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Modern Variation in Predation Intensity: Constraints on Assessing Predator-Prey Relationships in Paleoecologic Reconstructions

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Modern Variation in Predation Intensity:

Constraints on Assessing Predator-Prey Relationships

in Paleoecologic Reconstructions

by

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of the requirements for the degree of
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ABSTRACT

The complex interaction between predators and their prey is rarely preserved in the fossil record. However, predation of marine mollusks by drilling gastropods leaves a diagnostic hole in the shell of the prey, possibly allowing for quantitative analysis of this ecological interaction. Drilling frequency, as measured in marine mollusks both in the Modern and fossil record, has been heralded as a potential opportunity to quantify these ecological interactions and use these values in the testing of hypotheses.

This study employed the collection, tallying, and analysis of bulk samples derived from shelly deposits on 45 Modern beaches along the contiguous coast of the southeast United States (Virginia Beach, VA to Port Isabella, TX). The tallying scheme allowed for pooling and reduction of the data to compare drilling frequencies at several taxonomic and geographic scales. In addition, multivariate clustering analyses was used to generate groups of similar taxonomic abundances for direct comparison.

Understanding potential spatial variation in the natural environment is paramount to using quantified values of drilling frequency in temporal and spatial studies in the fossil record. Calculated drilling frequencies for bulk (location) samples ranged from 0 to over 100%. Similar ranges of drilling frequency were observed in more finely defined taxonomic groups. Calculated drilling frequency was higher in the Carolinian province

as compared to the Gulf-Louisianian and Virginian provinces. No correlation between drilling frequency and latitude was observed at any scale. An area of substantially increased drilling frequency was observed along the Carolina coast, at the ecotone between the Carolinian and Virginian provinces, suggesting that some environmental condition is present and responsible for the local increase in drilling frequency.

Finally, little attention has been paid to sampling techniques and their subsequent impact on the analysis of drilling frequency. As the bulk samples represent aggregate accumulations of shells from a myriad of environments, this introduces pronounced variation in the analysis that has not been previously accounted for. Statistically, much larger abundances of specimens in individual taxa, approaching 450 values for bivalves, are needed to effectively constrain this variability.

CHAPTER ONE

INTRODUCTION

Predation has been identified as one of the most important factors resulting in a cadre of long-term evolutionary morphologic trends in marine organisms (e.g., Vermeij, 1987). A concept developed from this notion is the hypothesis of escalation. Escalation, or the concurrent development of expressed adaptations to cope with increasing risks to individuals (prey) from predators and subsequently the predators' adaptations to increasing defense mechanisms, has been documented as a dominant force in the evolution of life (Vermeij, 1987). Specifically focused on marine mollusks and brachiopods, adaptive measures attributed to escalation have included changes in shell ornamentation, armoring, and thickness (e.g., Vermeij, 1987; Dietl and Kelley, 2002; Baumiller and Bambach, 2005; Baumiller et al., 2006). One of the important sources of information on predator-prey interactions are the drill holes left by predatory gastropods. They provide a rare and distinctive window into the interaction between marine mollusks – potentially allowing for quantitative and objective measurement of the escalative interplay between predators and their prey.

Vermeij (1987) argues that predation, hence escalation, "may rank as a close second to competition [in the ranking of selective agencies] (p. 24)" and expressed that evaluation of the escalation hypothesis required identifying *and measuring* an individual's "effectiveness" of surviving ubiquitous predatory pressures. One of the measures suggested by Vermeij to test the escalation hypothesis is the documentation of

drilling predation by a subset of gastropod clades (i.e., drilling or boring gastropods) on molluscs and brachiopods both in the fossil record and in the Modern.

Numerous studies have been conducted testing these temporal relationships employing quantitative analysis of drill holes (e.g., Kowalewski et al., 1998; Dudley and Vermeij, 1987; Vermeij, 1980; Allmon, et al., 1990; Kelley and Hansen, 1993, 1996, 2006; Kelley et al., 1999; Amano, 2006). However, spatial variability of gastropod drilling frequency (and predation for that matter) is poorly understood – and represents only one of a myriad of variables that can confound temporal analyses. Vermeij (1980, p. 334) illuminates the crux of this issue in the statement: "Variation in predation intensity is likely to be the rule rather than the exception… and must be taken into account in the search for geographical and temporal patterns of predation."

Latitudinal variation in drilling frequency has been widely discussed. Drawing on the previous works of Vermeij and Dudley (1982) and Taylor and Taylor (1977), Vermeij (1987, p. 172) concluded that the frequency of predation has a greater influence towards the lower latitudes as the drilling predators become more "strikingly" diverse. Following the impetus set forth by Vermeij (1980) and others, the primary focus of this study is to investigate spatial variation in drilling predation in shell assemblages from Modern beaches.

Specifically, using assemblage and lower taxonomic groups, this study will test the hypothesis that predation intensity, employing the frequency of drill holes as a proxy for this measure, increases towards the tropics (lower latitudes) by comparing drilling predation along an individual, isochronous time plane defined by the Modern for bulk samples and single abundant taxa contained in the aggregate samples. This investigation

employs a geographically widespread data set with an increased sampling (location) intensity as compared to previous studies, especially those examining the fossil record. Analyzing data from the Modern provides a relative unlimited opportunity to sample accumulations of shells. Previous studies have been hindered by the inability to sample more broadly in the rock record due to issues involving extent of outcrop exposure and accessibility. For example, original studies devoted to documenting possible geographic variation by Dudley and Vermeij (1978) concluded that a latitudinal "trend" existed by combining or pooling data for temperate (DF = 11% for 447 specimens) and tropical-subtropical (DF = 32% for 633 specimens) locations (thus providing only two aggregate measurements). Subsequent studies have also been limited in sample locations. Allmon et al. (1990) compared drilling frequencies between limited (and pooled) data sets from the Paleocene, using data from the Aquia Formation of Maryland as well as the Tuscahoma and Nanafalia formations of Alabama. They concluded that species found in the lower latitudes have lower rates of drilling. Hoffmeister and Kowalewski (2001) compared bulk samples originally collected from locations in central Europe, concluding that significant variation in drilling frequency was observed among the samples.

Additionally, the data investigated herein are further analyzed in a fashion that differs from previous workers by clustering the data *via* similarity (multivariate) analysis to associate samples with similar taxonomic abundances. This analysis is performed to provide a comparison of individual samples that likely represent similar environmental conditions (e.g., common biotic assemblages), as possibly drilling frequencies would be less variable within the same or similar ecologic conditions. This analysis may reduce some of the inherent noise associated with comparing samples from different

environmental settings. Cluster analysis has been used successfully to delineate assemblages using abundance data (e.g., Daley, et al., 2007), and the results, as applied here, should provide sample locations of similar taxonomic abundance.

Additionally, sampling and research techniques are scrutinized to determine potential limitations to current research methods. Some rough consistency is present in the studies of predation (e.g., drill holes are counted – resulting in at least an apparent measurement of frequency or intensity), but most studies employ variable means of acquiring these tallied measurements. Those studies generally have been performed on aggregate or pooled sample sets from field collections, museum collections, and formerly published references.

Finally, this study provides important implications relative to the generation of scientifically valid predator-prey relationship metrics using samples derived from the fossil record. A stronger understanding of variation in the record generated by both environmentally controlled variables and inherent limitations present in approaches to data analysis in conjunction with sampling issues is required prior to effectively assessing the questions addressed in this study.

Overview of the History and Nature of Drilling Gastropods

Drilling gastropods appear to have radiated in the Early to mid-Cretaceous (Sohl, 1969), although evidence of 'modern' gastropod drilling has been suggested as early as the Late Triassic (Fürsich and Jablonski, 1984). Several authors have suggested that earlier records of drilling predation exist (Bengston and Zhao, 1992; Baumiller 1996; Kowalewski et al., 1998), but the nature of these scars have been debated (e.g., Carriker and Yochelson, 1968; Harper et al., 1999; Wilson and Palmer, 2001). In general, most studies have suggested that drilling predation has became more pronounced in the Late Cretaceous and early Cenozoic, but established a relatively consistent maximum value of drilling frequency in the Late Cenozoic (e.g., Kowalewski et al., 1998; Kelley and Hansen, 1993, 1996, 2006; Kelley et al., 1999).

Drill holes found in marine post-Paleozoic gastropods and bivalves are primarily the result of predation by two gastropods families, Naticidae and Muricidae, although several other drilling predators have been identified, including octopods and annelids (for general discussions see Bengston 2002; Kowalewski, 1993; Kowalewski 2002). Furthermore, there remains a significant debate over the ability to identify which gastropod group was responsible for a given drillhole. Most earlier work assigned parabolic (*Oichnus parabolides*) and cylindrical (*O. simplex*) drill-hole morphologies to naticid and muricid boring gastropod predators, respectively. It was later shown that identification based on morphology of the predatory drillholes was problematic (Grey et al., 2005; Dietl and Kelley, 2006), but that identification of the predator responsible for the trace could be based on the location (G. Herbert, pers. comm., 2009).

Previous Work

Two primary approaches have been employed to compare drilling predation in marine mollusks. Most studies have examined data compiled at the assemblage level from sample sets recovered from either museum collections or bulk samples from outcrop locations (e.g., Hansen and Kelley, 1993, 1996; Kelley et al. 1999). Others have looked solely at extant lower taxonomic groups (e.g., Allmon et al., 1990). In general, binomial (drilled versus non-drilled) frequency data are often derived from single geographic localities or museum collections (whether for aggregate samples or restricted to a narrow taxonomic group). Where regional (or provincial) drilling frequencies are desired, the sample sets are pooled into coarser aggregate sample sets.

Spatial variation in predation and drilling frequency has been investigated by several workers in the fossil record. Most research appears to be rooted in initial research on Modern drilled bivalves in Guam made by Vermeij (1980). In that study, drilling frequencies were reported to range from between 0 to 75 percent between (measured at the species-location level) samples. Significant variation was observed within both local and larger (regional) geographic scales.

Hansen and Kelley (1995) examined drilling frequencies from two intervals of the Atlantic and Gulf Coastal Plain deposits (Eocene Cook Mountain and late Eocene Moodys Branch/Yazoo Formation intervals), concluding that considerable variation not only existed between Atlantic and Gulf deposits, but between samples locations within the paleogeographic locations themselves. They reported drilling intensities ranging from 6.8% to 38.7% and 4.0% to 21.9% in the Cook Mountain and Moodys Branch/Yazoo samples, respectively. Analysis of the samples contained in the Cook

Mountain interval showed a higher drilling frequency between pooled samples of Virginia as compared to pooled samples from the Gulf Coast.

Hoffmeister and Kowalewski (2001) documented apparently random drilling frequencies at local and regional scales in 17 bulk samples collected from two Miocene provinces (reported in the study as the Boreal and Paratethys realms). Significant variation was observed locally, regionally, and between different facies (clayey versus sandy substrates). Furthermore, depending on the methods used to combine data sets across facies or provinces, the authors found that variations between locations were either inflated or cloaked when the samples were combined or pooled in coarser analytical groupings, leading to their conclusion that: "[t]he spatial variation in the fossil record of all relevant predation parameters should be evaluated independently, and controlled for, before any large-scale temporal trends are inferred (p. 566)."

Baumiller and Bitner (2004) researched middle Miocene brachiopods and reported a significant variation in pooled drilling frequencies between three Polish localities ranging from 2.0% to 39.9%. Drilling frequencies among the individual species ranged from 0.0% to 47.9%. The authors were unable to explain the spatial variability between the three locations, but did suggest that the samples were derived from two distinctly different paleoenvironments (shallow-water, algal-vermetid reef versus deep-water fore reef).

CHAPTER TWO

MATERIALS AND METHODS

This study included the collection and determination of bivalve and gastropod abundances from 47 samples collected from 45 Modern beaches in the United States along the Atlantic Ocean and Gulf of Mexico (Fig. 1). Bulk samples were collected from accessible portions of the contiguous coastline from Rudee Inlet (Virginia Beach, Virginia) to Brazos Inlet State Park (Port Isabella, Texas). The initial sampling strategy targeted collecting samples along the coastline at approximate 60 to 80 km intervals. However, inaccessibility of specific localities as well as the lack of significant shelly deposits locally limited collection efforts. Replicate samples were collected from Honeymoon Island, Florida to assess variation in a single locality and also to examine the current sampling strategies employed by researchers. Samples were collected between the dates of October 23, 1999 to November 29, 2000 by the author; collection dates are listed in the Appendix along with each sample location data summary.

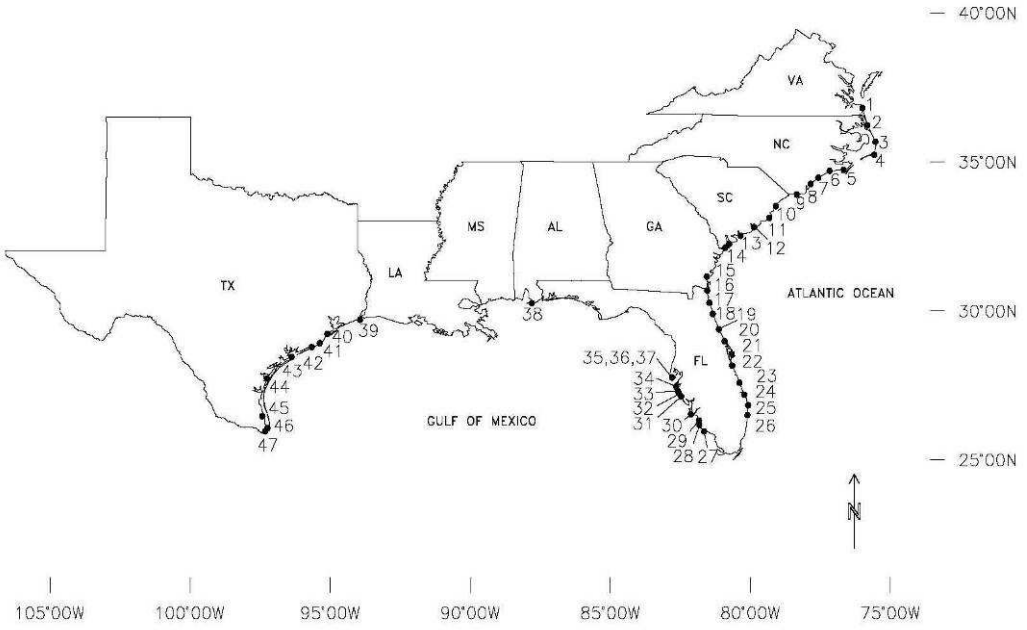

Figure 1. Map of study area. Numbers refer to sample locations, which are listed in Table 1 and in the Appendix.

Collection

Two different sampling strategies were employed, depending on the abundance and distribution of shells on the beach. The intent of both sampling strategies was to mimic "direct bulk sampling" techniques described by Kowalewski (2002) that have been applied to analyses garnered from outcrops (e.g., Hansen and Kelley, 1995; Kelley, et. al, 1999; Hoffmeister and Kowalewski, 2001).

If shells were relatively sparse on the beach (generally n = <10/m^2 in any area of the beach), an area large enough to yield a sample size of at least 50 whole shells was circumscribed with a shovel and specimens were collected manually. In general, when this approach was used an area of approximately 10 to 20 m^2 was required at most locations. Care was exercised to ensure all available specimens were collected in the delineated area, and this sampling technique allowed for presorting of whole shells from the broken ones. During manual collection methods, only those shells that were visible were collected – no effort was made to expose or collect any buried shell material.

In areas with significant shell accumulations, bulk samples of shells and sediment were first collected from an accessible location on the beach and then wet-sieved through a 4-mm sieve in the swash zone. Kowalewski and Hoffmeister (2003) and Bush, et al. (2007) found little variation in abundance of proportion of specimens and drilling frequency with mesh sizes greater than 4 mm using similar sampling techniques. This sampling technique resulted in the collection of both whole shells and a considerable amount of shell fragments; these entire collections were transported to the laboratory for sorting and counting. Approximately 7 liters of shell and shell fragments were collected for each locality.

Latitude and longitude for each collection site was recorded using a handheld Global Positioning Device (GPS) or was estimated using the USGS National Mapping Information website (http://geonames.usgs.gov) and available maps of the collection areas.

Sorting and Data Processing

Samples were first sorted into whole shells and shell fragments. For the purposes of this study, only whole shells were included in the final tally. Prior to discarding any fragments, they were first observed for preferential breakage along existing drill holes to determine if potential bias may be present in the data supplied by entire shells. Roy, et al. (1994) suggested a potential for bias in the data associated with preferential breakage of the valves through the borehole, although this style of preferential breakage was not typically observed in the samples used in this study.

Shells were then sorted by species and identified using several available resources (e.g., Rehder, 1997; Porter and Houser, 1997). Summaries for gastropods included total specimens and total drilled. Summaries for bivalves included total left and right valves and total drilled distinguished by valve. Although infrequent, edge drills and multiple drill holes were combined with total drilling if present. As discussed above, numerous studies have centered focused on the distinction between naticid and muricid drill hole morphology. For the purposes of this study, distinction was not made between parabolic and straight-edge drill holes nor was stereotypy used to differentiate between these groups.

Within this study, drilling frequency (DF) was calculated at species, familial, class (Bivalvia or Gastropoda), assemblage (all mollusks), and province levels. Drilling frequency (DF_{LTF} or Lower Taxon Frequency) was calculated for each species, family, and class within the sample and Drilling Frequency (D_{AF} or Assemblage Frequency) was calculated for the assemblage and province levels. Kowalewski (2002) extensively

discussed analytical methods commonly used in predation studies, and the equation for each of these variables is provided below:

$$DF_{LTF} = D_{TAXON}/N_{TAXON} \quad \text{(Eq. 1)}$$

$$DF_{AF} = \sum D_{TAXON}/\sum N_{TAXON} \quad \text{(Eq. 2)}$$

where D_{TAXON} = number of individuals drilled and N_{TAXON} = the total number of individuals. For gastropods, the number of individuals is equivalent to the total number of counted whole shells. For bivalves, which were generally found disarticulated, an adjustment is made to the equation where a conservative estimate of the number of individuals (or organisms) is calculated as half the valves counted and is given by the equation:

$$N_{TAXON\text{-}BIVALVE} = 0.5\ n_{TAXON} \quad \text{(Eq. 3)}$$

where N_{TAXON} = the total number of valves within the given taxonomic level (specifically, for this study, right + left valves). The bivalve input used in the relative abundance calculations were also adjusted using the same approach.

Data were initially compiled for each sample site separately, but were then pooled to create province-level data. The following provinces were delineated largely following the designations of Engle and Summers (2000): 1) Gulf-Louisianian (Rio Grande River, Texas to Port Charlotte, Florida); 2) Carolinian (Jupiter, Florida to Cape Hatteras, North Carolina; hypothesized to be a transitional area between Caribbean and Virginian provinces); and 3) Virginian (Cape Hatteras north to Cape Cod).

Engels and Summers (2000) also delineated south Florida as the northern extent of the Tropical or Caribbean biogeographic province. This small area within the study area

appears to be bound along Florida's coastline by Cape Romano, Florida (south of Marco Island) to the northwest and the westerly jog of the eastern coastline at Jupiter, Florida to the northeast. Samples were not collected within this region for this study.

Multivariate (Cluster) Analysis

In an attempt to possibly reduce error associated with varying environmental controls, groups or clusters of samples with similar abundance composition were generated using Euclidian statistical techniques. A cluster diagram (dendogram) was generated using the relative abundance data for each locality using Bray-Curtis similarity coefficients generated by PAST® (Paleontological Statistics) software package (Hammer, et al., 2001). Separate clusters, or groups, were identified at higher similarity coefficients (generally greater than a similarity of approximately 60%). The results of this phase of the study were used to identify abundance patterns in the samples in order to isolate environmental variables which may add to the complexity of assemblage-level comparisons. Assemblages with greater than 60% similarity were assigned community names (e.g., *Mulinia* community) with the most abundant species listed first (following Colbath, 1985).

