenovae	Atlantic sharpnose shark	0.04	0.04		0.03	0.03
Scomberomorus maculatus	Spanish mackerel		0.02			
Scophthalmus aquosus	Windowpane		0.01		0.32	
Selene setapinnis	Atlantic moonfish		0.05	0.08	0.06	0.01
Selene vomer	Lookdown	0.06	0.13	0.10	0.06	0.09
Sphoeroides maculatus	Northern puffer				0.06	0.01
Sphyraena barracuda	Great barracuda			0.07		
Stellifer lanceolatus	Starfishes	7.21	13.58		0.13	0.05
Stenotomus chrysops	Scup					0.05
Stomatopoda	Mantis shrimp		0.04		0.05	0.02
Symphurus plagiusa	Blackcheek tonguefish	0.76	0.25		0.16	
Syngnathus fuscus	Northern pipefish		0.00			
Synodus foetens	Inshore lizardfish					0.03
Trachinotus carolinus	Florida pompano		0.01			
Trinectes maculatus	Hogchoker	8.85	1.79	0.51	0.49	0.14
Xanthidae	Mud crabs		0.01		0.06	0.02
Mean Total Abundance (#/500m)		402	1869	696	359	1006
Total Number of Taxa		37	56	30	41	42

Table E-4. Total trawl catch (% occurrence) for Caswell Beach quarterly sampling									
		Fall 01		Winter 02		Spring 02		Summer 02	
Scientific Name	**Common Name**	**Caswell Beach**	**Reference**	**Caswell Beach**	**Reference**	**Caswell Beach**	**Reference**	**Caswell Beach**	**Reference**
Alosa aestivalis	Blue back herring				0.22				0.07
Alosa sapidissima	American shad				0.22				
Anchoa hepsetus	Striped anchovy	0.30	24.45		3.29	3.52	2.92	6.09	21.69
Anchoa mitchilli	Bay anchovy	96.38	16.53	14.55	45.86	66.59	89.30	74.03	70.30
Arenaeus cribrarius	Speckled swimming crab	0.00	0.69			0.37	0.02	1.70	0.39
Asteroidea	Star drum		0.26		0.20				
Astroscopus guttatus	Northern stargazer	0.00			0.22				
Bairdiella chrysoura	Silver perch							0.02	
Brevoortia tyrannus	Atlantic menhaden			1.19	0.26	0.04			0.01
Busycon carica	Knobbed whelk	0.01				0.12		0.02	
Busycotypus canaliculatus	Channeled whelk	0.00							
Callinectes danae	Dana swimming crab					0.02			
Callinectes sapidus	Blue crab	0.05		0.12	0.43	1.31	0.02		
Callinectes similis	Lesser blue crab	0.01		0.23		0.36	0.02	0.02	0.02
Cancer irroratus	Atlantic rock crab			0.30					
Centropristis striata	Black sea bass					0.03			
Cephalopoda	Squids	1.13	25.08	0.89	0.71	0.64	0.71	1.23	2.02
Chilomycterus schoepfi	Striped burrfish						0.04		0.03
Chloroscombrus chrysurus	Atlantic bumper	0.41	0.53					6.76	0.69
Citharichthys spilopterus	Bay whiff			0.08		0.15	0.05		
Crangon septemspinosa	Sand shrimp					1.64			
Cynoscion regalis	Weakfish	0.88		0.11		0.61		0.10	0.02
Dasyatis americana	Southern stingray					0.13	0.02		0.10
Dasyatis sabina	Atlantic stingray	0.00		0.99	0.65	0.04	0.02		
Echinoidea	Heart urchins							0.02	0.03
Etropus microstomus	Smallmouth flounder	0.00		1.30	0.41			0.12	0.04
Eucinostomus argenteus	Spotfin mojarra	0.00							
Gymnura spp.	Butter rays			0.12		0.93	0.85		
Gymnura micrura	Smooth butterfly ray	0.01	1.40			0.72	0.06	0.13	0.13
Hepatus epheliticus	Calico box crab								0.02
Hyporhamphus unifasciatus	Silverstripe halfbeak	0.00		0.15		0.41			
Hypsoblennius hentzi	Feather blenny					0.03			
Lagodon rhomboides	Pinfish	0.21	2.76	0.70	21.57	0.26	0.02	0.06	0.01
Larimus fasciatus	Banded drum	0.04	0.46	2.24		1.75	0.12	2.43	0.37
Leiostomus xanthurus	Spot	0.01	0.88	16.30	2.47	1.87	0.82	0.04	0.01
Libinia dubia	Longnose spider crab		0.85	0.04	1.24	1.75	0.87	0.12	0.19
Libinia emarginata	Portly spider crab	0.00	1.44	0.11	0.20		0.13		0.02
Limulus polyphemus	Horseshoe crab						0.02		
Membras martinica	Rough silverside	0.09							
Menippe mercenaria	Florida stone crab					0.05			
Menticirrhus americanus	Southern kingfish	0.01	0.90	1.88	1.14	3.56	0.18	5.50	2.05
Menticirrhus littoralis	Gulf kingfish	0.01		0.04	1.62	0.02			0.03