CHAPTER THREE

RESULTS

Species-level data were tallied for each location, and these data were later used to compile aggregate metrics, including results at the provincial, assemblage (locality), and familial levels. The tally sheets are included in the Appendix. 22,745 specimens were counted and included in this study. The sampled shell assemblages provided organisms from a myriad of environments, including freshwater/estuarine, brackish, back-barrier or bay, shallow nearshore, and inter-tidal zones. Samples commonly included organisms typically found living in fresh- or brackish-water environments (e.g., *Rangia cuneata, Mulinia sp*., and *Crassostrea virginica*) mixed with those found in shallow (grass flat), open, or inter-tidal marine settings (e.g., *Chione elevata, Plicatula gibbosa*, and *Donax variabilis*).

Bivalves accounted for a majority of the samples for most localities (22,188 specimens of 22,745 total or 97.6%). The bivalve genera *Chione*, *Anadara, Donax,* and *Mulinia* were the most commonly sampled and accounted for 23.1%, 17.0%, 16.8%, and 14.3% of the total individuals collected, respectively (aggregate of 71.2%). Lesser, but still numerically important, numbers of *Noetia, Tellina,* and *Rangia* were also common.

Gastropods were generally relatively rare with the exception of specific locations along the Gulf of Mexico and two locations along the southeast coast of Florida (Jupiter Island and Hutchinson Island), and were represented by 17 different gastropod families and 20 genera. Included in the limited number of gastropod specimens (557 total

individuals in the study) were 440 specimens (79.0%) of the genus *Crepidula* (primarily *C. plana* and *C. fornucata*). Ironically, specimens of drilling gastropods were rarely observed in the sample sets; they were only present in nine of the 45 sample sets containing a total of 18 drilling gastropod specimens. Due to the limited number of gastopods present in the data set, comparisons of drilling frequency are not conducted for gastropods. The gastropod data, however, are included in the calculations of drilling frequency for total fauna (assemblage) and provincial metrics to retain consistency with previous studies.

Province Level Drilling Frequency

Pooled provincial drilling frequencies are presented in Table 2. Drilling frequencies were relatively similar in the Virginian and Gulf provinces (14.0% and 16.1%, respectively), but higher in the Carolinian province (32.4%). Three outliers with substantially higher drilling frequencies were sampled along the Carolina coast. Removing these three outliers, the drilling frequency for the Carolinian province (17.7%) is closer to the calculated pooled drilling frequencies for the Virginian and Gulf provinces.

Table 1. Province summaries of drilling frequencies for bivalves, gastropods, and total fauna.

Province	Number of Specimens			Drilling Frequency	
	Bivalve	Gastropod	Total	Total	Bivalve
Virginian	1012	7	1019	14.0%	14.0%
Carolinian	9502	302	9804	28.7%	30.5%
Gulf-Louisianan	11674	248	11922	16.1%	16.7%

Assemblage Level Drilling Frequency

At the assemblage level (all mollusks for each location), bulk sample drilling frequency ranged from 0.0% (Gulf Shores, AL) to 120.6% (North Folly Beach, SC) (Table 1). Three outliers were identified with substantially higher drilling frequencies than the other localities: North Folly Beach, South Carolina (120.6%); Hilton Head, South Carolina (86.3%); and Ocean Isle Beach, North Carolina (63.1%). Excluding the three outliers discussed above, values for single sample location drilling frequency appears to be distributed around a mean of 16.6 ± 9.8% and a median of 14.8% (Fig. 2). The shape of the distribution appears to be lognormal (which is slightly right or positively skewed). Most, representing 30 of 47 localities, assemblage-level drilling frequencies ranged between 5% and 25%. Drilling frequency is plotted against latitude in Figure 3. Trend lines have been added for both the entire data set (black) and the entire data set less the three outliers from North Folly Beach, Hilton Head, and Ocean Isle (red).

Table 2. Summary assemblage abundance and drilling frequency for each location.

Province	Location	Latitude	Number of Specimens			Drilling Frequency	
			Bivalve	Gastropod	Total	Total	Bivalve
Virginian	1 - Rudee Inlet, VA	36.73	607	6	613	7.4%	7.6%
	2 - Corolla Beach, NC	36.38	121	0	121	34.7%	34.7%
	3 - Nags Head, NC	35.97	143	0	143	25.2%	25.2%
	4 - Cape Hatteras, NC	35.30	141	1	142	14.0%	12.8%
Carolinian	5 - Atlantic Beach, NC	34.70	140	3	143	13.7%	14.3%
	6 - Emerald Isle, NC	34.68	304	0	304	19.1%	19.1%
	7 - Wrightsville Beach, NC	34.21	280	0	280	6.4%	6.4%
	8 - Carolina Beach, NC	34.08	233	0	233	19.7%	19.7%
	9 - Ocean Isle Bch, NC	33.87	723	8	731	63.1%	64.5%
	10 - Myrtle Beach, SC	33.66	332	14	346	9.4%	10.2%
	11 - Litchfield Beach, SC	33.45	373	9	382	10.7%	10.7%
	12 - N Folly Beach, SC	32.66	465	3	468	120.6%	122.2%
	13 - Edisto Beach, SC	32.50	271	14	285	19.4%	21.4%
	14 - Hilton Head, SC	32.15	559	9	568	86.3%	88.0%
	15 - St. Simmons Island, GA	31.22	277	6	283	27.0%	28.2%
	16 - Ferdnandia Bch, FL	30.67	309	9	318	19.0%	20.1%
	17 - Guana State Park, FL	30.06	1087	3	1090	11.5%	11.6%
	18 - Palm Coast, FL	29.58	831	2	833	18.0%	18.1%
	19 - Ormond by the Sea, FL	29.28	445	0	445	24.7%	24.7%
	20 - Eldora, FL	28.91	309	1	310	26.4%	26.5%
	21 - Canaveral Beach, FL	28.68	864	1	865	18.7%	18.8%
	22 - Cocoa Beach, FL	28.19	479	94	573	24.0%	33.4%
	23 - Floridana Beach, FL	27.93	110	1	111	1.8%	1.8%
	24 – Sebastian Inlet , FL	27.85	276	1	277	22.30%	22.46%
	25 - Hutchinson Island, FL	27.28	354	57	411	12.0%	15.8%
	26 - Jupiter Island, FL	27.03	757	68	825	12.5%	14.8%
Gulf-Louisianan	27 - Marco Island, FL	25.94	892	3	895	6.7%	6.7%
	28 - Naples, FL	26.25	649	15	664	28.3%	29.6%
	29 - Bonita Beach, FL	26.35	416	0	416	7.2%	7.2%
	30 - Sanibel Island, FL	26.43	762	20	782	4.5%	4.7%
	31 - Venice Beach, FL	27.08	938	3	941	17.2%	17.3%
	32 - Longboat Key, FL	27.39	801	25	826	10.3%	11.0%
	33 - Anna Maria Island, FL	27.50	866	7	873	32.0%	32.6%
	34 - Lido Beach, FL	27.72	625	19	644	6.3%	6.7%
	35 - Honeymoon Island1, FL	28.07	308	22	330	5.1%	5.8%
	36 - Honeymoon Island2, FL	28.07	419	23	442	9.5%	10.5%
	37 - Honeymoon Island3, FL	28.07	319	26	345	9.7%	11.3%
	38 - Gulfshores, AL	30.25	156	0	156	0.0%	0.0%
	39 - Sabine Pass, TX	29.38	485	11	496	15.4%	16.1%
	40 - Surfside Beach, TX	28.94	774	0	774	15.8%	15.8%
	41 - Port Bolivar, TX	29.38	660	0	660	36.7%	36.7%
	42 - Hog Island, TX	28.60	498	12	510	14.2%	14.5%
	43 - Port O' Connor, TX	28.43	52	0	52	11.5%	11.5%
	44 - Port Aransas, TX	27.73	582	5	587	4.7%	4.8%
	45 - Mustang Island, TX	27.68	291	56	347	11.4%	14.4%
	46 - Padre Island, TX	26.10	624	0	624	39.4%	39.4%
	47 - Brazos Inlet, TX	26.07	557	1	558	22.9%	23.0%

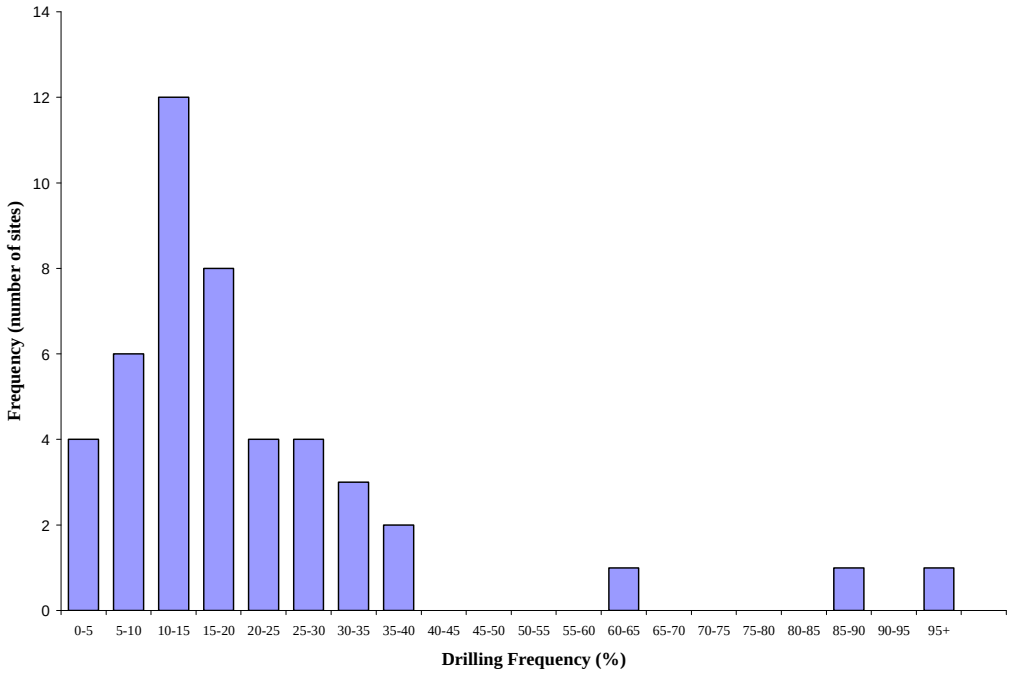

Figure 2. Histogram of assemblage drilling frequency for all locations.

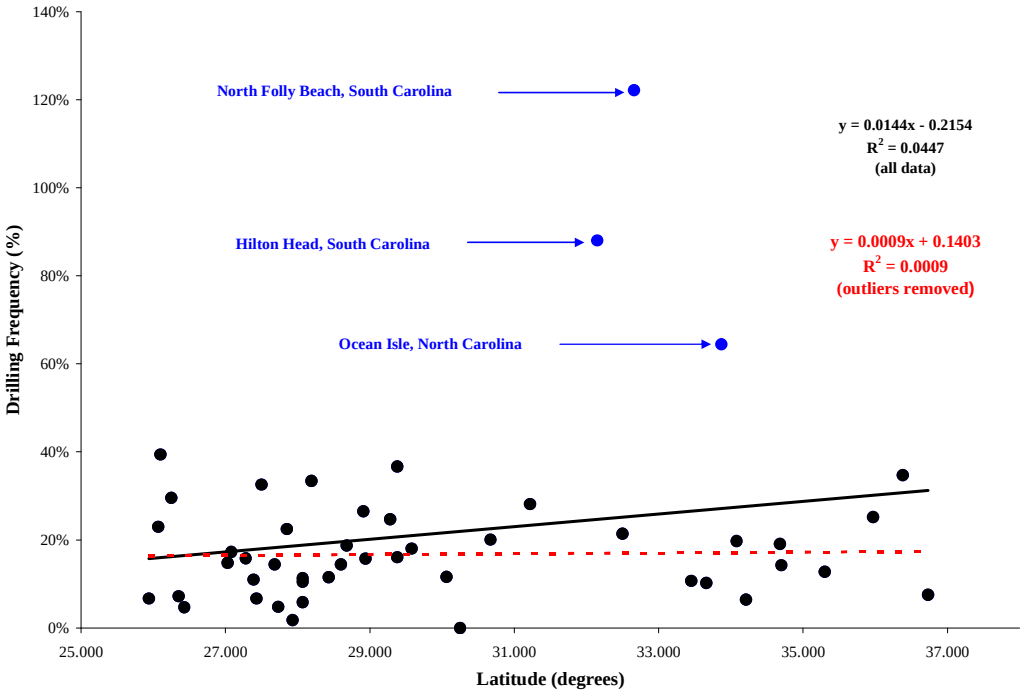

Figure 3. Scatter plot of assemblage drilling frequency verses latitude for all sample locations. Dashed trend line was constructed excluding outlier data.

Clustered Community-Level Drilling Frequency

The results of the cluster analysis (Fig. 4) reveal that a majority of the sites are linked by some common and abundant taxa (e.g., *Chione, Anadara, Donax,* and *Mulinia*). Three sites (Hutchinson Island, Jupiter Island, and Gulf Shores) are drastically different than the remainder of the samples and are dominated by genera absent or rarely represented in other sample sets (e.g., *Rangia* and *Glycymeris*). Two larger or coarse clusters were delineated, outlined in red and labeled A and B on Figure 4. These primary clusters were found to have minimum similarity coefficients greater than 40%.

Cluster A is primarily composed of the varying abundances genera *Anadara, Tellina, Donax,* and *Mulinia*. From an ecological or community composition perspective, the aggregate samples collected in cluster A most likely represent a mixture of organisms that typically occupy different marine environments, including subtidal, sea-grass/estuarine (*Mulinia* and *Tellina*), intertidal, swash zone (*Donax*), and subtidal, nearshore high energy (*Anadara*) environments. The locations contained in cluster A were sampled from areas found in varying provinces, including sample locations from North Carolina, South Carolina, Georgia, Florida, and Texas. Significant variation in drilling frequency was measured from each sample location in cluster A, ranging from 1.79% (Floridana Beach, FL) to 120.59% (North Folly Beach, SC).

Cluster B is broadly defined by elevated relative abundances of *Chione*, with lesser, but moderately percentages of arcid and mactrid bivalves. The samples are composed primarily of shallow, subtidal organisms that most likely lived in the back-barrier/estuarine environment and were subsequently transported by tidal and longshore currents to their sampled position on the beach face. Similar to cluster A, the locations

contained in cluster B were geographically widespread and found in all provinces. Drilling frequencies within the coarse cluster ranged from 4.49% (Sanibel Island, FL) to 32.05% (Anna Maria Island, FL).

The cluster analysis provided three groups with similarity coefficients greater than 60% that appear to be suitable for spatial analysis of assemblage or bulk drilling frequency (labeled 1, 2, and 3 on Figure 4). These clusters differed from the broadly defined clusters A and B, above, in that the similarity coefficient for each cluster was greater than approximately 60%. The higher similarity coefficient suggests that the samples are more closely related in taxonomic composition and abundance. These bulk samples with similar taxonomic compositions and abundances can then be used to reduce in a more detailed analysis, alleviating some of the environmental noise and ecological variability, if present, between samples.

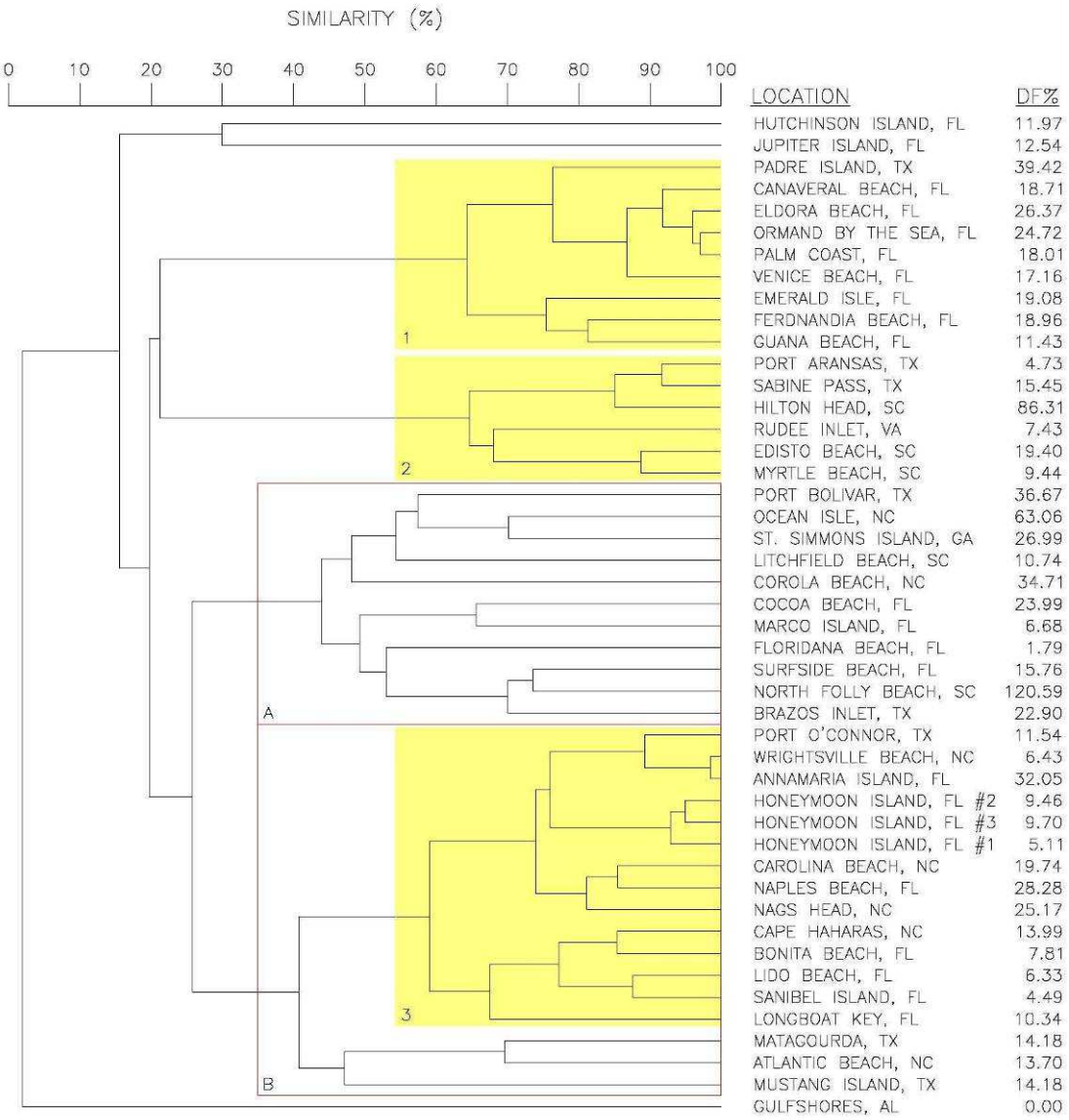

Figure 4. Dendogram output generated by PAST® showing results of cluster analysis used to generate molluscan communities. Clusters A, B, 1, 2, and 3 are discussed in the text.

Cluster 1 is predominantly characterized by relatively equal abundances of *Donax*, *Mulinia*, and *Anadara* specimens. This taxonomic mix most likely represents a combination of environments, including shallow-nearshore-subtidal and intertidal-swash-zone mollusks. The paucity of back-barrier and estuarine organisms suggests that these sample locations may be isolated or far from tidally dominated inlets, which could supply shells of estuarine or back-barrier organisms. Summary data for the nine locations in the *Donax-Mulinia-Anadara* community cluster are listed in Table 3. Assemblage drilling frequencies within the *Donax-Mulinia-Anadara* community cluster range from 11.5% (Guana State Park, FL) to 26.4% (Eldora, FL).