Table E-4. (Continued)

Scientific Name	Common Name	Fall 01		Winter 02		Spring 02		Summer 02	
		Caswell Beach	Reference	Caswell Beach	Reference	Caswell Beach	Reference	Caswell Beach	Reference
Menticirrhus saxatilis	Northern kingfish			0.28					
Micropogonias undulatus	Atlantic croaker	0.00	0.28	11.97	2.68	1.22			
Monacanthus hispidus	Planehead filefish	0.00	0.26			0.05	0.16		
Mustelus canis	Smooth dogfish						0.06		
Ophidion marginatum	Striped cusk eel			0.15		0.40	0.20		
Opisthonema oglinum	Atlantic thread herring							0.35	0.26
Opsanus tau	Oyster toadfish					0.05			
Ovalipes ocellatus	Lady crab	0.01	4.70	0.84	3.43	1.79	0.33	0.04	0.03
Ovalipes stephensoni	Coarsehand lady crab					0.17	0.06		0.01
Paguridae	Right handed hermit crabs	0.02	3.73	4.11	3.78	2.43	0.33	0.29	0.08
Paralichthys dentatus	Summer flounder	0.01	0.70	0.23	0.43	0.09			
Paralichthys lethostigma	Southern flounder	0.00		0.12		0.09			
Paralichthys oblongus	Fourspot flounder			0.15		0.03	0.13		0.03
Penaeus aztecus	Brown shrimp	0.01				1.16			0.02
Penaeus setiferus	Northern white shrimp	0.06	0.82	1.11	0.22	0.09		0.02	
Peprilus alepidotus	Harvestfish			0.15		0.02			
Peprilus triacanthus	Butterfish							0.06	
Persephona mediterranea	Mottled purse crab					0.02			
Pomatomus saltatrix	Bluefish	0.00	0.18			0.02			
Portunus gibbesii	Iridescent swimming crab		0.85	6.80	0.20	0.14	0.04	0.02	0.05
Portunus sayi	Sargassum swimming crab	0.02		0.45		0.39		0.04	
Prionotus carolinus	Northern searobin		0.22			0.32	0.52		0.64
Prionotus evolans	Striped searobin		0.28			0.20			0.19
Prionotus tribulus	Bighead searobin	0.00		0.22		0.62	0.02	0.04	0.03
Raja eglanteria	Clearnose skate	0.00	1.21			0.07	0.06		
Rhizoprionodon terraenovae	Atlantic sharpnose shark					0.02	0.02		0.03
Scomberomorus maculatus	Spanish mackerel	0.00							
Scophthalmus aquosus	Windowpane		1.22	0.38	1.20	0.29	0.43		
Selar crumenophthalmus	Bigeye scad						0.02		
Selene setapinnis	Atlantic moonfish	0.01				0.03		0.08	0.01
Selene vomer	Lookdown	0.00						0.10	0.09
Sphoeroides maculatus	Northern puffer					0.06	0.04		0.01
Sphyraena barracuda	Great barracuda							0.07	
Sphyraena guachancho	Guaguanche	0.03	0.18						
Stellifer lanceolatus	Starfishes	0.07		3.31		0.82			0.05
Stenotomus chrysops	Scup								0.05
Stomatopoda	Mantis shrimp					0.07			0.02
Symphurus plagiusa	Blackcheek tonguefish	0.05	0.28	1.84		0.05			
Syngnathus floridae	Dusky pipefish	0.00							
Syngnathus fuscus	Northern pipefish			0.31		0.11			
Synodus foetens	Inshore lizardfish		4.37				0.13		0.03
Trichiurus lepturus	Atlantic cutlassfish			0.21		0.02	0.02		