Table 3. Summary assemblage level abundance and drilling frequency by location for the *Donax-Mulinia-Anadara* community

Province	Location	Latitude	Number of Specimens			Drilling Frequency	
			Bivalve	Gastropod	Total	Total	Bivalve
Carolinian	6 - Emerald Isle, NC	34.68	304	0	304	19.1%	19.1%
	16 - Ferdnandia Bch, FL	30.67	309	9	318	19.0%	20.1%
	17 - Guana State Park, FL	30.06	1087	3	1090	11.5%	11.6%
	18 - Palm Coast, FL	29.58	831	2	833	18.0%	18.1%
	19 - Ormond by the Sea, FL	29.28	445	0	445	24.7%	24.7%
	20 - Eldora, FL	28.91	309	1	310	26.4%	26.5%
	21 - Canaveral Beach, FL	28.68	864	1	865	18.7%	18.8%
Gulf-Louisianan	31 - Venice Beach, FL	27.08	938	3	941	17.2%	17.3%
	46 - Padre Island, TX	26.10	624	0	624	39.4%	39.4%

Cluster 2 is dominated by *Mulinia*, with lesser quantities of *Chione* and *Anadara.* Similar to the *Donax-Mulinia-Anadara* community, the taxonomic mix most likely represents a combination of environments, including shallow-nearshore-subtidal and intertidal-swash-zone mollusks, but with a greater input of the genus *Chione*, which is considered a back-barrier/estuary/grass-flat inhabitant. Summary data for the six locations in the *Mulinia* community cluster 2 are listed in Table 4. Assemblage drilling

frequencies within the *Mulinia* community cluster range from 4.7% (Port Aransas, TX) to 86.3% (Hilton Head, SC).

Table 4. Summary assemblage level abundance and drilling frequency by location for the *Mulinia* community

Province	Location	Latitude	Number of Specimens			Drilling Frequency	
			Bivalve	Gastropod	Total	Total	Bivalve
Carolinian	1 - Rudee Inlet, VA	36.73	607	6	613	7.4%	7.6%
	14 - Hilton Head, SC	32.15	559	9	568	86.3%	88.0%
	10 - Myrtle Beach, SC	33.66	332	14	346	9.4%	10.2%
	13 - Edisto Beach, SC	32.50	271	14	285	19.4%	21.4%
Gulf-Louisianan	39 - Sabine Pass, TX	29.38	485	11	496	15.4%	16.1%
	44 - Port Aransas, TX	27.73	582	5	587	4.7%	4.8%

The bulk samples in cluster 3 share common primary abundances of *Chione*, with secondary abundances of *Anadara* in a small subcluster of five locations. This taxonomic composition is most likely dominated by back-barrier and estuarine organisms that have been transported to the beach/shoreface through tidally dominated inlets and then moved longitudinally across the beach by longshore currents. Summary data for the 14 locations in the *Chione* community cluster are listed in Table 5. Assemblage drilling frequencies within the *Chione* community cluster range from 4.5% (Sanibel Island, FL) to 32.0% (Anna Maria Island, FL).

Table 5. Summary assemblage level abundance and drilling frequency by location for the *Chione* community

Province	Location	Latitude	Number of Specimens			Drilling Frequency	
			Bivalve	Gastropod	Total	Total	Bivalve
Virginian	3 - Nags Head, NC	35.97	143	0	143	25.2%	25.2%
	4 - Cape Hatteras, NC	35.30	141	1	142	14.0%	12.8%
Carolinian	7 - Wrightsville Beach, NC	34.21	280	0	280	6.4%	6.4%
	8 - Carolina Beach, NC	34.08	233	0	233	19.7%	19.7%
Gulf-Louisianan	28 - Naples, FL	26.25	649	15	664	28.3%	29.6%
	29 - Bonita Beach, FL	26.35	416	0	416	7.2%	7.2%
	30 - Sanibel Island, FL	26.43	762	20	782	4.5%	4.7%
	32 - Longboat Key, FL	27.39	801	25	826	10.3%	11.0%
	33 - Anna Maria Island, FL	27.50	866	7	873	32.0%	32.6%
	34 - Lido Beach, FL	27.72	625	19	644	6.3%	6.7%
	35 - Honeymoon Island1, FL	28.07	308	22	330	5.1%	5.8%
	36 - Honeymoon Island2, FL	28.07	419	23	442	9.5%	10.5%
	37 - Honeymoon Island3, FL	28.07	319	26	345	9.7%	11.3%
	43 - Port O' Connor, TX	28.43	52	0	52	11.5%	11.5%

Drilling frequency versus latitude is plotted in Figure 5. The goal of plotting the data is to fit curves to the data contained in each cluster to determine if relationships between drilling frequency and latitude are present between sample locations comprised of similar environments. One outlier (Hilton Head, SC; DF = 86.3%) was removed from the *Mulinia* cluster to construct the trend line shown (in magenta/dashed).

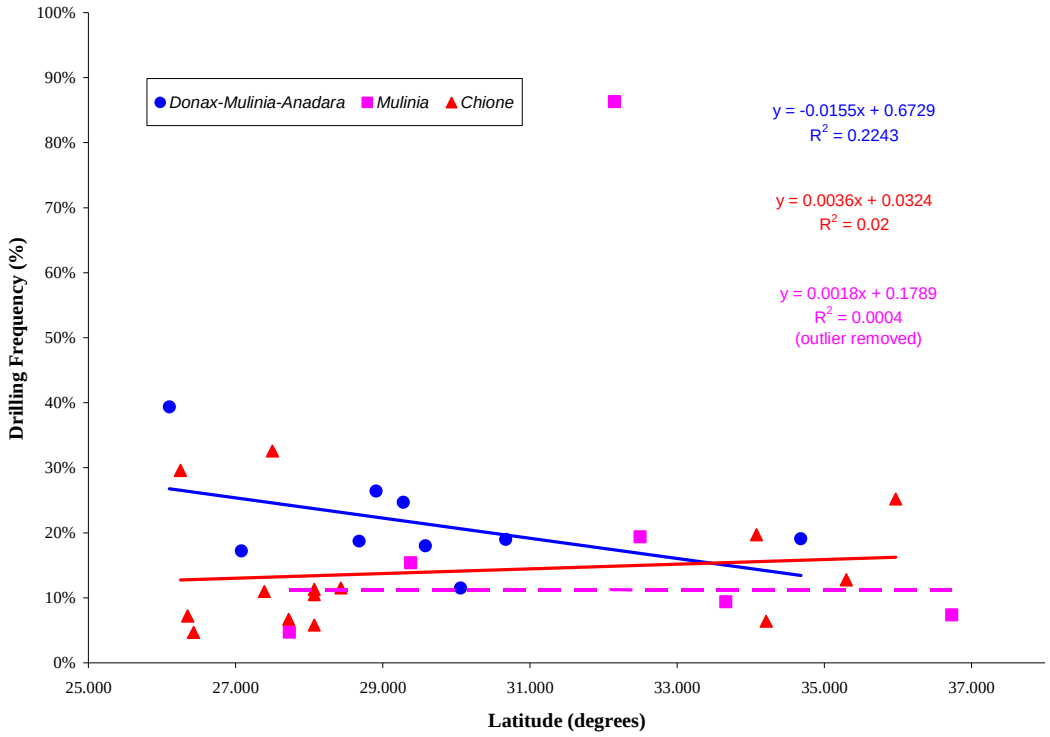

Figure 5. Scatter plot of assemblage drilling frequency versus latitude for clustered locations. Dashed trend lines do not include outlier data.

Lower Taxon Drilling Frequency

Several bivalve genera were widespread and frequently found in the collected assemblages. Genera with greater than 200 bivalve specimens per sample (representing >100 individuals) were examined in further detail. These genera included: *Donax*, *Chione*, *Anadara*, and *Mulinia*. Each of these genera originates from a different ecological area – discussed below for each taxon. Drilling frequencies within these lower taxon "subsamples" are presented in Tables 6 through 9 and are plotted collectively in Figure 6.

Donax

Eight of the 47 bulk samples contained ≥200specimens of the bivalve *Donax*. *Donax* is a burrowing bivalve found in the swash zone of the beach with a widespread geographic range (Rehder, 1997). The sample locations in this study with an elevated abundance of *Donax* were primarily contained within the Carolinian Province, with the exception of Venice Beach, Florida and Padre Island, Texas, which are included in the Gulf-Louisianan Province. Drilling frequencies ranged from 5.5% (Guana State Park, Florida) to 29.7% (Eldora, Florida), and pooled total drilling frequency for the genus was calculated at 19.5%.

Table 6. Location summaries for *Donax* bivalves with ≥200 specimens.

Location	**Latitude**	**Number of Specimens**	**Drilling Frequency**
		Donax	***Donax***
Ferdnandia Bch, FL	30.67	204	17.7%
Guana State Pk, FL	30.06	512	5.5%
Palm Coast, FL	29.58	708	15.5%
Ormond by the Sea, FL	29.28	408	24.0%
Eldora, FL	28.91	272	29.7%
Canaveral Beach, FL	28.68	695	17.8%
Venice Beach, FL	27.08	742	18.1%
Padre Island, TX	26.10	438	37.9%
TOTAL		3979	19.5%

Chione

Ten of the 47 bulk samples contained ≥200 specimens of the bivalve *Chione.* *Chione* is primarily found in grass flats and back-barrier, shallow-water environments. The sample locations with ≥200 valves of *Chione* were primarily limited to the Gulf-Louisianan Province, with the exception of Wrightsville Beach, North Carolina which is located in the Carolinian Province. Drilling frequencies ranged from 4.2% (Wrightsville Beach, NC) to 37.1% (Lido Beach, FL), and pooled total drilling frequency for the genus was calculated at 15.0%.

Table 7. Location summaries for *Chione* bivalves with ≥200 specimens.

Location	Latitude	Number of Specimens	Drilling Frequency
		Chione	*Chione*
Wrightsville Beach, NC	34.21	240	4.2%
Naples, FL	26.25	441	39.9%
Bonita Beach, FL	26.35	222	4.5%
Sanibel Island, FL	26.43	392	5.6%
Longboat Key, FL	27.39	216	18.9%
Anna Maria Island, FL	27.50	734	7.6%
Lido Beach, FL	27.72	315	37.1%
Honeymoon Island-1, FL	28.07	257	4.7%
Honeymoon Island-2, FL	28.07	336	11.9%
Honeymoon Island-3, FL	28.07	256	10.9%
TOTAL		3409	15.0%

Anadara

Six of the 47 bulk samples contained ≥200 specimens of the bivalve *Anadara.* *Anadara* are found throughout the shallow, nearshore marine environment. Large concentrations are common in higher-energy, sub-tidal portions of the shore (Rollins and West, 1996). The sample localities with ≥200 specimens of *Anadara* were equally

distributed between the Gulf-Louisianan Province and the Carolinian Province. Drilling frequencies ranged from 5.5% (Longboat Key, FL) to 175.9% (North Folly Beach, SC), and pooled total drilling frequency for the genus was calculated at 42.9%.

Review of the data for North Folly Beach (Appendix, #12 – North Folly Beach, SC) reveals a right valve to left valve ratio of 214:52 for *Anadara* solely. The right valve to left valve discrepancy was not observed for two other moderately abundant genera (greater than 60 specimens), *Mulinia* and *Noetia*. This artifact may be a result of some *post mortem* sorting and is discussed below.

Table 8. Location summaries for *Anadara* bivalves with ≥200 specimens.

Location	Latitude	Number of Specimens	Drilling Frequency
		Anadara	*Anadara*
Ocean Isle Bch, NC	33.87	245	85.7%
N Folly Beach, SC	32.66	266	175.9%
Cocoa Beach, FL	28.19	392	27.0%
Marco Island, FL	25.94	565	7.4%
Longboat Key, FL	27.39	253	5.5%
Surfside Beach, TX	28.94	293	8.2%
TOTAL		2014	42.9%

Mulinia

Four of the 47 bulk samples contained ≥200 specimens of the bivalve *Mulinia.* *Mulinia* is generally found in shallow tidally dominated grass flats and back-barrier environments. The sample locations with ≥200 specimens of *Mulinia* were primarily situated in the Gulf-Louisianan Province, with the exception of Hilton Head, South Carolina. Drilling frequencies ranged from 5.3% (Port Aransas, TX) to 91.4% (Hilton Head, SC), and pooled total drilling frequency for the genus was calculated at 35.0%. As seen in the *Anadara*-dominated samples from North Folly Beach, South Carolina and

Ocean Isle, North Carolina, a drilling frequency greater than 50% was observed for *Mulinia* bivalves in the Hilton Head, South Carolina sample.

Table 9. Location summaries for *Mulinia* bivalves with ≥200 specimens.

Location	Latitude	Number of Specimens	Drilling Frequency
		Mulinia	***Mulinia***
Hilton Head, SC	32.15	464	91.4%
Sabine Pass, TX	29.38	403	15.9%
Surfside Beach, TX	28.94	256	24.2%
Port Aransas, TX	27.73	528	5.3%
TOTAL		1651	35.0%

Pooled-drilling frequencies were the highest in the subsamples of *Anadara* and *Mulinia*, including the outliers described above. Excluding these outliers, the pooled-drilling frequencies are more similar and ranged from 12.4%, to 19.5%.

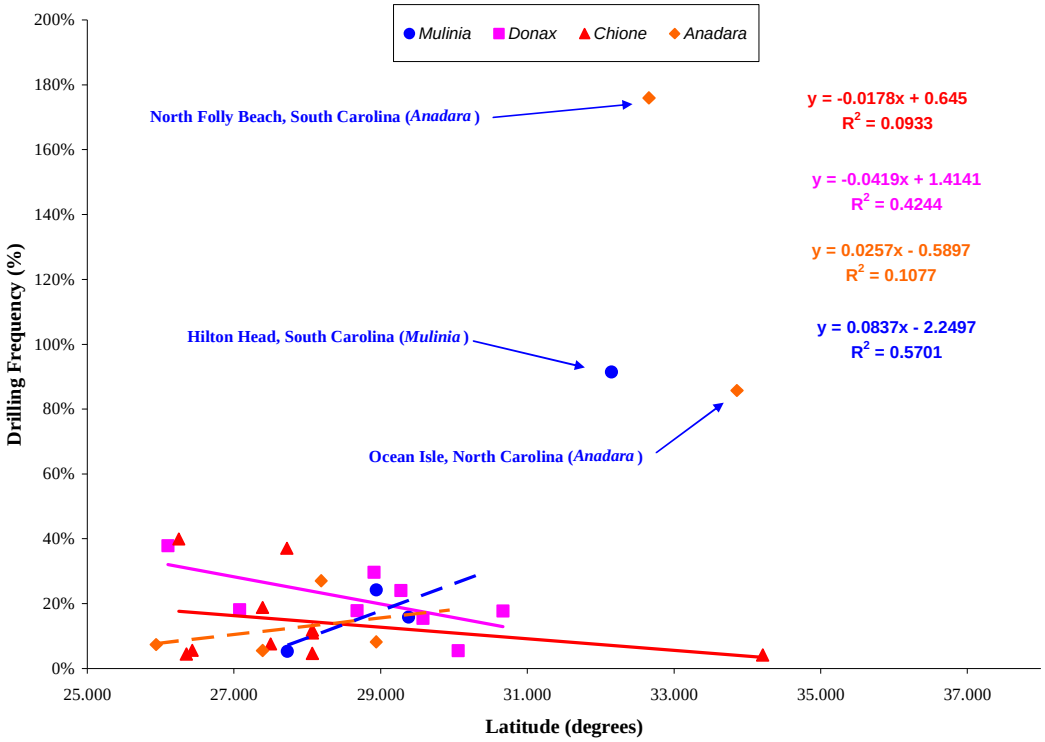

Figure 6. Scatter plot of drilling frequency for *Mulinia*, *Anadara*, *Chione*, and *Donax* subsamples plotted against latitude. Dashed lines represent trend lines exclude outlier data.

CHAPTER FOUR

DISCUSSION

Modern beach deposits are similar to the types of time-averaged deposits found in the fossil record that have been used in assessing potential paleoecologic relationships (e.g., Daley, et al., 2007, De Francesco and Alexander, 2008). The beach shell assemblages represent a spatially and temporally averaged accumulation of transported remains of dead mollusks (*see* Flessa et al., 1993 for general discussion). This apparent similarity between wrack-line shell assemblages and the fossil record establishes a unique opportunity to test spatial hypotheses in the Modern normally not afforded to limited data sets constructed from outcrop or museum collections.

Variation in Drilling Frequency

The results of the study indicate that considerable variation in calculated drilling frequency was observed in the collected data sets with no trends related to changing latitude. The apparent disparity between locations was observed at all scales, which included analysis of pooled sample sets to measure drilling frequencies at the province level and subsamples generated by extracting data for lower taxonomic levels (i.e., genus-level analyses). Measured assemblage drilling frequency values for individual sample locations ranged from 0.0% to 120.59%. Most of the measured assemblage drilling frequencies ranged from approximately 5% to 30%, with the exclusion of three

outlier values of 63.06%, 86.31%, and 120.59% for Ocean Isle, North Carolina; Hilton Head, South Carolina; and North Folly Beach, South Carolina, respectively.

Ranges of drilling frequency in the clustered groups of similar ecologic sources resembled those reported for the assemblage data sets. Interestingly, assemblage drilling frequencies differed from one another even in samples with multivariate analysis (clustering) similarity coefficients greater that 95%. Examples of these samples from extremely similar ecological origins include Ormond by the Sea, Florida and Palm Coast, Florida (DF = 24.72% and 18.01%, respectively) and Wrightsville Beach, North Carolina and Anna Maria Island, Florida (DF = 6.43% and 32.05%, respectively) (Fig. 4).

Variation in drilling frequency was also present in the lower taxonomic calculations. Several samples contained ≥200 valves of a single genus, thereby making direct comparisons in drilling frequency feasible at finer scale than assemblage level analyses. Drilling frequency ranges resembled those of the assembly level measurements, and, remarkably, a disparity between sites within close proximity of each other existed. These anecdotal observations included a disparity between samples of *Chione* collected from a single beach (Honeymoon Island, FL, DF = 4.7% to 11.9% for samples collected at the same beach in different locations at the same time), *Donax* collected from the a 100-kilometer stretch along the east coast of Florida (Palm Coast, FL, DF = 15.5%; Ormond by the Sea, FL, DF = 24.0%; and Guana State Park, FL, DF = 5.5%), and *Mulinia* subsamples derived from locations within 240 kilometers on the Texas coast (Surfside Beach, TX, DF = 24.2% and Port Aransas, TX, DF = 5.3%).

A majority of the calculated drilling frequencies in this study fall between 5% to 25%, resembling the range reported in the fossil record. Hansen and Kelley (1995) reported Eocene drilling frequencies ranging from 6.8% to 38.7% for the Cook Mountain interval and 4.0% to 21.9% for the Moodys Branch Formation. Middle Miocene assemblage or bulk drilling frequencies calculated from 18 marine deposits in modern central Europe ranged from 8.9% to 36.3% (Hoffmeister and Kowalewski, 2001). Baumiller and Bitner (2004) reported middle Miocene drilling frequencies (in brachiopods) ranging from 2.0% to 39.9% between three sampling locations, with individual species drilling frequencies reported as high as 47.9%. Lastly, pooled drilling frequencies for the Ripley and Providence Formations (Cretaceous) were reported to be 13.2% and 19.4%, respectively.