Table E-4. (Continued)

Scientific Name	Common Name	Fall 01		Winter 02		Spring 02		Summer 02	
		Caswell Beach	Reference	Caswell Beach	Reference	Caswell Beach	Reference	Caswell Beach	Reference
Trinectes maculatus	Hogchoker	0.11	3.98	2.11	0.41	2.18	0.17	0.51	0.14
Upeneus parvus	Dwarf goatfish				0.22				
Urophycis regia	Spotted hake			23.05	4.55	0.04	1.01		
Xanthidae	Mud crabs		0.48	0.88	2.14	0.04	0.09		0.02
Mean Total Abundance (#/500m)		23784	63	325	56	654	657	696	1006
Total Number of Taxa		43	30	40	28	59	39	29	42

Table E-5. Total trawl catch (% occurrence) for Oak Island							
		Fall %					
		Oak Island			Reference		
Scientific Name	Common Name	Undisturbed	Disturbed	1-Year Later	Undisturbed	1-Year Later
Anchoa hepsetus	Striped anchovy	22.73	18.55	23.76	35.59	
Anchoa mitchilli	Bay anchovy	43.14	63.53		1.51	
Arenaeus cribrarius	Speckled swimming crab	1.01	1.27	1.87	0.86	
Asteroidea	Star drum				0.44	
Astroscopus guttatus	Northern stargazer			1.87		
Brevoortia tyrannus	Atlantic menhaden	0.37	0.43	4.55		
Busycotypus canaliculatus	Channeled whelk	0.21				2.51
Callinectes sapidus	Blue crab	0.11	0.14			
Callinectes similis	Lesser blue crab	0.18	0.22			
Cephalopoda	Squids	0.35			36.76	
Chasmodes bosquianus	Striped blenny	0.11				
Chilomycterus schoepfi	Striped burrfish	0.08	0.11			
Chloroscombrus chrysurus	Atlantic bumper	2.09	3.52	3.88		
Crangon septemspinosa	Sand shrimp	0.27				
Dasyatis sabina	Atlantic stingray	0.08				
Echinoidea	Heart urchins	0.72	0.27			
Etropus microstomus	Smallmouth flounder	0.39	0.11	1.04		
Gymnura micrura	Smooth butterfly ray	3.53	0.28	8.82	2.34	2.80
Hepatus epheliticus	Calico box crab	0.08				
Lagodon rhomboides	Pinfish		0.22		0.60	
Larimus fasciatus	Banded drum	1.49	0.21	4.76		
Leiostomus xanthurus	Spot	0.53	0.21		0.30	
Libinia dubia	Longnose spider crab			2.14		
Libinia emarginata	Portly spider crab	0.08	0.11		2.41	
Menticirrhus americanus	Southern kingfish	3.41	1.19	40.67	1.51	84.09
Menticirrhus littoralis	Gulf kingfish		0.12			
Menticirrhus saxatilis	Northern kingfish	0.62	0.42			
Monacanthus hispidus	Planehead filefish	0.58			0.44	2.80
Mugil curema	White mullet	0.32	0.43			
Narcine brasiliensis	Lesser electric ray	0.11				
Ovalipes ocellatus	Lady crab	1.00	1.81		3.85	2.51
Paguridae	Right handed hermit crabs	1.19	1.16			
Paralichthys dentatus	Summer flounder	0.92	0.11		1.17	
Paralichthys lethostigma	Southern flounder	0.11	0.14			
Penaeus aztecus	Brown shrimp	0.08	0.11			
Penaeus setiferus	Northern white shrimp	2.68	1.75		0.43	
Persephona mediterranea	Mottled purse crab	0.08				
Pomatomus saltatrix	Bluefish		0.31		0.30	
Portunus sayi	Sargassum swimming crab	0.28	0.13			
Prionotus carolinus	Northern searobin				0.36	5.30
Prionotus evolans	Striped searobin	0.11				
Prionotus tribulus	Bighead searobin	0.42				
Raja eglanteria	Clearnose skate	0.11		2.38	1.43	
Scophthalmus aquosus	Windowpane	2.17	0.70		2.04	
Selene setapinnis	Atlantic moonfish	0.08	0.22			
Sphoeroides maculatus	Northern puffer	0.10				
Sphyraena guachancho	Guaguanche	0.28	0.44			
Stellifer lanceolatus	Starfishes		0.11			
Stomatopoda	Mantis shrimp	0.10				
Symphurus plagiusa	Blackcheek tonguefish	0.10				
Syngnathus fuscus	Northern pipefish	0.11				
Synodus foetens	Inshore lizardfish	3.19		0.07	7.31	
Trachinotus carolinus	Florida pompano	0.11	0.14			