Several other investigations have focused on drilling frequency in the Modern, at least in part, with similar reported variation in drilling frequency. Vermeij's (1980) foundational work on drilling predation on bivalves in Guam provided drilling frequencies for individual species ranging from 0.0% to 75.0%, with most values varying between 5.0% to 20.0%. Rollins and West (1997) documented the influence of storm events on the deposition of *Anadara brasiliana* tests on a beach face in Georgia. Although the focus of the research was to illustrate potential taphonomic biases in death assemblages, drilling frequency for both articulated and disarticulated valves was reported. Drilling frequency for articulated valves collected along a single transect along the beach face was reported as 55% of 104 specimens. Interestingly, this reported value differs from the value that would be calculated for disarticulated specimens. 130 of 244 disarticulated tests were recovered along a separate transect, located within 10 m of the

second transect. Employing equation 3, above, for the calculation of drilling frequency, the calculated drilling frequency for the disarticulated sample set would be 106.56% (double that directly observed in articulated specimens). The location sampled in the Rollins and West (1997) study is in close proximity to the area where significantly higher drilling frequencies were measured in this study, including a value greater than 100% (North Folly Beach, SC).

A similar study to this research was conducted by Kelley and Hansen (2007), which documented latitudinal variation in drilling frequencies in Modern beach samples employing approximately the same sampling and tallying techniques. Results of the investigations were similar. They reported provincial drilling frequencies for the Virginian, Carolinian, and Gulf Provinces of 13%, 28%, and 15%, with the Carolinian drilling frequency containing several sites with above normal or elevated calculated drilling frequency. Drilling frequencies for total fauna were reported to range from 0.0% to 45.1%. Analyzing pooled provincial data, the authors concluded a latitudinal decrease from the Carolinian province northward through the Virginian and a similar decrease from the Carolinian toward lower latitude of the Gulf province.

Their study employed "split" samples from individual locations which were analyzed and counted separately by different workers. Oftentimes, variable results in assemblage drilling frequency were observed from the same location within their study. Several illustrative examples of drilling frequency differences between samples collected from the same site and at the same time by Kelley and Hansen (2007) include arcid bivalves (p. 295, Table 6) from Fort Pierce, FL (DF = 9.95% vs. 22.2%), Barengat, NJ (DF = 15.4% vs. 36.4%), and Venice Beach, FL (DF = 3.3% vs. 44.6%).

Some locations were sampled both by this study and the contemporaneous work by Kelley and Hansen (2007). The overlap between sample locations between the two similar studies provides additional opportunity to scrutinize the analysis of bulk or aggregate assemblage data for any given location. Common sites between the two studies included three locations in Florida (Sanibel Island, Ormond by the Sea, and Venice) and one site in North Carolina (Cape Hatteras). Considerable variation in reported drilling frequency for all bivalves was observed at all study overlap locations, with the exception of Sanibel Island, FL (Table 10).

Table 10. Overlap location drilling frequencies for all bivalves for this study and Kelley and Hansen (2007).

Location	**Drilling Frequency (Bivalves)**	
	Kelley and Hansen (2007)	***This study***
Sanibel Island, FL	4.5%	4.7%
Ormond by the Sea, FL	8.8%	24.7%
Venice Beach, FL	6.4%	12.8%
Cape Hatteras, NC	29.8%	17.3%

Sources of Variation in Drilling Frequency

Several observations shed light on potential environmental, biotic, and taphonomic sources of variability in the samples typically employed in drilling predation studies. As previously discussed and illuminated by numerous studies, variation in predation or drilling frequency appears to the norm rather than the exception. Based on our understanding of the complexity biotic and ecological interactions, some expected inherent variation in drilling frequency must exist. However, as with any scientific

investigation employing data collection and analysis, the question must be asked: *Do the drilling frequency values calculated for the wrack-line assemblages represent the drilling frequency of the open system it is intended to represent?*

Substantial research has focused on providing insight into a myriad of biases ubiquitous in ecological and paleontologic studies (summarized by Kowalewski, 2002). Vermeij (1980) warned that estimation of drilling frequency by boring gastropods can be problematic. Vermeij's discussion focused on biotic or ecologic interactions, such as the consumption of razor clams by *Polonices duplicatus* by attacking the soft parts of the prey in lieu of drilling the valves and the suffocation of *Olivella biplicata* gastropods by *Polonices* prior to drilling. Furthermore, the influence of the destruction of empty valves was cited as a potential bias in the measurement of drilling.

Some of the research thrusts have included the effect of preferential breakage of drilled vs. undrilled tests (Roy, et al. 1986; Zuschin and Stanton, 2001) and hydrodynamic sorting of drilled vs. undrilled valves (Kaplan and Baumiller, 2000). Specific to the data contained in this study, careful attention was paid to shell breakage passing through the borehole in drilled fragments (if present). From a qualitative perspective, fractures through existing boreholes were only rarely observed in this study.

One assemblage from North Folly Beach, SC contained 227:59 right to left valve ratio for arcid bivalves. In addition to this anomalous observation in the proportion of right to left valves, significantly high (and clearly unrealistic) drilling frequencies were calculated for the assemblage (120.6%). This drilling frequency was consistent with the information presented by Rollins and West (1996), where an apparently unrealistically elevated drilling frequency of 106% was recorded for disarticulated *Anadara brasiliana*

valves. The unequal count of right valves to left valves and the extremely high measurements of drilling frequency may be a product of hydrodynamic sorting.

Other relatively unconstrainable biological or ecological factors have been discussed, primarily within other studies on drilling predation. Consistent with the discussion provided by Vermeij (1980), underestimation of drilling frequency or the predatory influence of boring gastropods due to edge drilling and smothering has been proposed (Ansell and Morten, 1987). Potential bias in the collected samples may be introduced by the influence of other predators, including mollusk-consuming fish, crabs, and birds (Vermeij, 1980). Little is known if these predators exclude drilled specimens, or if their feeding habits indeterminately allow for the ingestion of both drilled and undrilled mollusks.

Kitchell et al. (1981) experimentally demonstrated that preference based on a cost-to-benefit ratio can drive prey-size selectivity when all sizes are available. Given the results of the experiments, it is reasonable to conclude that drilling frequencies can vary significantly due to shell size variations in the sample sets; an attribute not examined in this study. Kowalewski and Hoffmeister (2003) performed several meta-analyses on databases of drilling frequency measurements that were coupled with shell-size information. The results of the study suggested that paleontological parameters are affected by sieve size. A majority of the existing work in drilling predation, including this study, has not attempted to compare drilling frequency within specified size ranges. Therefore, some of the observed difference in drilling frequencies likely can be attributed to size selection in boring gastropods.

Several lines of research have suggested that the skeletal material found on the beach face are the result of mixing of populations from normal, steady-state conditions controlled by tidal and longshore currents coupled with intermittent storm events (Frey, 1987; Rollins and West, 1997; Henderson and Frey, 1986). Data presented in this study also show that the samples are composed of a mixture of materials (bivalve and gastropod tests) from various marine and brackish environments. One illustrative sample is the assemblage collected from Surfside Beach, Texas (Appendix, #41 - Surfside Beach, TX). The assemblage is comprised of approximately 38% arcid, 33% mactrid, and 14% tellinid bivalves with drilling frequencies of 8.2%, 24.2%, and 27.3%, respectively. The assemblage (or bulk) drilling frequency for the location was calculated to be 15.8%. This calculated "bulk" drilling frequency of 15.8% for the assemblage was heavily influenced by the aggregate (pooled) values of relatively low-drilling frequencies of the arcid bivalves mixed with higher drilling frequency values of the mactrid and tellinid bivalves. Excluding the arcids, which most likely were deposited on the beach face in recent storm events, the drilling frequency for the location would be closer to 25%. Focusing solely on the arcid bivalve drilling frequency, the calculated rate would be substantially lower and more closely resemble that of the arcid bivalves. It is conceivable that some of the sample abundances, and calculated drilling frequency, may be altered over short temporal intervals by the sudden deposition of shells from the intertidal zone (e.g., *Donax*) or the shallow nearshore (e.g., *Anadara*). An assemblage drilling frequency of 15.8% does not represent the actual measured drilling frequencies for the two distinct groups present from ecologically different origins. Based on the previous discussion, one can expect assemblage composition, and drilling frequency, to vary significantly with seasonal

changes in wave energy. This consideration most likely is pertinent to the discussion of variations found in the "split" samples employed in the Kelley and Hansen (2007) work and analysis of the three samples collected from Honeymoon Island in this study.

Much of the bias associated with the aggregate or bulk sample calculations can be alleviated by focusing on either aggregate samples from similar environmental composition (as performed in this study) or within finer taxonomic resolution at the family, genus, or species level. Kowalewski (2002) suggests that assemblage-level data collection and analysis is preferred because of the paucity of organisms that are present across wide-ranging geographically and temporal scales. However, the original work performed by Vermeij (1980) relied on species-level calculations of drilling frequency. Several studies focusing on single taxonomic groups have eliminated potential bias in the comparison of dissimilar assemblage level data. One example is the work produced by Dietl and Alexander (2000) on cannibalistic predation in naticids. In addition to eliminating controversy of pooled drilling frequencies by directly calculating and comparing drilling predation metrics using a single taxon, the research benefited from employing solely gastropods, therefore alleviating potential bias introduced by corrections for right and left valves in the calculation of drilling frequency for bivalves.

While most researchers have focused on potential taphonomic, environmental, and biotic controls on drilling predation, few approach the methods of research and data analyses historically used in predation studies. To date, no study has investigated qualifying the reliability of using pooled assemblage (aggregate) data in statistical or scientific inference. Furthermore, statistical and scientific inference used in many previous studies is seldom scrutinized.

In addition to the use of aggregate or pooled data sets, the effect of sample size on drilling frequency is poorly understood and researched. Drilling data represent proportional or binomial data, where each valve represents one of two possible outcomes, drilled or not drilled. The observations are then summed or tallied and a value for drilling frequency is calculated for the sample.

Vermeij's (1980) original work on bivalves in Guam was based on sample sizes ranging from 22 to 504 valves, with many less than 40 to 50. Based on a theoretical average drilling frequency of 17% (as measured in this study), the minimum sample size resulting in a 10% sampling error would be calculated at 54 observations. Because one successful act of drilling produces one drilled and one undrilled valve in bivalves, a total specimen count required for a sampling error of 10% is 108 valves. To provide a sampling error of 5%, a total of 433 bivalve shells are required per sample. As gastropods are univalved, they require only 217 and 54 conchs for sampling errors of 5% and 10%, respectively.

Earlier studies were founded on small sample sizes – and most likely provided a significant amount of apparent variation in the data due to higher sampling errors. Dudley and Vermeij (1978) stated that "the samples studies are large, and we feel that the drilling frequencies are indicative of the predation pressure exerted by drilling snails at that time." (p. 437). Fifty nine of the 77 *Turritella* sample sizes for the individual taxa were comprised of less than 30 individuals, and would have produced significant sampling errors in many instances. Current studies, including this investigation, are still hindered by sampling errors. Many workers have apparently generated large sample sets by collecting and analyzing bulk or aggregate samples, as described above. Uncertainty

in drilling frequency calculations would be increased through the pooling of unrelated data from different populations.

Ecological Implications

Notwithstanding the above scrutiny raised above regarding the methods of research and analysis employed both by previous researchers and this study, significant new information may be gleaned from the data set and subsequent analysis. One interesting observation is the occurrence of significantly higher drilling frequencies at both the assemblage level and within individual genera (*Anadara* and *Mulinia*). These higher drilling frequencies were grouped together along the Carolina coast. Similar high drilling frequencies were noted by Kelley and Hansen (2007) for samples collected from Isle of Palms, South Carolina (assemblage level DF = 45.1%) and Tybee Island, Georgia (assemblage level DF = 36.5%). Rollins and West (1996) reported drilling frequencies roughly consistent to the data in this study from samples collected on St. Catherine's Island, Georgia (*Anadara brasiliana*, DF = 55% for articulated and 106% for disarticulated valves).

Vermeij (1987) suggested that drilling frequency should increase towards the tropics (lower latitudes). The specific reasons for the formulation of this hypothesis were a measured increase in diversity of drilling gastropods in the tropics (Taylor and Taylor, 1977) and increased productivity in the tropics. Contrary to the hypothesis, this study documented areas of highest drilling frequencies occurring at the ecotone or transition between the Carolinian and Virginian provinces. This physical setting creates an area with significant biotic overlap between the two provinces and it is common to have

species adapted to both environments. Productivity and diversity can be high – therefore satisfying Vermeij's (1980) assertion that predation should increase in areas with increased (primary) productivity and diversity.

Areas of significantly higher predation have been observed in the fossil record. Hoffmeister and Kowalewski (2001) reported assemblage drilling frequencies for most locations ranged from 10% to 25%, with the exception of one Boreal sample (number 3) with a drilling frequency of 36.3% (all mollusks) and 41.5% (gastropods). Similarly, Baumiller and Bitner (2006) documented high drilling frequency values of 47.9% in the Miocene for *Megathiris detruncata* (brachiopod). Although it is unknown if these limited areas correspond with ecotone transitions between physical marine regimes, further research may shed light on former ecologic provinces through geologic time.

The results of this study provide that drilling frequency is typically the result of a cadre of random variables and that an approximate value for total drilling frequency in the Modern along the Gulf and Atlantic Coastal Plain of the United States can be estimated by using either the mean of 16.6% ± 9.8% or the median value of 14.8%. The repeated occurrence of outlier samples of higher than typical drilling frequency suggests that the observations is perhaps dependent on some ecological variable present in the vicinity. A new working hypothesis may be therefore developed, suggesting that ecotones provide areas of increased productivity and diversity. These areas, in turn, result in increased predation. Based on initial analysis, the working hypothesis appears to fit data presented in previous works both in the Modern and in the fossil record.

CHAPTER FIVE

CONCLUSIONS

Community ecological research is riddled with difficulties associated with measuring biological variables and interactions. These scientific conundrums are compounded in paleontologic/paleoecologic research with the addition of time averaging and taphonomic processes. As potential focal environmental and biotic factors are identified (*in casu*, predation), practical methods for measurement and analysis are required. Rarely do environmental factors vary alone, making the isolation and quantitative measurement of a single environmental variable problematic. In addition, the variability in biotic distributions and interactions occur at scales generally unknown to the researcher at the incipient stages of the research.

Subjectively, the interplay between predators and prey undoubtedly plays an important role in the evolution of both participants. Quantification and subsequent analysis of this interaction is problematic; however, boreholes left by drilling gastropods provide a rare opportunity to measure the complex interaction in marine benthic environments. This study employed several techniques that have been used in previous research coupled with multivariate analyses to analyze spatial variation in drilling frequencies in Modern beach deposits. The primary results are:

1. Drilling frequency for assemblage (bulk) aggregate samples collected from 45 Modern beaches ranged from 0.0% to over 100%. The 45 sampling locations were located along the contiguous United States coastline from Rudee Inlet, Virginia to Brazos Inlet, Texas and represent three provinces (Virginian, Carolinian, and Gulf-Louisianian). Significant variation in drilling frequency was observed between samples, lower taxonomic subsamples, and pooled provinces. In addition, similar variability was observed in clustered sample sets of similar environmental origin. Contrary to Vermeij's (1980) hypothesis, latitudinal gradients or trends were not observed in the assemblage, lower taxonomic subsamples, or environmentally related clustered data sets.

2. The assemblage drilling frequency follows an approximate lognormal distribution pattern about an aggregate sample mean of 16.6 ± 9.8% and a median of 14.8% (excluding three outlier values recorded along the Carolina coast). The shape of the distribution curve of drilling frequency values may suggest that drilling frequency is random in nature. Therefore, drilling frequency is most likely the cumulative effect of many interwoven, complex, and random variables, akin to other biological data and cannot be reliably estimated in any given singular time and space.

3. An anomalous and isolated area of significantly higher drilling frequencies was observed along the Carolina coast that represents an ecotone between the Carolinian and Virginian provinces. Localized areas of higher drilling frequencies have been documented by others in the fossil record by previous researchers. Further study is warranted to explain possible larger scale increases in predation rates in these areas, perhaps requiring a new hypothesis for spatial relationships of drilling predation in the marine environment.

4. The transportation and accumulation of the shells is complex and involves intricate steady-state nearshore dynamics joined with stochastic events, like storm deposition of *Anadara* shells on the beach face. Although these processes ultimately reflect those responsible for the formation of fossil-rich death assemblages in the geologic record, both settings provide noteworthy challenges to statistical or scientific inference.

5. The findings of this research were consistent with previously conducted studies in both the Modern and in the geologic past. This study provides another data set to illuminate the importance of constraining conclusions about drilling predation drawn on limited and/or pooled data sets in both space and time.

6. Most researchers have focused on the influence of environmental or biotic controls on drilling predation without first verifying research models, designs of experiment, and analyses. Sampling techniques and sample sizes for most previously published studies have not provided for reliable analysis. Sampling errors are compounded through the pooling of poorly related data from differing environments. The wrack line assemblages represent an aggregate accumulation of shells from nearshore, back barrier, tidal inlet, brackish, and freshwater environments. To date, no study has provided for the variation at a single locality across multiple depositional occurrences, such as storm events. If reliable knowledge is to be generated from using existing methods or calculations of drilling frequency, a new emphasis should be placed on design of a consistent sampling and analysis strategy, perhaps focusing on specimens from a single family, genus, or species.