Table E-5. (Continued)

Scientific Name	Common Name	Fall %				
		Oak Island			Reference	
		Undisturbed	Disturbed	1-Year Later	Undisturbed	1-Year Later
Trinectes maculatus	Hogchoker	4.08	1.52	4.18		
Xanthidae	Mud crabs	0.12			0.33	
Mean Total Abundance (#/500m)		94	105	6	50	17
Total Number of Taxa		47	33	13	20	6

Table E-6. Total trawl catch (% occurrence) for Oak Island quarterly sampling

Scientific Name	Common Name	Winter 02		Spring 02		Summer 02		Fall 02	
		Oak Island	Reference	Oak Island	Reference	Oak Island	Reference	Oak Island	Reference
Alosa aestivalis	Blue back herring					1.52	0.07		
Alosa pseudoharengus	Alewife	1.31							
Anchoa hepsetus	Striped anchovy			6.02	2.92	84.15	21.69	23.76	
Anchoa mitchilli	Bay anchovy	62.31	36.03	67.59	89.30	4.98	70.30		
Arenaeus cribrarius	Speckled swimming crab			0.64	0.02	0.59	0.39	1.87	
Astroscopus guttatus	Northern stargazer							1.87	
Astroscopus y-graecum	Southern stargazer					0.00			
Bivalvia	Clams					0.02			
Brevoortia tyrannus	Atlantic menhaden	0.69					0.01	4.55	
Busycotypus canaliculatus	Channeled whelk								2.51
Callinectes sapidus	Blue crab				0.02				
Callinectes similis	Lesser blue crab			0.32	0.02		0.02		
Cephalopoda	Squids	0.88		2.29	0.71	0.81	2.02		
Chilomycterus schoepfi	Striped burrfish				0.04		0.03		
Chloroscombrus chrysurus	Atlantic bumper					2.90	0.69	3.88	
Citharichthys spilopterus	Bay whiff			0.32	0.05				
Crangon septemspinosa	Sand shrimp					0.04			
Cynoscion regalis	Weakfish	0.58				0.21	0.02		
Dasyatis americana	Southern stingray	0.26		0.76	0.02	0.12	0.10		
Dasyatis sabina	Atlantic stingray			0.15	0.02				
Echinoidea	Heart urchins	0.26				0.16	0.03		
Etropus microstomus	Smallmouth flounder			0.48		0.08	0.04	1.04	
Eucinostomus gula	Silver jenny					0.02			
Gymnura spp.	Butter rays			2.76	0.85				
Gymnura altavela	Spiny butterfly ray				0.00				
Gymnura micrura	Smooth butterfly ray				0.06	0.16	0.13	8.82	2.80
Hepatus epheliticus	Calico box crab						0.02		
Lagodon rhomboides	Pinfish	19.14	20.54	0.62	0.02	0.04	0.01		
Larimus fasciatus	Banded drum				0.12	0.30	0.37	4.76	
Leiostomus xanthurus	Spot	0.58		1.75	0.82	0.04	0.01		
Libinia dubia	Longnose spider crab			3.16	0.87	0.83	0.19	2.14	
Libinia emarginata	Portly spider crab				0.13		0.02		
Limulus polyphemus	Horseshoe crab				0.02				
Menidia menidia	Atlantic silverside		26.06						
Menticirrhus americanus	Southern kingfish	1.02		3.56	0.18	0.97	2.05	40.67	84.09
Menticirrhus littoralis	Gulf kingfish	0.26	8.48			0.11	0.03		
Menticirrhus saxatilis	Northern kingfish		2.96						
Monacanthus hispidus	Planehead filefish	0.24		0.46	0.16	0.08			2.80
Mustelus canis	Smooth dogfish				0.06				
Ophidion marginatum	Striped cusk eel				0.20				
Opisthonema oglinum	Atlantic thread herring	2.25	2.96	0.29			0.26		
Ovalipes ocellatus	Lady crab	1.72		6.61	0.33		0.03		2.51

Table E-6. (Continued)

Scientific Name	Common Name	Winter 02		Spring 02		Summer 02		Fall 02	
		Oak Island	Reference	Oak Island	Reference	Oak Island	Reference	Oak Island	Reference
Ovalipes stephensoni	Coarsehand lady crab				0.06	0.02	0.01		
Paguridae	Right handed hermit crabs				0.33	0.31	0.08		
Paralichthys dentatus	Summer flounder	0.58		0.15		0.03			
Paralichthys oblongus	Fourspot flounder				0.13	0.03	0.03		
Penaeus aztecus	Brown shrimp						0.02		
Penaeus setiferus	Northern white shrimp	5.95							
Persephona mediterranea	Mottled purse crab					0.04			
Pomatomus saltatrix	Bluefish					0.02			
Portunus gibbesii	Iridescent swimming crab				0.04	0.06	0.05		
Portunus sayi	Sargassum swimming crab					0.04			
Prionotus carolinus	Northern searobin	0.15			0.52	0.55	0.64		5.30
Prionotus evolans	Striped searobin					0.06	0.19		
Prionotus tribulus	Bighead searobin				0.02		0.03		
Raja eglanteria	Clearnose skate			0.15	0.06			2.38	
Renilla mulleri	Sea pansy	0.26							
Rhizoprionodon terraenovae	Atlantic sharpnose shark			0.15	0.02	0.07	0.03		
Scophthalmus aquosus	Windowpane			1.43	0.43				
Selar crumenophthalmus	Bigeye scad				0.02				
Selene setapinnis	Atlantic moonfish						0.01		
Selene vomer	Lookdown					0.02	0.09		
Sphoeroides maculatus	Northern puffer			0.15	0.04	0.02	0.01		
Stellifer lanceolatus	Starfishes						0.05		
Stenotomus chrysops	Scup						0.05		
Stomatopoda	Mantis shrimp						0.02		
Synodus foetens	Inshore lizardfish				0.13	0.04	0.03	0.07	
Trichiurus lepturus	Atlantic cutlassfish				0.02				
Trinectes maculatus	Hogchoker	0.26		0.17	0.17	0.58	0.14	4.18	
Urophycis chuss	Red hake	1.07							
Urophycis regia	Spotted hake	0.26			1.01				
Xanthidae	Mud crabs		2.96		0.09		0.02		
Mean Total Abundance (#/500m)		6	17	89	657	642	1006	66	10
Total Number of Taxa		21	7	23	40	37	42	13	6