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APPENDIX

Location: **1 - Rudee Inlet, Virginia**

Latitude: 36.73 degrees north | Date Collected: November 23, 2000

Longitude: 76.00 degrees west | Province: Virginian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Mactridae	380	1	381	9	0	9	61.55	4.72
Mulinia lateralis	368	0	368	8	0	8	59.45	4.35
Mactra fagilis	9	0	9	1	0	1	1.45	22.22
Rangia cuneata	3	1	4	0	0	0	0.65	0.00
Tellinidae	149	0	149	10	0	10	24.07	13.42
Tellina spp.	149	0	149	10	0	10	24.07	13.42
Arcidae	22	20	42	0	3	3	6.79	14.29
Anadara ovalis	21	16	37	0	3	3	5.98	16.22
Anadara transversa	1	4	5	0	0	0	0.81	0.00
Donacidae	4	6	10	1	0	1	1.62	20.00
Donax variabilis	4	6	10	1	0	1	1.62	20.00
Ostreidae	9	0	9	0	0	0	1.45	0.00
Crassostrea virginica	9	0	9	0	0	0	1.45	0.00
Solenidae	9	0	9	0	0	0	1.45	0.00
Siliqua sp.	9	0	9	0	0	0	1.45	0.00
Noetidae	1	2	3	0	0	0	0.48	0.00
Noetia ponderosa	1	2	3	0	0	0	0.48	0.00
Veneridae	1	2	3	0	0	0	0.48	0.00
Mercenaria campechiensis	1	2	3	0	0	0	0.48	0.00
Pectinidae	1	0	1	0	0	0	0.16	0.00
Argopecten gibbus	1	0	1	0	0	0	0.16	0.00
TOTAL BIVALVIA	**576**	**31**	**607**	**20**	**3**	**23**	**98.06**	**7.58**
GASTROPODA								
Crepidulidae			5			0	1.62	0.00
Crepidula fornicata			4			0	1.29	0.00
Crepidula plana			1			0	0.32	0.00
Natacidae			1			0	0.32	0.00
Sinum perspectivum			1			0	0.32	0.00
TOTAL GASTROPODA			**6**			**0**	**1.94**	**0.00**
TOTAL		**n =**	**613**	**specimens**			**100.0**	**7.43**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **2 - Corolla Beach, North Carolina**

Latitude: 36.38 degrees north Date Collected: November 29, 2000

Longitude: 75.83 degrees west Province: Virginaian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Arcidae	23	11	34	5	3	8	28.10	47.06
Anadara ovalis	20	10	30	5	3	8	24.79	53.33
Barbatia candita	3	1	4	0	0	0	3.31	0.00
Mactridae	24	0	24	9	0	9	19.83	75.00
Mactra fragilis	24	0	24	9	0	9	19.83	75.00
Tellinidae	18	0	18	4	0	4	14.88	44.44
Tellina spp.	18	0	18	4	0	4	14.88	44.44
Veneridae	15	2	17	0	0	0	14.05	0.00
Chione elevata	12	2	14	0	0	0	11.57	0.00
Divaricella quadrisulcata	3	0	3	0	0	0	2.48	0.00
Anomiidae	12	0	12	0	0	0	9.92	0.00
Anomia simplex	12	0	12	0	0	0	9.92	0.00
Noetidae	5	0	5	0	0	0	4.13	0.00
Noetia ponderosa	5	0	5	0	0	0	4.13	0.00
Ostreidae	4	0	4	0	0	0	3.31	0.00
Crassostraca virginicus	4	0	4	0	0	0	3.31	0.00
Pectinidae	3	0	3	0	0	0	2.48	0.00
Argopecten gibbus	3	0	3	0	0	0	2.48	0.00
Lucinidae	3	0	3	0	0	0	2.48	0.00
Mercenaria mercenaria	3	0	3	0	0	0	2.48	0.00
Donacidae	0	1	1	0	0	0	0.83	0.00
Donax variabilis	0	1	1	0	0	0	0.83	0.00
TOTAL BIVALVIA	**107**	**14**	**121**	**18**	**3**	**21**	**100.00**	**34.71**
TOTAL		**n =**	**121**	**specimens**			**100.0**	**34.71**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **3 - Nags Head, North Carolina**

Latitude: 35.97 degrees north | Date Collected: November 24, 2000

Longitude: 75.51 degrees west | Province: Virginian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	41	50	91	6	4	10	63.64	21.98
Chione elevata	36	48	84	6	4	10	58.74	23.81
Mercinaria mercinaria	5	2	7	0	0	0	4.90	0.00
Noetidae	1	27	28	0	0	0	19.58	0.00
Noetia pondrosa	1	27	28	0	0	0	19.58	0.00
Arcidae	10	4	14	2	4	6	9.79	85.71
Anadara ovalis	7	3	10	1	3	4	6.99	80.00
Barbatia candida	3	1	4	1	1	2	2.80	100.00
Donacidae	3	2	5	1	1	2	3.50	80.00
Donax variabilis	3	2	5	1	1	2	3.50	80.00
Anomiidae	2	0	2	0	0	0	1.40	0.00
Anomia simplex	2	0	2	0	0	0	1.40	0.00
Pectinidae	1	0	1	0	0	0	0.70	0.00
Argopecten gibbus	1	0	1	0	0	0	0.70	0.00
Ostreidae	1	0	1	0	0	0	0.70	0.00
Crassostrea virginica	1	0	1	0	0	0	0.70	0.00
Mactridae	1	0	1	0	0	0	0.70	0.00
Mactra fragilis	1	0	1	0	0	0	0.70	0.00
TOTAL BIVALVIA	**60**	**83**	**143**	**9**	**9**	**18**	**100.00**	**25.17**
TOTAL		**n =**	**143**	**specimens**			**100.00**	**25.17**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **4 - Cape Hatteras, North Carolina**

Latitude: 35.30 degrees north | Date Collected: November 23, 2000

Longitude: 75.50 degrees west | Province: Virginian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	39	25	64	1	2	3	44.76	9.38
Chione elevata	37	25	62	1	2	3	43.36	9.68
Mercenaria mercenaria	2	0	2	0	0	0	1.40	0.00
Arcidae	32	18	50	2	3	5	34.97	20.00
Anadara ovalis	21	9	30	1	2	3	20.98	20.00
Anadara transversa	11	9	20	1	1	2	13.99	20.00
Noetidae	8	3	11	1	0	1	7.69	18.18
Noetia ponderosa	8	3	11	1	0	1	7.69	18.18
Ostreidae	7	0	7	0	0	0	4.90	0.00
Crassostrea virginica	7	0	7	0	0	0	4.90	0.00
Mactridae	4	0	4	0	0	0	2.80	0.00
Mulina lateralis	4	0	4	0	0	0	2.80	0.00
Anomiidae	2	0	2	0	0	0	1.40	0.00
Anomia simplex	2	0	2	0	0	0	1.40	0.00
Pectinidae	2	0	2	0	0	0	1.40	0.00
Argopecten gibbus	2	0	2	0	0	0	1.40	0.00
Lucinidae	1	0	1	0	0	0	0.70	0.00
Divaricella quadrisulcata	1	0	1	0	0	0	0.70	0.00
TOTAL BIVALVIA	**95**	**46**	**141**	**4**	**5**	**9**	**98.60**	**12.77**
GASTROPODA								
Naticidae			1			1	1.40	100.00
Natica sp.			1			1	1.40	100.00
TOTAL GASTROPODA			**1**			**1**	**1.40**	**100.00**
TOTAL		**n =**	**142**	**specimens**			**100.0**	**13.99**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **5 - Atlantic Beach, North Carolina**

Latitude: 34.70 degrees north — Date Collected: November 23, 2000

Longitude: 76.74 degrees west — Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Mactridae	44	0	44	1	0	1	31.43	4.55
Mulinia lateralis	44	0	44	1	0	1	31.43	4.55
Veneridae	17	17	34	2	0	2	24.29	11.76
Chione elevata	16	17	33	2	0	2	23.57	12.12
Gemma gemma	1	0	1	0	0	0	0.71	0.00
Tellinadae	24	0	24	2	0	2	17.14	16.67
Tellina spp.	24	0	24	2	0	2	17.14	16.67
Arcidae	12	3	15	2	1	3	10.71	40.00
Anadara ovalis	12	3	15	2	1	3	10.71	40.00
Donacidae	3	7	10	0	0	0	7.14	0.00
Donax variabilis	3	7	10	0	0	0	7.14	0.00
Noetidae	2	2	4	0	0	0	2.86	0.00
Noetia ponderosa	2	2	4	0	0	0	2.86	0.00
Lucinidae	1	1	2	1	1	2	1.43	200.00
Divarcella quadrisulcata	1	1	2	1	1	2	1.43	200.00
Pectinidae	2	0	2	0	0	0	1.43	0.00
Argopecten gibbus	2		2	0		0	1.43	0.00
Ostreidae	2	0	2	0	0	0	1.43	0.00
Crassostrea virginica	2	0	2	0	0	0	1.43	0.00
Corbulculidae	2	0	2	0	0	0	1.43	0.00
Polymesoda carolina	2	0	2	0	0	0	1.43	0.00
Cardiidae	1	0	1	0	0	0	0.71	0.00
Trachycardium muricatum	1	0	1	0	0	0	0.71	0.00
TOTAL BIVALVIA	**110**	**30**	**140**	**8**	**2**	**10**	**100**	**14.29**
GASTROPODA								
Crepidulidae			3			0	4.29	0.00
Crepidula fornucata			2			0	2.86	0.00
Crepidula plana			1			0	1.43	0.00
TOTAL GASTROPODA			**3**			**0**	**4.11**	0.00
TOTAL		**n =**	**143**	**specimens**			**104.1**	**13.70**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **6 - Emerald Isle, North Carolina**

Latitude: 34.68 degrees north | Date Collected: November 24, 2000

Longitude: 76.95 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Donacidae	61	54	115	3	5	8	37.83	13.91
Donax variabilis	61	54	115	3	5	8	37.83	13.91
Mactridae	76	0	76	1	0	1	25.00	2.63
Mulinia lateralis	76	0	76	1	0	1	25.00	2.63
Veneridae	27	14	41	7	1	8	13.49	39.02
Chione elevata	26	14	40	7	1	8	13.16	40.00
Discus sp.	1	0	1	0	0	0	0.33	0.00
Arcidae	31	17	48	10	2	12	15.79	50.00
Anadara ovalis	13	10	23	4	2	6	7.57	52.17
Anadara transversa	15	5	20	6	0	6	6.58	60.00
Anadara brasiliana	3	2	5	0	0	0	1.64	0.00
Noetidae	9	8	17	0	0	0	5.59	0.00
Noetia ponderosa	9	8	17	0	0	0	5.59	0.00
Glycymerididae	3	0	3	0	0	0	0.99	0.00
Glycymeris undata	3	0	3	0	0	0	0.99	0.00
Ostreidae	2	0	2	0	0	0	0.66	0.00
Crassostrea virginica	2	0	2	0	0	0	0.66	0.00
Lucinidae	1	0	1	0	0	0	0.33	0.00
Divarcella quadrisulcata	1	0	1	0	0	0	0.33	0.00
Cardiidae	1	0	1	0	0	0	0.33	0.00
Trachycardium muricatum	1	0	1	0	0	0	0.33	0.00
TOTAL BIVALVIA	**211**	**93**	**304**	**21**	**8**	**29**	**100**	**19.08**
TOTAL		**n =**	**304**	**specimens**			**100.0**	**19.08**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **7 - Wrightville Beach, North Carolina**

Latitude: 34.21 degrees north | Date Collected: November 24, 2000

Longitude: 77.80 degrees west | Province: Carolinaian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	142	102	244	1	4	5	87.14	4.10
Chione elevata	141	99	240	1	4	5	85.71	4.17
Mercenaria mercenaria	1	3	4	0	0	0	1.43	0.00
Arcidae	12	13	25	2	1	3	8.93	24.00
Anadara ovalis	12	12	24	2	0	2	8.57	16.67
Anadara notabilis	0	1	1	0	1	1	0.36	200.00
Noetidae	4	5	9	0	1	1	3.21	22.22
Noetia pondrosa	4	5	9	0	1	1	3.21	22.22
Donacidae	1	0	1	0	0	0	0.36	0.00
Donax variabilis	1	0	1	0	0	0	0.36	0.00
Pectinidae	1	0	1	0	0	0	0.36	0.00
Argopecten gibbus	1	0	1	0	0	0	0.36	0.00
TOTAL BIVALVIA	**160**	**120**	**280**	**3**	**6**	**9**	**100**	**6.43**
TOTAL		**n =**	**280**	**specimens**			**100.0**	**6.43**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **8 - Carolina Beach, North Carolina**

Latitude: 34.08 degrees north | Date Collected: November 23, 2000

Longitude: 77.87 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	77	88	165	8	9	17	70.82	20.61
Chione elevata	70	83	153	8	9	17	65.67	22.22
Mercenaria mercenaria	7	5	12	0	0	0	5.15	0.00
Arcidae	13	13	26	3	2	5	11.16	38.46
Anadara ovalis	13	11	24	3	2	5	10.30	41.67
Barbatia candida	0	2	2	0	0	0	0.86	0.00
Noetiadae	6	5	11	1	0	1	4.72	18.18
Noetia pondrosa	6	5	11	1	0	1	4.72	18.18
Ostreidae	9	0	9	0	0	0	3.86	0.00
Crassostrea virginica	9	0	9	0	0	0	3.86	0.00
Tellindae	9	0	9	0	0	0	3.86	0.00
Tellina spp.	9	0	9	0	0	0	3.86	0.00
Donacidae	3	3	6	0	0	0	2.58	0.00
Donax variabilis	3	3	6	0	0	0	2.58	0.00
Anomiidae	4	0	4	0	0	0	1.72	0.00
Anomia simplex	4	0	4	0	0	0	1.72	0.00
Pectinidae	1	0	1	0	0	0	0.43	0.00
Argopecten gibbus	1	0	1	0	0	0	0.43	0.00
Lucinidae	0	1	1	0	0	0	0.43	0.00
Lucina sp.	0	1	1	0	0	0	0.43	0.00
Mactridae	1	0	1	0	0	0	0.43	0.00
Mactra fragilis	1	0	1	0	0	0	0.43	0.00
TOTAL BIVALVIA	**123**	**110**	**233**	**12**	**11**	**23**	**100.00**	**19.74**
TOTAL		**n =**	**233**	**specimens**			**100.0**	**19.74**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **9 - Ocean Isle Beach, North Carolina**
Latitude: 33.87 degrees north
Longitude: 78.44 degrees west
Date Collected: November 24, 2000
Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Arcidae	153	129	282	69	45	114	38.16	80.85
Anadara ovalis	100	87	187	50	34	84	25.30	89.84
Anadara notabilis	27	31	58	10	11	21	7.85	72.41
Barbatia candida	26	11	37	9	0	9	5.01	48.65
Tellindae	144	0	144	58	0	58	19.49	80.56
Tellina spp.	144	0	144	58	0	58	19.49	80.56
Donacidae	63	51	114	17	13	30	15.43	52.63
Donax variabilis	63	51	114	17	13	30	15.43	52.63
Veneridae	27	34	61	7	2	9	8.25	29.51
Chione elevata	21	30	51	2	2	4	6.90	15.69
Gemma gemma	5	0	5	4	0	4	0.68	160.00
Anomalocardia auberiana	1	3	4	1	0	1	0.54	50.00
Dosinia discus	0	1	1	0	0	0	0.14	0.00
Cardiidae	33	22	55	6	3	9	7.44	32.73
Carditamera floridana	21	13	34	3	0	3	4.60	17.65
Dinocardium robustum	11	9	20	3	3	6	2.71	60.00
Trachycardium mericatum	1	0	1	0	0	0	0.14	0.00
Noetidae	14	27	41	3	10	13	5.55	63.41
Noetia pondrosa	14	27	41	3	10	13	5.55	63.41
Anomiidae	9	0	9	0	0	0	1.22	0.00
Anomia simplex	9	0	9	0	0	0	1.22	0.00
Pectinidae	7	0	7	0	0	0	0.95	0.00
Argopecten gibbus	7	0	7	0	0	0	0.95	0.00
Ostreidae	7	0	7	0	0	0	0.95	0.00
Crassostrea virginica	7	0	7	0	0	0	0.95	0.00
Lucinidae	1	1	2	0	0	0	0.27	0.00
Anadontia alba	0	1	1	0	0	0	0.14	0.00
Divaricella quadrisulcata	1	0	1	0	0	0	0.14	0.00
Mactridae	1	0	1	0	0	0	0.14	0.00
Mactra fragilis	1	0	1	0	0	0	0.14	0.00
TOTAL BIVALVIA	**459**	**264**	**723**	**160**	**73**	**233**	**97.83**	64.45
GASTROPODA								
Crepidulidae			4			0	1.08	0.00
Crepidula fornucata			4			0	1.08	0.00
Fissurellidae			4			0	1.08	0.00
Lucapina suffusa			4			0	1.08	0.00
TOTAL GASTROPODA			**8**			**0**	**2.17**	**0.00**
TOTAL		**n =**	**731**	**specimens**			**100.0**	**63.06**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **10 - Myrtle Beach, South Carolina**
Latitude: 33.66 degrees north
Longitude: 78.93 degrees west
Date Collected: November 24, 2000
Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Mactridae	193	0	193	8	0	8	53.61	8.29
Mulina lateralis	193	0	193	8	0	8	53.61	8.29
Arcidae	61	27	88	4	2	6	24.44	13.64
Anadara transversa	61	27	88	4	2	6	24.44	13.64
Veneridae	12	11	23	0	0	0	6.39	0.00
Chione elevata	12	11	23	0	0	0	6.39	0.00
Noetidae	7	6	13	1	0	1	3.61	15.38
Noetia ponderosa	7	6	13	1	0	1	3.61	15.38
Donacidae	0	4	4	0	1	1	1.11	50.00
Donax variabilis	0	4	4	0	1	1	1.11	50.00
Plicatulidae	3	0	3	0	0	0	0.83	0.00
Plicatula gibbosa	3	0	3	0	0	0	0.83	0.00
Cardiidae	3	0	3	0	0	0	0.83	0.00
Trachycardium mericatum	3	0	3	0	0	0	0.83	0.00
Lucinidae	2	1	3	1	0	1	0.83	66.67
Lucina sp.	2	0	2	1	0	1	0.56	100.00
Divarcella quadrisulcata	0	1	1	0	0	0	0.28	0.00
Anomiidae	1	0	1	0	0	0	0.28	0.00
Anomia simplex	1	0	1	0	0	0	0.28	0.00
Corbulidae	0	1	1	0	0	0	0.28	0.00
Corbula contracta	0	1	1	0	0	0	0.28	0.00
TOTAL BIVALVIA	**282**	**50**	**332**	**14**	**3**	**17**	**92.22**	**10.24**
GASTROPODA								
Olividae			5			0	2.78	0.00
Oliva sayana			5			0	2.78	0.00
Crepidulidae			4			0	2.22	0.00
Crepidula fornucata			4			0	2.22	0.00
Naticidae			2			0	1.11	0.00
Neverita duplicata			2			0	1.11	0.00
Marginellidae			1			0	0.56	0.00
Marginella bella			1			0	0.56	0.00
Terebridae			1			0	0.56	0.00
Terebra dislocata			1			0	0.56	0.00
Muricidae			1			0	0.56	0.00
Urosalpinx cinerea			1			0	0.56	0.00
TOTAL GASTROPODA			**14**			**0**	**7.78**	**0.00**
TOTAL		**n =**	**346**				**100.0**	**9.44**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **11 - Litchfield Beach, South Carolina**

Latitude: 33.45 degrees north | Date Collected: November 24, 2000

Longitude: 79.10 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Tellinidae	165	0	165	9	0	9	42.20	10.91
Tellina spp.	165	0	165	9	0	9	42.20	10.91
Arcidae	46	27	73	3	3	6	18.67	16.44
Anadra ovalis	26	11	37	1	0	1	9.46	5.41
Anadara transversa	20	16	36	2	3	5	9.21	27.78
Mactridae	28	46	74	2	2	4	18.93	10.81
Mulinia lateralis	28	45	73	2	2	4	18.67	10.96
Spisula sp.	0	1	1	0	0	0	0.26	0.00
Noetidae	19	9	28	0	1	1	7.16	7.14
Noetia ponderosa	19	9	28	0	1	1	7.16	7.14
Veneridae	9	7	16	0	0	0	4.09	0.00
Chione cancellata	9	7	16	0	0	0	4.09	0.00
Donacidae	4	2	6	0	0	0	1.53	0.00
Donax variabilis	4	2	6	0	0	0	1.53	0.00
Lucinidae	2	1	3	0	0	0	0.77	0.00
Divarcella quadrisulcata	2	1	3	0	0	0	0.77	0.00
Anomiidae	2	0	2	0	0	0	0.51	0.00
Anomia simplex	2	0	2	0	0	0	0.51	0.00
Cardiidae	2	1	3	0	0	0	0.77	0.00
Trachycardium mericatum	2	0	2	0	0	0	0.51	0.00
Dinocardium robustum	0	1	1	0	0	0	0.26	0.00
Pectinidae	1	0	1	0	0	0	0.26	0.00
Argopecten gibbus	1	0	1	0	0	0	0.26	0.00
Glycymerididae	1	0	1	0	0	0	0.26	0.00
Glycymeris undata	1	0	1	0	0	0	0.26	0.00
Nuculidae	1	0	1	0	0	0	0.26	0.00
Nucula proxima	1	0	1	0	0	0	0.26	0.00
TOTAL BIVALVIA	**280**	**93**	**373**	**14**	**6**	**20**	**95.40**	**10.67**
GASTROPODA								
Crepidulididae			8			0	4.09	0.00
Crepidula aculeata			6			0	3.07	0.00
Crepidula fornucata			2			0	1.02	0.00
Naticidae			1			1	0.51	100.00
Neverita duplicata			1			1	0.51	100.00
TOTAL GASTROPODA			**9**			**1**	**4.60**	**11.11**
TOTAL		**n =**	**382**	**specimens**			**100.0**	**10.74**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **12 - North Folly Beach, South Carolina**

Latitude: 32.66 degrees north | Date Collected: October 23, 1999

Longitude: 79.92 degrees west | Province: Carolinian

Taxon	Abundance (Number) R Valve*	L Valve	Total	Bored R Valve*	L Valve	Total	Relative Abundance (%)	Predation Intensity (%)
BIVALVIA								
Arcidae	227	59	286	196	46	242	60.72	169.23
Anadara ovalis	214	52	266	190	44	234	56.48	175.94
Barbatia candida	13	7	20	6	2	8	4.25	80.00
Mactridae	37	36	73	3	3	6	15.50	16.44
Mulinia lateralis	37	36	73	3	3	6	15.50	16.44
Noetidae	37	24	61	19	13	32	12.95	104.92
Noetia ponderosa	37	24	61	19	13	32	12.95	104.92
Ostreidea	29	0	29	0	0	0	6.16	0.00
Crassostrea virginica	29	0	29	0	0	0	6.16	0.00
Anomiidae	7	0	7	0	0	0	1.49	0.00
Anomia simplex	7	0	7	0	0	0	1.49	0.00
Cardiidae	2	2	4	1	2	3	0.85	150.00
Trachycardium muricatum	1	2	3	1	2	3	0.64	200.00
Trachycardium egmontium	1	0	1	0	0	0	0.21	0.00
Solinidae	2	1	3	0	0	0	0.64	0.00
Siliqua costata	2	1	3	0	0	0	0.64	0.00
Donacidae	1	1	2	1	0	1	0.42	100.00
Donax variabilis	1	1	2	1	0	1	0.42	100.00
TOTAL BIVALVIA	**342**	**123**	**465**	**220**	**64**	**284**	**98.72611465**	**122.15**
GASTROPODA								
Credpidulidae			2			0	0.85	0.00
Crepidula fornucata			2			0	0.85	0.00
Fissurellidae			1			0	0.42	0.00
Lucapina suffusa			1			0	0.42	0.00
TOTAL GASTROPODA			**3**			**0**	**1.27**	**0.00**
TOTAL		**n =**	**468**	**specimens**			**100.0**	**120.59**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **13 - Edisto Beach, South Carolina**

Latitude: 32.50 degrees north | Date Collected: November 24, 2000

Longitude: 80.32 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Mactridae	158	3	161	21	0	21	53.85	26.09
Mulinia lateralis	156	0	156	21	0	21	52.17	26.92
Rangia cuneata	2	3	5	0	0	0	1.67	0.00
Arcidae	46	9	55	4	3	7	18.39	25.45
Anadara transversa	31	8	39	4	3	7	13.04	35.90
Anadara ovalis	15	1	16	0	0	0	5.35	0.00
Veneridae	16	7	23	1	0	1	7.69	8.70
Chione elevata	15	6	21	0	0	0	7.02	0.00
Gemma gemma	1	0	1	1	0	1	0.33	200.00
Mercenaria mercenaria	0	1	1	0	0	0	0.33	0.00
Noetidae	7	4	11	0	0	0	3.68	0.00
Noetia ponderosa	7	4	11	0	0	0	3.68	0.00
Donacidae	4	5	9	0	0	0	3.01	0.00
Donax variabilis	4	5	9	0	0	0	3.01	0.00
Cardiidae	5	0	5	0	0	0	1.67	0.00
Trachycardium mericatum	5	0	5	0	0	0	1.67	0.00
Ostreidae	4	0	4	0	0	0	1.34	0.00
Crassostrea virginica	4	0	4	0	0	0	1.34	0.00
Pectinidae	1	0	1	0	0	0	0.33	0.00
Argopecten gibbus	1	0	1	0	0	0	0.33	0.00
Mytilidae	1	0	1	0	0	0	0.33	0.00
Brachiodontes sp.	1	0	1	0	0	0	0.33	0.00
Glycymerididae	1	0	1	0	0	0	0.33	0.00
Glycymeris undata	1	0	1	0	0	0	0.33	0.00
TOTAL BIVALVIA	**243**	**28**	**271**	**26**	**3**	**29**	**90.64**	**21.40**
GASTROPODA								
Crepidulidae			13			0	8.70	0.00
Crepidula aculeata			9			0	6.02	0.00
Crepidula fornucata			4			0	2.68	0.00
Terebidae			1			0	0.67	0.00
Terebra dislocata			1			0	0.67	0.00
TOTAL GASTROPODA			**14**			**0**	**9.36**	**0.00**
TOTAL		**n =**	**285**	**specimens**			**100.0**	**19.40**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **14 - Hilton Head, South Carolina**

Latitude: 32.15 degrees north | Date Collected: November 24, 2000

Longitude: 80.75 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Mactridae	464	0	464	212	0	212	80.42	91.38
Mulinia lateralis	464	0	464	212	0	212	0.80	91.38
Arcidae	29	25	54	12	12	24	9.36	88.89
Anadara brasiliana	18	11	29	10	7	17	5.03	117.24
Anadara ovalis	11	14	25	2	5	7	4.33	56.00
Lucinidae	19	11	30	5	3	8	5.20	53.33
Divaricella quadrisulcata	19	11	30	5	3	8	5.20	53.33
Noetidae	4	2	6	1	1	2	1.04	66.67
Noetia ponderosa	4	2	6	1	1	2	1.04	66.67
Veneridae	2	1	3	0	0	0	0.52	0.00
Dosinia discus	2	1	3	0	0	0	0.52	0.00
Donacidae	1	1	2	0	0	0	0.35	0.00
Donax variabilis	1	1	2	0	0	0	0.35	0.00
TOTAL BIVALVIA	**519**	**40**	**559**	**230**	**16**	**246**	**96.88**	**88.01**
GASTROPODA								
Naticidae								
Neverita duplicata			4			3	1.39	75.00
Terebidae								
Terebra dislocata			5			0	1.73	0.00
TOTAL GASTROPODA			**9**			**3**	**3.12**	**33.33**
TOTAL		**n =**	**568**	**specimens**			**100.0**	**86.31**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **15 - St. Simons Island, Georgia**

Latitude: 31.22 degrees north | Date Collected: November 26, 2000

Longitude: 81.36 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Arcidae	73	70	143	11	20	31	50.53	43.36
Anadara notabilis	71	65	136	11	18	29	48.06	42.65
Anadara ovalis	2	4	6	0	1	1	2.12	33.33
Barbatia candida	0	1	1	0	1	1	0.35	200.00
Tellinidae	92	0	92	4	0	4	32.51	8.70
Tellina spp.	92	0	92	4	0	4	32.51	8.70
Donacidae	15	22	37	2	2	4	13.07	21.62
Donax variabilis	15	22	37	2	2	4	13.07	21.62
Cardiidae	1	1	2	0	0	0	0.71	0.00
Dinocardium robustum	1	1	2	0	0	0	0.71	0.00
Mactridea	2	0	2	0	0	0	0.71	0.00
Mactra fragilis	2	0	2	0	0	0	0.71	0.00
Pectinidae	1	0	1	0	0	0	0.35	0.00
Argopecten gibbus	1	0	1	0	0	0	0.35	0.00
TOTAL BIVALVIA	**184**	**93**	**277**	**17**	**22**	**39**	**97.88**	**28.16**
GASTROPODA								
Crepidulidae			3			0	2.12	0.00
Crepidula fornucata			3			0	2.12	0.00
TOTAL GASTROPODA			**6**			**0**		**0.00**
TOTAL		**n =**	**283**	**specimens**			**100.0**	**26.99**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **16 - Ferdnandia Beach, Florida**

Latitude: 30.67 degrees north | Date Collected: March 13, 2000

Longitude: 81.47 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Donacidae	104	100	204	10	8	18	62.39	17.65
Donax variabilis	104	100	204	10	8	18	62.39	17.65
Mactridae	44	0	44	6	0	6	13.46	27.27
Mulinia lateralis	44	0	44	6	0	6	13.46	27.27
Arcidae	29	17	46	5	1	6	14.07	26.09
Anadara notabilis	16	10	26	4	1	5	7.95	38.46
Anadara ovalis	12	7	19	1	0	1	5.81	10.53
Anadra brasiliana	1	0	1	0	0	0	0.31	0.00
Noetia	4	5	9	0	0	0	2.75	0.00
Noetia ponderosa	4	5	9	0	0	0	2.75	0.00
Veneridae	2	1	3	0	0	0	0.92	0.00
Chione elevata	2	1	3	0	0	0	0.92	0.00
Glycymeridae	2	0	2	1	0	1	0.61	100.00
Glycymeris undata	2		2	1		1	0.61	100.00
Pectinidae	1	0	1	0	0	0	0.31	0.00
Argopecten gibbus	1	0	1	0	0	0	0.31	0.00
TOTAL BIVALVIA	**186**	**123**	**309**	**22**	**9**	**31**	**94.50**	**20.06**
GASTROPODA								
Crepidulidae			9			1	5.50	11.11
Crepidula fornucata			9			1	5.50	11.11
TOTAL GASTROPODA			**9**			**0**	**2.83**	11.11
TOTAL		**n =**	**318**	**specimens**			**97.3**	**18.96**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **17 - Guana State Park, Florida**

Latitude: 30.06 degrees north | Date Collected: March 13, 2000

Longitude: 81.35 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Donacidae	237	275	512	8	6	14	46.84	5.47
Donax variabilis	237	275	512	8	6	14	46.84	5.47
Mactridae	194	0	194	12	0	12	17.75	12.37
Mulinia lateralis	194	0	194	12	0	12	17.75	12.37
Arcidae	105	97	202	16	9	25	18.48	24.75
Anadara ovalis	101	91	192	15	9	24	17.57	25.00
Anadara notabalis	4	6	10	1	0	1	0.91	20.00
Tellinidae	149	0	149	10	0	10	13.63	13.42
Tellina spp.	149	0	149	10	0	10	13.63	13.42
Noetidae	15	14	29	1	1	2	2.65	13.79
Noetia ponderosa	15	14	29	1	1	2	2.65	13.79
Cardiidae	1	0	1	0	0	0	0.09	0.00
Dinocardium robustum	1	0	1	0	0	0	0.09	0.00
TOTAL BIVALVIA	**701**	**386**	**1087**	**47**	**16**	**63**	**99.45**	**11.59**
GASTROPODA								
Crepidulidae			3			0	0.55	0.00
Crepidula fornucata			2			0	0.37	0.00
Crepidula plana			1			0	0.18	
TOTAL GASTROPODA			**3**			**0**	**0.55**	0.00
TOTAL		**n =**	**1090**	**specimens**			**100.0**	**11.53**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **18 - Palm Coast, Florida**

Latitude: 29.58 degrees north | Date Collected: March 13, 2000

Longitude: 81.21 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Donacidae	378	330	708	24	31	55	84.99	15.54
Donax variabilis	378	330	708	24	31	55	84.99	15.54
Arcidae	30	37	67	6	8	14	8.04	41.79
Anadara ovalis	16	25	41	2	6	8	4.92	39.02
Anadara notabilis	12	11	23	3	1	4	2.76	34.78
Anadara brasiliana	2	1	3	1	1	2	0.36	133.33
Mactridae	34	0	34	5	0	5	4.08	29.41
Mulinia lateralis	34	0	34	5	0	5	4.08	29.41
Veneridae	6	0	6	1	0	1	0.72	33.33
Gemma gemma	6	0	6	1	0	1	0.72	33.33
Noetidae	7	8	15	0	0	0	1.80	0.00
Noetia ponderosa	7	8	15	0	0	0	1.80	0.00
Pectinidae	1	0	1	0	0	0	0.12	0.00
Argopecten gibbus	1		1	0		0	0.12	0.00
TOTAL BIVALVIA	**456**	**375**	**831**	**36**	**39**	**75**	**99.76**	**18.05**
GASTROPODA								
Crepidulidae			1			0	0.24	0
Crepidula fornucata			1			0	0.24	0.00
TOTAL GASTROPODA			**1**			**0**	**0.24**	0.00
TOTAL		**n =**	**832**	**specimens**			**100.0**	**18.01**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **19 - Ormond by the Sea, Florida**

Latitude: 29.28 degrees north | Date Collected: March 13, 2000

Longitude: 81.05 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Donacidae	149	259	408	22	27	49	91.69	24.02
Donax variabilis	149	259	408	22	27	49	91.69	24.02
Arcidae	17	9	26	3	1	4	5.84	30.77
Anadara ovalis	9	5	14	1	1	2	3.15	28.57
Anadara transversa	8	4	12	2	0	2	2.70	33.33
Noetidae	2	4	6	0	0	0	1.35	0.00
Noetia ponderosa	2	4	6	0	0	0	1.35	0.00
Mactidae	5	0	5	2	0	2	1.12	80.00
Mulinia lateralis	5	0	5	2	0	2	1.12	80.00
TOTAL BIVALVIA	**173**	**272**	**445**	**27**	**28**	**55**	**100.00**	**24.72**
TOTAL		**n =**	**445**	**specimens**			**100.0**	**24.72**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **20 - Eldora, Florida**

Latitude: 28.91 degrees north | Date Collected: March 14, 2000

Longitude: 80.82 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Donacidae	131	141	272	30	10	40	87.46	29.41
Donax variabilis	131	141	272	30	10	40	87.46	29.41
Noetidae	10	7	17	0	0	0	5.47	0.00
Noetia ponderosa	10	7	17	0	0	0	5.47	0.00
Arcidae	7	5	12	0	1	1	3.86	16.67
Anadara ovalis	7	4	11	0	0	0	3.54	0.00
Barbatia candida	0	1	1	0	1	1	0.32	200.00
Pectinidae	4	0	4	0	0	0	1.29	0.00
Argopecten gibbus	4	0	4	0	0	0	1.29	0.00
Veneridae	1	1	2	0	0	0	0.64	0.00
Chione elevata	1	1	2	0	0	0	0.64	0.00
Ostreidae	1	0	1	0	0	0	0.32	0.00
Crassostrea virginica	1	0	1	0	0	0	0.32	0.00
Glycymeridae	1	0	1	0	0	0	0.32	0.00
Glycymeris undata	1	0	1	0	0	0	0.32	0.00
TOTAL BIVALVIA	**155**	**154**	**309**	**30**	**11**	**41**	**99.36**	**26.54**
GASTROPODA								
Crepidulidae			1			0	0.64	0
Crepidula fornucata			1			0	0.64	0.00
TOTAL GASTROPODA			**1**			**0**	**0.64**	0.00
TOTAL		**n =**	**310**	**specimens**			**100.0**	**26.37**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **21 - Canaveral Beach, Florida**

Latitude: 28.68 degrees north | Date Collected: March 14, 2000

Longitude: 80.70 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Donacidae	363	332	695	33	29	62	80.25	17.84
Donax variabilis	363	332	695	33	29	62	80.25	17.84
Mactridae	109	0	109	14	0	14	12.59	25.69
Mulinia lateralis	109	0	109	14	0	14	12.59	25.69
Arcidae	26	15	41	2	2	4	4.73	19.51
Anadara ovalis	22	12	34	2	2	4	3.93	23.53
Anadara notabilis	4	3	7	0	0	0	0.81	0.00
Noetidae	3	5	8	1	0	1	0.92	25.00
Noetia ponderosa	3	5	8	1	0	1	0.92	25.00
Veneridae	6	0	6	0	0	0	0.69	0.00
Gemma gemma	6	0	6	0	0	0	0.69	0.00
Glycymerididae	4	0	4	0	0	0	0.46	0.00
Glycymeris undata	4	0	4	0	0	0	0.46	0.00
Plicatellidae	1	0	1	0	0	0	0.12	0.00
Plicatula gibbosa	1	0	1	0	0	0	0.12	0.00
TOTAL BIVALVIA	**512**	**352**	**864**	**50**	**31**	**81**	**99.77**	**18.75**
GASTROPODA								
Crepidulidae			1			0	0.23	0.00
Crepidula fornucata			1			0	0.23	0.00
TOTAL GASTROPODA			**1**			**0**	**0.23**	**0.00**
TOTAL		**n =**	**865**	**specimens**			**100.0**	**18.71**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **22 - Cocoa Beach, Florida**

Latitude: 28.19 degrees north | Date Collected: March 17, 2000

Longitude: 80.36 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Arcidae	263	192	455	34	33	67	68.22	29.45
Anadara ovalis	148	112	260	23	16	39	38.98	30.00
Anadara ponderosa	65	38	103	0	2	2	15.44	3.88
Barbatia candida	30	33	63	6	8	14	9.45	44.44
Anadara notabilis	20	9	29	5	7	12	4.35	82.76
Donacidae	3	7	10	3	5	8	1.50	160.00
Donax variabilis	3	7	10	3	5	8	1.50	160.00
Mactridae	7	0	7	4	0	4	1.05	0.00
Mulinia lateralis	7	0	7	4	0	4	1.05	114.29
Anomidae	4	0	4	0	0	0	0.60	0.00
Anomia simplex	4	0	4	0	0	0	0.60	0.00
Cardiidae	0	2	2	0	1	1	0.30	100.00
Trachycardium municatum	0	2	2	0	1	1	0.30	100.00
Pectinidae	1	0	1	0	0	0	0.15	0.00
Argopecten gibbus	1		1	0		0	0.15	0.00
TOTAL BIVALVIA	**278**	**201**	**479**	**41**	**39**	**80**	**71.81**	**33.40**
GASTROPODA								
Crepidulidae			94			0	28.19	0
Crepidula fornucata			94			0	28.19	0.00
TOTAL GASTROPODA			**94**			**0**	**28.19**	0.00
TOTAL		**n =**	**573**	**specimens**			**100.0**	**23.99**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **23 - Floridana Beach, Florida**

Latitude: 27.93 degrees north | Date Collected: March 17, 2000

Longitude: 80.50 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Arcidae	30	31	61	0	0	0	54.46	0.00
Anadara ovalis	17	21	38	0	0	0	33.93	0.00
Barbatia candida	13	10	23	0	0	0	20.54	0.00
Noetidae	26	17	43	0	0	0	38.39	0
Noetia ponderosa	26	17	43	0	0	0	38.39	0.00
Donacidae	1	1	2	0	0	0	1.79	0.00
Donax variabilis	1	1	2	0	0	0	1.79	0.00
Semelidae	0	1	1	0	1	1	0.89	200.00
Abra aequalis	0	1	1	0	1	1	0.89	200.00
Anomidae	1	0	1	0	0	0	0.89	0.00
Anomia simplex	1	0	1	0	0	0	0.89	0.00
Pectinidae	1	0	1	0	0	0	0.89	0.00
Argopecten gibbus	1	0	1	0	0	0	0.89	0.00
Cardiidae	1	0	1	0	0	0	0.89	0.00
Dinocardium robustum	1	0	1	0	0	0	0.89	0.00
TOTAL BIVALVIA	**60**	**50**	**110**	**0**	**1**	**1**	**98.21**	**1.82**
GASTROPODA								
Crepidulidae			1			0	1.79	0.00
Crepidula fornucata			1			0	1.79	0.00
TOTAL GASTROPODA			**1**			**0**	**1.79**	0.00
TOTAL		**n =**	**111**	**specimens**			**100.0**	**1.79**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **24 - Sebastian Inlet, Florida**

Latitude: 27.85 degrees north | Date Collected: March 12, 2000

Longitude: 80.43 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Donacidae	39	60	99	9	10	19	35.61	38.38
Donax variabilis	39	60	99	9	10	19	35.61	38.38
Arcidae	41	25	66	3	3	6	23.74	18.18
Anadara notabilis	35	22	57	3	3	6	20.50	21.05
Anadara ovalis	6	3	9	0	0	0	3.24	0.00
Tellinidae	39	0	39	4	0	4	14.03	20.51
Tellina spp.	39	0	39	4	0	4	14.03	20.51
Veneridae	22	25	47	1	1	2	16.91	8.51
Chione elevata	22	25	47	1	1	2	16.91	8.51
Noetidae	13	8	21	0	0	0	7.55	0.00
Noetia ponderosa	13	8	21	0	0	0	7.55	0.00
Pectinidae	3	0	3	0	0	0	1.08	0.00
Argopecten gibbus	3	0	3	0	0	0	1.08	0.00
Glycemeridae	1	0	1	0	0	0	0.36	0.00
Glycymeris arata	1	0	1	0	0	0	0.36	0.00
TOTAL BIVALVIA	**158**	**118**	**276**	**17**	**14**	**31**	**99.28**	**22.46**
GASTROPODA								
Crepidulidae			1			0	0.72	0
Crepidula fornucata			1			0	0.72	0.00
TOTAL GASTROPODA			**1**			**0**	**0.72**	0.00
TOTAL		**n =**	**277**	**specimens**			**100.0**	**22.30**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **25 - Hutchinson Island, Florida**