Table E-7. Total trawl catch (% occurrence) for Holden Beach						
		Winter %				
		Holden Beach			Reference	
Scientific Name	**Common Name**	**Undisturbed**	**Disturbed**	**1-Year Later**	**Undisturbed**	**1-Year Later**
Alosa aestivalis	Blue back herring				0.19	
Alosa sapidissima	American shad	0.20	0.87		0.19	
Anchoa hepsetus	Striped anchovy	56.51	5.94		5.73	
Anchoa mitchilli	Bay anchovy	34.42	55.98	44.17	42.03	36.03
Arenaeus cribrarius	Speckled swimming crab	0.16	0.06		0.16	
Astroscopus guttatus	Northern stargazer		0.17	0.53	0.19	
Brevoortia tyrannus	Atlantic menhaden	0.12	1.09		0.22	
Callinectes sapidus	Blue crab	0.02	0.18		0.36	
Cephalopoda	Squids	1.37	0.24		3.50	
Chloroscombrus chrysurus	Atlantic bumper	0.04			0.49	
Citharichthys spilopterus	Bay whiff	0.06				
Dasyatis americana	Southern stingray		0.12			
Dasyatis sabina	Atlantic stingray	0.02	3.07		0.37	
Echinoidea	Heart urchins	0.02	0.24			
Etropus microstomus	Smallmouth flounder		0.06			
Gymnura micrura	Smooth butterfly ray	0.09				
Lagodon rhomboides	Pinfish	1.43	9.69	0.62	19.83	20.54
Larimus fasciatus	Banded drum	0.02	0.06		0.43	
Leiostomus xanthurus	Spot	1.77	10.20		2.73	
Libinia dubia	Longnose spider crab		0.06		0.98	
Libinia emarginata	Portly spider crab		0.18			
Menidia menidia	Atlantic silverside		0.32	40.02		26.06
Menticirrhus americanus	Southern kingfish	0.47	1.18		0.79	
Menticirrhus littoralis	Gulf kingfish	0.10	1.43	2.15	1.36	8.48
Menticirrhus saxatilis	Northern kingfish					2.96
Micropogonias undulatus	Atlantic croaker			7.93	0.26	
Ophidion marginatum	Striped cusk eel	0.08				
Opisthonema oglinum	Atlantic thread herring					2.96
Ovalipes ocellatus	Lady crab	1.70	3.00		4.43	
Paguridae	Right handed hermit crabs	0.20	1.23	1.21	4.62	
Paralichthys dentatus	Summer flounder	0.06	0.06		0.19	
Paralichthys oblongus	Fourspot flounder		0.07			
Penaeus setiferus	Northern white shrimp	0.04	0.24	0.62	0.72	
Pomatomus saltatrix	Bluefish	0.04				
Portunus gibbesii	Iridescent swimming crab	0.41	0.84		0.79	
Portunus sayi	Sargassum swimming crab	0.02	0.12			
Prionotus carolinus	Northern searobin			0.49		
Prionotus evolans	Striped searobin	0.02			0.26	
Prionotus tribulus	Bighead searobin	0.02				
Raja eglanteria	Clearnose skate	0.10	0.12	0.51	0.33	
Scophthalmus aquosus	Windowpane		0.12		1.01	
Sphyraena guachancho	Guaguanche	0.02			0.16	
Stellifer lanceolatus	Starfishes		0.20			
Symphurus plagiusa	Blackcheek tonguefish				0.26	
Trinectes maculatus	Hogchoker	0.43	0.06		3.74	
Upeneus parvus	Dwarf goatfish				0.19	
Urophycis regia	Spotted hake	0.04	2.10	1.24	2.44	
Xanthidae	Mud crabs		0.71	0.51	1.03	2.96
Mean Total Abundance (#/500m)		483	76	27	67	10
Total Number of Taxa		31	33	12	32	7