Latitude: 27.28 degrees north | Date Collected: March 17, 2000

Longitude: 81.22 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Anomidae	103	0	103	2	0	2	22.01	3.88
Anomia simplex	103	0	103	2	0	2	22.01	3.88
Veneridae	22	36	58	2	6	8	12.39	27.59
Chione granulata	22	35	57	2	6	8	12.18	28.07
Dosinia sp.	0	1	1	0	0	0	0.21	0.00
Tellinidae	49	0	49	10	0	10	10.47	40.82
Tellina spp.	49	0	49	10	0	10	10.47	40.82
Arcidae	28	21	49	0	0	2	10.47	8.16
Anadara notabilis	28	21	49	0	0	2	10.47	8.16
Pectinidae	48	0	48	0	0	0	10.26	0.00
Argopecten gibbus	48	0	48	0	0	0	10.26	0.00
Glycymerididae	31	0	31	4	0	4	6.62	25.81
Glycymeris undata	31	0	31	4	0	4	6.62	25.81
Corbulidae	4	6	10	2	0	2	2.14	40.00
Corbula sp.	4	6	10	2	0	2	2.14	40.00
Cardiidae	5	0	5	0	0	0	1.07	0.00
Trachycardium mericatum	5	0	5	0	0	0	1.07	0.00
Noetidae	0	1	1	0	0	0	0.21	0.00
Noetia ponderosa	0	1	1	0	0	0	0.21	0.00
TOTAL BIVALVIA	**290**	**64**	**354**	**20**	**6**	**28**	**75.64**	**15.82**
GASTROPODA								
Crepidulidae			57			0	24.36	0.00
Crepidula fornucata			57			0	24.36	0.00
TOTAL GASTROPODA			**57**			**0**	**24.36**	0.00
TOTAL		**n =**	**411**	**specimens**			**100.0**	**11.97**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **26 - Jupiter Island, Florida**

Latitude: 27.03 degrees north | Date Collected: March 17, 2000

Longitude: 80.10 degrees west | Province: Carolinian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Glycymerididae	682	0	682	49	0	49	76.37	14.37
Glycymeris undata	682	0	682	49	0	49	76.37	14.37
Veneridae	14	23	37	1	2	3	4.14	16.22
Chione granulata	7	13	20	1	1	2	2.24	20.00
Chione elevata	7	10	17	0	1	1	1.90	11.76
Arcidae	12	5	17	3	1	4	1.90	47.06
Anadara ovalis	6	3	9	2	1	3	1.01	66.67
Barbatia candida	6	2	8	1	0	1	0.90	25.00
Noetia	3	4	7	0	0	0	0.78	0
Noetia ponderosa	3	4	7	0	0	0	0.78	0.00
Tellinidae	7	0	7	0	0	0	0.78	0.00
Tellina spp.	7	0	7	0	0	0	0.78	0.00
Mactridae	2	0	2	0	0	0	0.22	0.00
Mactra fragilis	2	0	2	0	0	0	0.22	0.00
Plicatulidae	2	0	2	0	0	0	0.22	0.00
Plicatula gibbosa	2	0	2	0	0	0	0.22	0.00
Lucinidae	1	0	1	0	0	0	0.11	0.00
Anadontia alba	1	0	1	0	0	0	0.11	0.00
Anomidae	1	0	1	0	0	0	0.11	0.00
Anomia simplex	1	0	1	0	0	0	0.11	0.00
Cardiidae	1	0	1	0	0	0	0.11	0.00
Trachycardium mericatum	1	0	1	0	0	0	0.11	0.00
TOTAL BIVALVIA	**725**	**32**	**757**	**53**	**3**	**56**	**84.77**	**14.80**
GASTROPODA								
Crepidulidae			68			0	15.23	0.00
Crepidula fornucata			68			0	15.23	0.00
TOTAL GASTROPODA			**68**			**0**	**15.23**	0.00
TOTAL		**n =**	**825**	**specimens**			**100.0**	**12.54**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **27 - Marco Island, Florida**

Latitude: 25.94 degrees north | Date Collected: May 25, 2000

Longitude: 81.72 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Arcidae	271	294	565	11	10	21	62.92	7.43
Anadara notabilis	271	294	565	11	10	21	62.92	7.43
Veneridae	74	56	130	3	3	6	14.48	9.23
Chione elevata	74	55	129	3	3	6	14.37	9.30
Macrocallista nimbosa	0	1	1	0	0	0	0.11	0.00
Donacidae	32	40	72	0	1	1	8.02	2.78
Donax variabilis	32	40	72	0	1	1	8.02	2.78
Anomidae	33	0	33	0	0	0	3.67	0.00
Anomia simplex	33	0	33	0	0	0	3.67	0.00
Mactridae	33	1	34	2	0	2	3.79	0.00
Mactra fragilis	31	0	31	2	0	2	3.45	12.90
Mulinia lateralis	2	1	3	0	0	0	0.33	0.00
Noetidae	9	15	24	0	0	0	2.67	0.00
Noetia ponderosa	9	15	24	0	0	0	2.67	0.00
Semelidae	2	8	10	0	0	0	1.11	0.00
Abra aequalis	2	8	10	0	0	0	1.11	0.00
Pectinidae	9	0	9	0	0	0	1.00	0.00
Argopecten gibbus	9	0	9	0	0	0	1.00	0.00
Plicatellidae	8	0	8	0	0	0	0.89	0.00
Plicatula gibbosa	8	0	8	0	0	0	0.89	0.00
Carditidae	2	5	7	0	0	0	0.78	0.00
Carditamera floridana	2	5	7	0	0	0	0.78	0.00
TOTAL BIVALVIA	**473**	**419**	**892**	**16**	**14**	**30**	**99.33**	**6.73**
GASTROPODA								
Crepidulidae			3			0	0.67	0.00
Crepidula fornucata			3			0	0.67	0.00
TOTAL GASTROPODA			**3**			**0**	**0.67**	0.00
TOTAL		**n =**	**895**	**specimens**			**100.0**	**6.68**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **28 - Naples, Florida**

Latitude: 26.25 degrees north | Date Collected: May 25, 2000

Longitude: 81.80 degrees west | Provonce: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	195	250	445	35	54	89	65.54	39.91
Chione elevata	192	249	441	34	54	88	64.95	39.91
Dosinia sp.	1	1	2	1	0	1	0.29	100.00
Gemma gemma	2	0	2	0	0	0	0.29	0.00
Arciddae	49	19	68	5	1	6	10.01	17.65
Anadara ovalis	49	19	68	5	1	6	10.01	17.65
Donacidae	32	24	56	0	0	0	8.25	0.00
Donax variabilis	32	24	56	0	0	0	8.25	0.00
Chamidae	8	15	23	0	1	1	3.39	8.70
Arcinella cornuta	8	15	23	0	1	1	3.39	8.70
Plicatulidae	23	0	23	0	0	0	3.39	0.00
Plicatula gibbosa	23		23	0		0	3.39	0.00
Noetidae	9	8	17	0	0	0	2.50	0.00
Noetia ponderosa	9	8	17	0	0	0	2.50	0.00
Pectinidae	5	0	5	0	0	0	0.74	0.00
Argopecten gibbus	5	0	5	0	0	0	0.74	0.00
Carditidae	3	2	5	0	0	0	0.74	0.00
Carditamera floridana	3	2	5	0	0	0	0.74	0.00
Tellinidae	3	0	3	0	0	0	0.44	0.00
Tellina spp.	3	0	3	0	0	0	0.44	0.00
Glycymerididae	2	0	2	0	0	0	0.29	0.00
Glycymeris undata	2	0	2	0	0	0	0.29	0.00
Lucinidae	1	0	1	0	0	0	0.15	0.00
Divarcella quadrisulcata	1	0	1	0	0	0	0.15	0.00
Cardiidae	1	0	1	0	0	0	0.15	0.00
Trachycardium mericatum	1	0	1	0	0	0	0.15	0.00
TOTAL BIVALVIA	**331**	**318**	**649**	**40**	**56**	**96**	**95.58**	**29.58**
GASTROPODA								
Crepidulidae			15			0	4.42	0.00
Crepidula plana			9			0	2.65	0.00
Crepidula fornucata			5			0	1.47	0.00
Crepidula aculeata			1			0	0.29	0.00
TOTAL GASTROPODA			**15**			**0**	**4.42**	0.00
TOTAL		**n =**	**664**	**specimens**			**100.0**	**28.28**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **29 - Bonita Beach, Florida**

Latitude: 26.35 degrees north | Date Collected: May 25, 2000

Longitude: 81.85 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	103	119	222	3	2	5	53.37	4.50
Chione elevata	103	119	222	3	2	5	53.37	4.50
Arcidae	69	55	124	4	2	6	29.81	9.68
Anadara ovalis	69	54	123	4	2	6	29.57	9.76
Anadara notabilis	0	1	1	0	0	0	0.24	0.00
Noetidae	31	17	48	3	1	4	11.54	16.67
Noetia ponderosa	31	17	48	3	1	4	11.54	16.67
Donacidae	6	11	17	0	0	0	4.09	0.00
Donax variabilis	6	11	17	0	0	0	4.09	0.00
Pectinidae	2	0	2	0	0	0	0.48	0.00
Argopecten gibbus	2	0	2	0	0	0	0.48	0.00
Chamidae	1	0	1	0	0	0	0.24	0.00
Arcinella cornuta	1	0	1	0	0	0	0.24	0.00
Carditidae	0	1	1	0	0	0	0.24	0.00
Carditamera floridana	0	1	1	0	0	0	0.24	0.00
Cardiidae	1	0	1	0	0	0	0.24	0.00
Trachycardium mericatum	1	0	1	0	0	0	0.24	0.00
TOTAL BIVALVIA	**213**	**203**	**416**	**10**	**5**	**15**	**100.00**	**7.21**
TOTAL		**n =**	**416**	**specimens**			**100.0**	**7.21**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **30 - Sanibel Island, Florida**

Latitude: 26.43 degrees north | Date Collected: May 25, 2000

Longitude: 82.10 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	195	197	392	2	9	11	48.88	5.61
Chione elevata	195	197	392	2	9	11	48.88	5.61
Arcidae	105	79	184	5	2	7	22.94	7.61
Anadra ovalis	105	79	184	5	2	7	22.94	7.61
Plicatulidae	48	0	48	0	0	0	5.99	0.00
Plicatula gibbosa	48	0	48	0	0	0	5.99	0.00
Donacidae	20	14	34	0	0	0	4.24	0.00
Donax variabilis	20	14	34	0	0	0	4.24	0.00
Anomiidae	28	0	28	0	0	0	3.49	0.00
Anomia simplex	28	0	28	0	0	0	3.49	0.00
Noetidae	7	15	22	0	0	0	2.74	0.00
Noetia ponderosa	7	15	22	0	0	0	2.74	0.00
Glycymeridae	13	0	13	0	0	0	1.62	0.00
Glycymeris undata	13	0	13	0	0	0	1.62	0.00
Mactridae	6	7	13	0	0	0	1.62	0.00
Mactra fragilis	6	7	13	0	0	0	1.62	0.00
Carditidae	7	8	15	0	0	0	1.87	0.00
Carditamere floridana	7	8	15	0	0	0	1.87	0.00
Pectinidae	9	0	9	0	0	0	1.12	0.00
Argopecten gibbus	9	0	9	0	0	0	1.12	0.00
Lucinidae	1	2	3	0	0	0	0.37	0.00
Lucina sp.	1	2	3	0	0	0	0.37	0.00
Cardiidea	1	0	1	0	0	0	0.12	0.00
Trachycardium mericatum	1	0	1	0	0	0	0.12	0.00
TOTAL BIVALVIA	**440**	**322**	**762**	**7**	**11**	**18**	**95.01**	**4.72**
GASTROPODA								
Crepidulidae			10			0	2.49	0.00
Crepidula plana			10			0	2.49	0.00
Strombidae			3			0	0.75	0.00
Strombus alatus			3			0	0.75	0.00
Melongenidae			2			0	0.50	0.00
Busycon spp.			2			0	0.50	0.00
Cerithiidae			2			0	0.50	0.00
Cerithium sp.			2			0	0.50	0.00
Olividae			2			0	0.50	0.00
Oliva sp.			2			0	0.50	0.00
Muricidae			1			0	0.25	0.00
Urosalpinx cinerea			1			0	0.25	0.00
TOTAL GASTROPODA			**20**			**0**	**4.99**	0.00
TOTAL		**n =**	**782**	**specimens**			**100.0**	**4.49**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **31 - Venice Beach, Florida**

Latitude: 27.42 degrees north | Date Collected: May 25, 2000

Longitude: 82.26 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Donacidae	444	298	742	31	36	67	78.60	18.06
Donax variabilis	444	298	742	31	36	67	78.60	18.06
Veneridae	41	62	103	4	2	6	10.91	11.65
Chione elevata	41	62	103	4	2	6	10.91	11.65
Arcidae	41	30	71	4	1	5	7.52	14.08
Barbatia candida	29	27	56	1	1	2	5.93	7.14
Anadara ovalis	11	3	14	3	0	3	1.48	42.86
Anadra notabilis	1	0	1	0	0	0	0.11	0.00
Noetidae	5	6	11	0	0	0	1.17	0.00
Noetia ponderosa	5	6	11	0	0	0	1.17	0.00
Carditidae	0	3	3	0	0	0	0.32	0.00
Carditamera floridana	0	3	3	0	0	0	0.32	0.00
Plicatelidae	2	0	2	0	0	0	0.21	0.00
Plicatula gibbosa	2	0	2	0	0	0	0.21	0.00
Mactridae	6	0	6	3	0	3	0.64	0.00
Mactra fragilis	1	0	1	0	0	0	0.11	0.00
Mulinia lateralis	5	0	5	3	0	3	0.53	120.00
TOTAL BIVALVIA	**539**	**399**	**938**	**42**	**39**	**81**	**99.36**	**17.27**
GASTROPODA								
Crepidulidae			3			0	0.64	0.00
Crepidula fornucata			2			0	0.42	0.00
Crepidula plana			1			0	0.21	0.00
TOTAL GASTROPODA			**3**			**0**	**0.64**	0.00
TOTAL		**n =**	**941**	**specimens**			**100.0**	**17.16**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **32 - Longboat Key, Florida**

Latitude: 27.39 degrees north | Date Collected: May 25, 2010

Longitude: 82.64 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Arcidae	146	107	253	4	3	7	29.73	5.53
Anadra ovalis	146	107	253	4	3	7	29.73	5.53
Veneridae	149	116	265	11	14	25	31.14	18.87
Chione elevata	123	93	216	8	12	20	25.38	18.52
Chione grus	17	17	34	3	2	5	4.00	29.41
Macrocallista nimbosa	9	6	15	0	0	0	1.76	0.00
Donacidae	101	73	174	6	3	9	20.45	10.34
Donax variabilis	101	73	174	6	3	9	20.45	10.34
Plicatellidae	36	0	36	0	0	0	4.23	0.00
Plicatula gibbosa	36	0	36	0	0	0	4.23	0.00
Cardiidae	20	2	22	1	0	1	2.59	0.00
Trachycardium mericatum	17	0	17	1	0	1	2.00	11.76
Laevicardium laevigatum	3	2	5	0	0	0	0.59	0.00
Pectinidae	15	0	15	0	0	0	1.76	0.00
Argopecten gibbus	15	0	15	0	0	0	1.76	0.00
Glycymeridae	8	0	8	1	0	1	0.94	25.00
Glycymeris undata	8	0	8	1	0	1	0.94	25.00
Tellinidae	6	0	6	1	0	1	0.71	33.33
Tellina spp.	6	0	6	1	0	1	0.71	33.33
Lucinidae	4	5	9	0	0	0	1.06	0.00
Lucina sp.	2	3	5	0	0	0	0.59	0.00
Parvilucina nassula	2	2	4	0	0	0	0.47	0.00
Mactridae	5	0	5	0	0	0	0.59	0.00
Mactra sp.	5	0	5	0	0	0	0.59	0.00
Noetidae	3	1	4	0	0	0	0.47	0.00
Noetia ponderosa	3	1	4	0	0	0	0.47	0.00
Anomidae	2	0	2	0	0	0	0.24	0.00
Anomia simplex	2	0	2	0	0	0	0.24	0.00
Chamidae	1	0	1	0	0	0	0.12	0.00
Arcinella cornuta	1	0	1	0	0	0	0.12	0.00
Carditidae	1	0	1	0	0	0	0.12	0.00
Carditamera floridana	1	0	1	0	0	0	0.12	0.00
TOTAL BIVALVIA	**497**	**304**	**801**	**24**	**20**	**44**	**94.12**	**10.99**
GASTROPODA								
Crepidulidae			21			0	4.94	0.00
Crepidula fornucata			21			0	4.94	0.00
Terebidae			3			0	0.71	0.00
Terebra spp.			3			0	0.71	0.00
Olividae			1			0	0.24	0.00
Oliva sp.			1			0	0.24	0.00
TOTAL GASTROPODA			**25**			**0**	**5.88**	0.00
TOTAL		**n =**	**826**	**specimens**			**100.0**	**10.34**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **33 - Lido Beach, Florida**

Latitude: 27.43 degrees north | Date Collected: May 25, 2000

Longitude: 84.44 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	162	154	316	11	1	12	47.66	7.62
Chione elevata	162	153	315	11	1	12	47.51	7.62
Macrocalista nimbosa	0	1	1	0	0	0	0.15	0.00
Arcidae	80	63	143	1	1	2	21.57	0.00
Anadra ovalis	80	62	142	1	1	2	21.42	2.82
Arca zebra	0	1	1	0	0	0	0.15	0.00
Donacidae	50	32	82	3	2	5	12.37	12.20
Donax variabilis	50	32	82	3	2	5	12.37	12.20
Anomidae	27	0	27	0	0	0	4.07	0.00
Anomia simplex	27	0	27	0	0	0	4.07	0.00
Mactridae	18	0	18	2	0	2	2.71	22.22
Mactra fragilis	18	0	18	2	0	2	2.71	22.22
Cardiidae	12	0	12	0	0	0	1.81	0.00
Trachycardium mericatum	12	0	12	0	0	0	1.81	0.00
Noetidae	2	9	11	0	0	0	1.66	0.00
Noetia ponderosa	2	9	11	0	0	0	1.66	0.00
Pectinidae	7	0	7	0	0	0	1.06	0.00
Argopecten gibbus	7	0	7	0	0	0	1.06	0.00
Carditidae	2	3	5	0	0	0	0.75	0.00
Carditimera floridana	2	3	5	0	0	0	0.75	0.00
Lucinidae	2	1	3	0	0	0	0.45	0.00
Lucina sp.	2	1	3	0	0	0	0.45	0.00
Plicatulidae	1	0	1	0	0	0	0.15	0.00
Plicatula gibbosa	1	0	1	0	0	0	0.15	0.00
TOTAL BIVALVIA	**363**	**262**	**625**	**17**	**4**	**21**	**94.27**	**6.72**
GASTROPODA								
Crepidulidae			19			0	5.73	0.00
Crepidula fornucata			16			0	4.83	0.00
Crepidula plana			2			0	0.60	0.00
Crepidula aculeata			1			0	0.30	0.00
TOTAL GASTROPODA			**19**			**0**	**5.73**	0.00
TOTAL		**n =**	**644**	**specimens**			**100.0**	**6.33**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **34 - Anna Maria Island, Florida**