Table E-8. Total trawl catch (% occurrence) for Holden Beach quarterly sampling

Scientific Name	Common Name	Spring 02		Summer 02		Fall 02		Winter 03	
		Holden Beach	Reference	Holden Beach	Reference	Holden Beach	Reference	Holden Beach	Reference
Alosa aestivalis	Blue back herring				0.07				
Anchoa hepsetus	Striped anchovy	2.22	2.92	2.05	21.69	41.31			
Anchoa mitchilli	Bay anchovy	0.35	89.30	87.06	70.30	19.51		44.17	36.03
Arenaeus cribrarius	Speckled swimming crab	0.35	0.02	0.46	0.39	2.43			
Astroscopus guttatus	Northern stargazer							0.53	
Bairdiella chrysoura	Silver perch			0.01		0.40			
Brevoortia tyrannus	Atlantic menhaden				0.01				
Busycon carica	Knobbed whelk	0.16		0.01					
Busycotypus canaliculatus	Channeled whelk						2.51		
Callinectes sapidus	Blue crab	0.52	0.02						
Callinectes similis	Lesser blue crab	0.87	0.02		0.02				
Caranx hippos	Crevalle jack			0.02					
Cephalopoda	Squids	1.00	0.71	2.25	2.02	0.10			
Chilomycterus schoepfi	Striped burrfish		0.04		0.03				
Chloroscombrus chrysurus	Atlantic bumper			1.21	0.69				
Citharichthys spilopterus	Bay whiff		0.05						
Cynoscion regalis	Weakfish			0.01	0.02	0.61			
Dasyatis americana	Southern stingray	1.23	0.02	0.06	0.10				
Dasyatis sabina	Atlantic stingray		0.02						
Echinoidea	Heart urchins	0.34			0.03				
Etropus microstomus	Smallmouth flounder				0.04				
Gymnura spp.	Butter rays		0.85						
Gymnura micrura	Smooth butterfly ray	0.35	0.06	0.24	0.13	0.40	2.80		
Hepatus epheliticus	Calico box crab				0.02				
Lagodon rhomboides	Pinfish	0.35	0.02	0.01	0.01			0.62	20.54
Larimus fasciatus	Banded drum		0.12	0.44	0.37	9.96			
Leiostomus xanthurus	Spot	2.04	0.82	0.05	0.01				
Libinia dubia	Longnose spider crab	1.20	0.87	0.03	0.19				
Libinia emarginata	Portly spider crab	0.35	0.13		0.02				
Limulus polyphemus	Horseshoe crab		0.02						
Menidia menidia	Atlantic silverside							40.02	26.06
Menippe mercenaria	Florida stone crab	0.53							
Menticirrhus americanus	Southern kingfish	3.27	0.18	1.88	2.05	13.07	84.09		
Menticirrhus littoralis	Gulf kingfish				0.03			2.15	8.48
Menticirrhus saxatilis	Northern kingfish								2.96
Micropogonias undulatus	Atlantic croaker							7.93	
Monacanthus hispidus	Planehead filefish	0.34	0.16				2.80		
Mustelus canis	Smooth dogfish		0.06						
Ophidion marginatum	Striped cusk eel		0.20						
Opisthonema oglinum	Atlantic thread herring			0.26	0.26				2.96
Ovalipes ocellatus	Lady crab	0.17	0.33	0.03	0.03		2.51		
Ovalipes stephensoni	Coarsehand lady crab		0.06		0.01				

Table E-8. (Continued)

Scientific Name	Common Name	Spring 02		Summer 02		Fall 02		Winter 03	
		Holden Beach	Reference	Holden Beach	Reference	Holden Beach	Reference	Holden Beach	Reference
Paguridae	Right handed hermit crabs	63.75	0.33	0.02	0.08	0.40		1.21	
Paralichthys dentatus	Summer flounder	0.17		0.04		0.39			
Paralichthys oblongus	Fourspot flounder	1.37	0.13		0.03				
Penaeus aztecus	Brown shrimp			0.01	0.02				
Penaeus setiferus	Northern white shrimp			0.11		9.44		0.62	
Peprilus alepidotus	Harvestfish			0.01					
Portunus gibbesii	Iridescent swimming crab		0.04		0.05				
Prionotus carolinus	Northern searobin	9.54	0.52	0.08	0.64		5.30	0.49	
Prionotus evolans	Striped searobin			0.03	0.19				
Prionotus tribulus	Bighead searobin	0.18	0.02		0.03				
Raja eglanteria	Clearnose skate	0.17	0.06					0.51	
Rhizoprionodon terraenovae	Atlantic sharpnose shark		0.02		0.03				
Scophthalmus aquosus	Windowpane	2.92	0.43	0.01					
Selar crumenophthalmus	Bigeye scad		0.02						
Selene setapinnis	Atlantic moonfish				0.01				
Selene vomer	Lookdown			0.01	0.09				
Sphoeroides maculatus	Northern puffer	2.96	0.04	0.02	0.01				
Sphyraena barracuda	Great barracuda			0.09					
Sphyraena guachancho	Guaguanche	0.17							
Stellifer lanceolatus	Starfishes			0.73	0.05				
Stenotomus chrysops	Scup				0.05				
Stomatopoda	Mantis shrimp			0.01	0.02				
Syngnathus floridae	Dusky pipefish	0.17							
Synodus foetens	Inshore lizardfish	0.51	0.13	0.07	0.03	1.99			
Trachinotus carolinus	Florida pompano			0.09					
Trichiurus lepturus	Atlantic cutlassfish		0.02						
Trinectes maculatus	Hogchoker	0.17	0.17	2.53	0.14				
Urophycis regia	Spotted hake		1.01					1.24	
Xanthidae	Mud crabs	2.28	0.09		0.02			0.51	2.96
Mean Total Abundance (#/500m)		942	1006	31	17	27	10	65	657
Total Number of Taxa		31	40	34	42	14	6	12	7