Latitude: 27.50 degrees north | Date Collected: May 25, 2000

Longitude: 82.75 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	345	393	738	53	83	136	83.86	36.86
Chione elevata	341	393	734	53	83	136	83.41	37.06
Dosinia sp.	4	0	4	0	0	0	0.45	0.00
Arcidae	52	48	100	2	3	5	11.36	10.00
Anadara notabilis	52	48	100	2	3	5	11.36	10.00
Plicatelidae	9	0	9	0	0	0	1.02	0.00
Plicatula gibbosa	9	0	9	0	0	0	1.02	0.00
Donacidae	4	4	8	0	0	0	0.91	0.00
Donax variabilis	4	4	8	0	0	0	0.91	0.00
Carditidae	3	1	4	0	0	0	0.45	0.00
Carditamera floridana	3	1	4	0	0	0	0.45	0.00
Chamidae	1	1	2	0	0	0	0.23	0.00
Arcinella cornuta	1	1	2	0	0	0	0.23	0.00
Cardiiae	2	0	2	0	0	0	0.23	0.00
Trachycardium mericatum	2	0	2	0	0	0	0.23	0.00
Anomidae	1	0	1	0	0	0	0.11	0.00
Anomia simplex	1	0	1	0	0	0	0.11	0.00
Pectinidae	1	0	1	0	0	0	0.11	0.00
Argopecten gibbus	1	0	1	0	0	0	0.11	0.00
Glycymeridae	1	0	1	0	0	0	0.11	0.00
Glycymeris undata	1	0	1	0	0	0	0.11	0.00
TOTAL BIVALVIA	**419**	**447**	**866**	**55**	**86**	**141**	**98.40**	**32.56**
GASTROPODA								
Crepidulidae			5			0	1.14	0
Crepidula fornucata			5			0	1.14	0.00
Teribidae			2			0	0.45	0
Terebra dislocata			2			0	0.45	
TOTAL GASTROPODA			**7**			**0**	**1.59**	0.00
TOTAL		**n =**	**873**	**specimens**			**100.0**	**32.05**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **35 - Honeymoon Island #1, Florida**

Latitude: 28.07 degrees north | Date Collected: May 25, 2010

Longitude: 82.83 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	127	130	257	3	3	6	73.01	4.67
Chione elevata	127	130	257	3	3	6	73.01	4.67
Tellinidae	14	0	14	2	0	2	3.98	28.57
Tellina spp.	14	0	14	2	0	2	3.98	28.57
Anomidae	11	0	11	0	0	0	3.13	0.00
Anomia simplex	11	0	11	0	0	0	3.13	0.00
Cardiidae	9	0	9	0	0	0	2.56	0.00
Trachycardium mericatum	9	0	9	0	0	0	2.56	0.00
Lucinidae	1	7	8	0	0	0	2.27	0.00
Parvilucina multilineata	1	5	6	0	0	0	1.70	0.00
Parvilucina nassula	0	2	2	0	0	0	0.57	0.00
Pectinidae	4	0	4	0	0	0	1.14	0.00
Argopecten gibbus	4	0	4	0	0	0	1.14	0.00
Donacidae	1	2	3	1	0	1	0.85	66.67
Donax variabilis	1	2	3	1	0	1	0.85	66.67
Noetidae	1	1	2	0	0	0	0.57	0.00
Noetia ponderosa	1	1	2	0	0	0	0.57	0.00
TOTAL BIVALVIA	**168**	**140**	**308**	**6**	**3**	**9**	**87.50**	**5.84**
GASTROPODA								
Crepidulidae			12			0	6.82	0.00
Crepidula plana			7			0	3.98	0.00
Crepidula fornucata			3			0	1.70	0.00
Crepidula aculeata			2			0	1.14	0.00
Turbinidae			4			0	2.27	0.00
Turbo castanea			4			0	2.27	0.00
Terebidae			3			0	1.70	0.00
Terebra spp.			3			0	1.70	0.00
Bullidae			2			0	1.14	0.00
Bulla umbilicata			2			0	1.14	0.00
Fasciolariidae			1			0	0.57	0.00
Fasciolaria lilium			1			0	0.57	0.00
TOTAL GASTROPODA			**22**			**0**	**12.50**	0.00
TOTAL		**n =**	**330**	**specimens**			**100.0**	**5.11**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **36 - Honeymoon Island #2, Florida**

Latitude: 28.07 degrees north | Date Collected: May 25, 2000

Longitude: 82.83 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	161	177	338	9	11	20	72.69	11.83
Chione elevata	159	177	336	9	11	20	72.26	11.90
Mercenaria campechienses	1	0	1	0	0	0	0.22	0.00
Macrocallista nimbosa	1	0	1	0	0	0	0.22	0.00
Anomidae	17	0	17	0	0	0	3.66	0.00
Anomia simplex	17	0	17	0	0	0	3.66	0.00
Lucinidae	10	6	16	1	0	1	3.44	12.50
Parvilucina multilineata	10	6	16	1	0	1	3.44	12.50
Pectinidae	14	0	14	0	0	0	3.01	0.00
Argopecten gibbus	14	0	14	0	0	0	3.01	0.00
Cardiidae	7	0	7	0	0	0	1.51	0.00
Trachycardium mericatum	7	0	7	0	0	0	1.51	0.00
Tellinidae	11	0	11	0	0	0	2.37	0.00
Tellina sp.	11	0	11	0	0	0	2.37	0.00
Donacidae	1	7	8	0	0	0	1.72	0.00
Donax variabilis	1	7	8	0	0	0	1.72	0.00
Arcidae	1	3	4	0	1	1	0.86	50.00
Anadara notabilis	1	3	4	0	1	1	0.86	50.00
Plicatulidae	2	0	2	0	0	0	0.43	0.00
Plicatula gibbosa	2	0	2	0	0	0	0.43	0.00
Mactridae	2	0	2	0	0	0	0.43	0.00
Mactra fragilis	2	0	2	0	0	0	0.43	0.00
TOTAL BIVALVIA	**226**	**193**	**419**	**10**	**12**	**22**	**90.11**	**10.50**
GASTROPODA								
Crepidulidae			11			0	4.73	0.00
Crepidula plana			8			0	3.44	0.00
Crepidula fornucata			3			0	1.29	0.00
Turbinidae			4			0	1.72	0.00
Turbo castanea			4			0	1.72	0.00
Bullidae			4			0	1.72	0.00
Bulla umbilicata			4			0	1.72	0.00
Nassariidae			2			0	0.86	0.00
Nassarius vibex			2			0	0.86	0.00
Coniidae			1			0	0.43	0.00
Conus floridana			1			0	0.43	0.00
Terebidae			1			0	0.43	0.00
Terebra sp.			1			0	0.43	0.00
TOTAL GASTROPODA			**23**			**0**	**9.89**	0.00
TOTAL		**n =**	**442**	**specimens**			**100.0**	**9.46**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **37 - Honeymoon Island #3, Florida**

Latitude: 28.07 degrees north | Date Collected: May 25, 2000

Longitude: 82.83 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	117	139	256	9	5	14	69.00	10.94
Chione elevata	117	139	256	9	5	14	69.00	10.94
Tellinidae	16	0	16	2	0	2	4.31	25.00
Tellina sp.	16	0	16	2	0	2	4.31	25.00
Anomidae	14	0	14	1	0	1	3.77	14.29
Anomia simplex	14	0	14	1	0	1	3.77	14.29
Lucinidae	6	4	10	0	1	1	2.70	20.00
Parvilucina multilineata	6	4	10	0	1	1	2.70	20.00
Pectinidae	4	0	4	0	0	0	1.08	0.00
Argopecten gibbus	4	0	4	0		0	1.08	0.00
Cardiidae	5	0	5	0	0	0	1.35	0.00
Trachycardium mericatum	5	0	5	0	0	0	1.35	0.00
Arcidae	4	6	10	0	0	0	2.70	0.00
Anadara notabilis	2	5	7	0	0	0	1.89	0.00
Barbatia candida	2	1	3	0	0	0	0.81	0.00
Donacidae	0	3	3	0	0	0	0.81	0.00
Donax variabilis	0	3	3	0	0	0	0.81	0.00
Mytilidae	0	1	1	0	0	0	0.27	0.00
Brachiodontes exustus	0	1	1	0	0	0	0.27	0.00
TOTAL BIVALVIA	**166**	**153**	**319**	**12**	**6**	**18**	**85.98**	**11.29**
GASTROPODA								
Crepidulidae			21			0	11.32	0.00
Crepidula plana			14			0	7.55	0.00
Crepidula fornucata			4			0	2.16	0.00
Crepidula aculeata			3			0	1.62	0.00
Turbinidae			2			0	1.08	0.00
Turbo castanea			2			0	1.08	0.00
Terebidae			2			0	1.08	0.00
Terebra dislocata			2			0	1.08	0.00
Muricidae			1			0	0.54	0.00
Urosalpinx cinerea			1			0	0.54	0.00
Bullidae			1			0	0.54	0.00
Bulla umbilicata			1			0	0.54	0.00
Naticidae			1			1	0.54	100.00
Neverita duplicata			1			1	0.54	100.00
TOTAL GASTROPODA			**26**			**0**	**14.02**	**0.00**
TOTAL		**n =**	**345**	**specimens**			**100.0**	**9.70**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **38 - Gulfshores, Alabama**

Latitude: 30.25 degrees north | Date Collected: July 18, 2000

Longitude: 87.69 degrees west | Province: Gulf - Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Mactridae	70	80	150	0	0	0	96.15	0.00
Rangia cuneata	70	80	150	0	0	0	96.15	0.00
Ostreidea	6	0	6	0	0	0	3.85	0.00
Crassostrea virginica	6	0	6	0	0	0	3.85	0.00
TOTAL BIVALVIA			**156**			**0**	**100.0**	**0.00**
TOTAL		**n =**	**78**	**specimens**			**100.0**	**0.00**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **39 - Sabine Pass, Texas**

Latitude: 29.38 degrees north Date Collected: July 18, 2000

Longitude: 94.78 degrees west Province Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Mactridae	403	0	403	32	0	32	81.91	15.88
Mulinia spp.	403	0	403	32	0	32	81.91	15.88
Veneridae	43	14	57	3	2	5	11.59	17.54
Gemma gemma	43	0	43	3	0	3	8.74	13.95
Chione elevata	0	14	14	0	2	2	2.85	28.57
Arcidae	1	0	1	0	0	0	0.20	0.00
Anadara transversa	9	6	15	2	0	2	3.05	26.67
Anadara ovalis	1	0	1	0	0	0	0.20	0.00
Anomiidae	5	0	5	0	0	0	1.02	0.00
Anomia simplex	5	0	5	0	0	0	1.02	0.00
Donacidae	0	2	2	0	0	0	0.41	0.00
Donax variabilis	0	2	2	0	0	0	0.41	0.00
Cardiidae	2	0	2	0	0	0	0.41	0.00
Trachycardium muricatum	2	0	2	0	0	0	0.41	0.00
TOTAL BIVALVIA	**454**	**16**	**470**	**35**	**2**	**37**	**95.53**	**15.74**
GASTROPODA								
Crepidulidae			11			1	4.47	9.09
Crepidula fornucata			6			1	1.22	16.67
Crepidiula plana			5			0	1.02	0.00
TOTAL GASTROPODA			**11**			**1**	**4.47**	**9.09**
TOTAL		**n =**	**246**	**specimens**			**100.0**	**15.45**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **40 - Port Bolivar, Texas**

Latitude: 29.38 degrees north | Date Collected: July 18, 2000

Longitude: 94.78 degrees west | Province Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Noetidae	56	158	214	4	14	18	32.42	16.82
Noetia ponderosa	56	158	214	4	14	18	32.42	16.82
Arcidae	74	48	122	11	9	20	18.48	32.79
Anadara ovalis	35	22	57	8	5	13	8.64	45.61
Barbatia candida	31	20	51	3	2	5	7.73	19.61
Anadara notabilis	7	6	13	0	2	2	1.97	30.77
Anadontia alba	1	0	1	0	0	0	0.15	0.00
Tellinidae	169	0	169	48	0	48	25.61	56.80
Tellina spp.	169	0	169	48	0	48	25.61	56.80
Donacidae	50	42	92	10	21	31	13.94	67.39
Donax variabilis	50	42	92	10	21	31	13.94	67.39
Mactirdae	13	13	26	1	0	1	3.94	7.69
Rangia cuneata	11	13	24	1	0	1	3.64	8.33
Mactra fragilis	2	0	2	0	0	0	0.30	0.00
Veneridae	13	12	25	2	1	3	3.79	24.00
Chione elevata	11	12	23	2	1	3	3.48	26.09
Chione lateralis	2	0	2	0	0	0	0.30	0.00
Ostreidae	7	0	7	0	0	0	1.06	0.00
Crassostrea virginica	7	0	7	0	0	0	1.06	0.00
Pectinidae	3	0	3	0	0	0	0.45	0.00
Argopecten gibbus	3	0	3	0	0	0	0.45	0.00
Anomiidae	1	0	1	0	0	0	0.15	0.00
Anomia simplex	1	0	1	0	0	0	0.15	0.00
Cardiidae	0	1	1	0	0	0	0.15	0.00
Trachycardium muricatum	0	1	1	0	0	0	0.15	0.00
TOTAL BIVALVIA	**386**	**274**	**660**	**76**	**45**	**121**	**100**	**36.67**
TOTAL		**n =**	**660**	**specimens**			**100.0**	**36.67**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **41 - Surfside Beach, Texas**

Latitude: 28.94 degrees north | Date Collected: July 18, 2000

Longitude: 95.29 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Arcidae	141	152	293	7	5	12	37.86	8.19
Anadara ovalis	78	99	177	2	2	4	22.87	4.52
Anadara brasiliana	51	37	88	3	3	6	11.37	13.64
Anadara transversa	12	16	28	2	0	2	3.62	14.29
Mactridae	256	0	256	31	0	31	33.07	24.22
Mulinia lateralis	256	0	256	31	0	31	33.07	24.22
Tellinidae	110	0	110	15	0	15	14.21	27.27
Tellina sp.	110	0	110	15	0	15	14.21	27.27
Noetidae	56	49	105	1	0	1	13.57	1.90
Noetia ponderosa	56	49	105	1	0	1	13.57	1.90
Donacidae	3	7	10	1	1	2	1.29	40.00
Donax variabilis	3	7	10	1	1	2	1.29	40.00
TOTAL BIVALVIA	**566**	**208**	**774**	**55**	**6**	**61**	**100.00**	**15.76**
TOTAL		**n =**	**774**	**specimens**			**100.0**	**15.76**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **42 - Matagorda (Hog Island), Texas**

Latitude: 28.60 degrees north | Date Collected: July 17, 2000

Longitude: 95.93 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	80	104	184	13	6	19	35.25	20.65
Chione elevata	61	83	144	11	5	16	27.59	22.22
Anomalocardina auberiana	11	21	32	0	1	1	6.13	6.25
Gemma gemma	7	0	7	2	0	2	1.34	57.14
Chione lateralis	1	0	1	0	0	0	0.19	0.00
Mactridae	149	0	149	3	0	3	28.54	4.03
Mulinia spp.	146	0	146	2	0	2	27.97	2.74
Mactra fragilis	3	0	3	1	0	1	0.57	66.67
Arcidae	36	13	49	6	3	9	9.39	36.73
Anadara ovalis	19	10	29	3	1	4	5.56	27.59
Barbatia candida	11	2	13	2	2	4	2.49	61.54
Anadara brasiliana	6	1	7	1	0	1	1.34	28.57
Carditidae	40	12	52	2	1	3	9.96	11.54
Carditamera spp.	40	12	52	2	1	3	9.96	11.54
Lucinidae	18	20	38	1	0	1	7.28	5.26
Anadontia alba	18	20	38	1	0	1	7.28	5.26
Noetidae	4	0	4	0	0	0	0.77	0.00
Anomia simplex	4	0	4	0	0	0	0.77	0.00
Anomiidae	7	6	13	1	0	1	2.49	15.38
Noetia ponderosa	7	6	13	1	0	1	2.49	15.38
Donacidae	3	1	4	0	0	0	0.77	0.00
Donax variabilis	3	1	4	0	0	0	0.77	0.00
Pectinidae	2	0	2	0	0	0	0.38	0.00
Argopecten gibbus	2	0	2	0	0	0	0.38	0.00
Ostreidae	2	0	2	0	0	0	0.38	0.00
Crassostrea virginica	2	0	2	0	0	0	0.38	0.00
Plicatulidae	1	0	1	0	0	0	0.19	0.00
Plicatula gibbosa	1	0	1	0	0	0	0.19	0.00
TOTAL BIVALVIA	**342**	**156**	**498**	**26**	**10**	**36**	**95.40**	**24.39**
GASTROPODA								
Crepidulididae			9			1	3.45	11.11
Crepidula fornucata			7			0	2.68	0.00
Crepidula plana			2			1	0.77	50.00
Olividae			2			0	0.77	0.00
Oliva sp.			2			0	0.77	0.00
Muricidae			1			0	0.38	0.00
Nassarius vibex			1			0	0.38	0.00
TOTAL GASTROPODA			**12**			**1**	**4.60**	**8.33**
TOTAL		**n =**	**510**	**specimens**			**100.0**	**14.18**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **43 - Port O'Connor, Texas**

Latitude: 28.43 degrees north | Date Collected: July 17, 2000

Longitude: 96.42 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	24	24	48	2	1	3	92.31	12.50
Chione elevata	24	24	48	2	1	3	92.31	12.50
Ostreidea	3	0	3	0	0	0	5.77	0.00
Crassostrea virginicus	3	0	3	0	0	0	5.77	0.00
Mactridae	1	0	1	0	0	0	1.92	0.00
Rangia cuneata	1	0	1	0	0	0	1.92	0.00
TOTAL BIVALVIA	**28**	**24**	**52**	**2**	**1**	**3**	**100.00**	**11.54**
TOTAL		**n =**	**52**				**100.0**	**11.54**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **44 - Port Aransas Inlet, Texas**

Latitude: 27.73 degrees north Date Collected: July 17, 2000

Longitude: 97.13 degrees west Province Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Mactridae	528	0	528	14	0	14	89.19	5.30
Mulinia lateralis	528	0	528	14	0	14	89.19	5.30
Veneridae	42	1	43	0	0	0	7.26	0.00
Chione elevata	1	1	2	0	0	0	0.34	0.00
Gemma gemma	41	0	41	0	0	0	6.93	0.00
Arcidae	0	7	7	0	0	0	1.18	0.00
Anadara notabilis	0	2	2	0	0	0	0.34	0.00
Acar dominigenesis	0	5	5	0	0	0	0.84	0.00
Cardiidae	4	0	4	0	0	0	0.68	0.00
Trachycardium muricatum	4	0	4	0	0	0	0.68	0.00
TOTAL BIVALVIA	**574**	**8**	**582**	**14**	**0**	**14**	**98.31**	**4.81**
GASTROPODA								
Natacidae			4			0	1.35	0.00
Sinum perspectivum			4			0	1.35	0.00
Fissurellidae			1			0	0.34	0.00
Megathura sp.			1			0	0.34	0.00
TOTAL GASTROPODA			**5**			**0**	**1.69**	**0.00**
TOTAL		**n =**	**296**	**specimens**			**100.0**	**4.73**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **45 - North Mustang Island, Texas**

Latitude: 27.68 degrees north | Date Collected: July 17, 2000

Longitude: 97.15 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Veneridae	85	41	126	11	3	14	31.27	22.22
Chione elevata	50	41	91	10	3	13	22.58	28.57
Gemma gemma	35	0	35	1	0	1	8.68	5.71
Mactridae	12	15	27	0	0	0	6.70	0.00
Rangia cuneata	11	15	26	0	0	0	6.45	0.00
Mactra fragilis	1	0	1	0	0	0	0.25	0.00
Arcidae	19	13	32	2	1	3	7.94	18.75
Anadara transversa	16	13	29	2	1	3	7.20	20.69
Anadara brasiliana	3	0	3	0	0	0	0.74	0.00
Carditidae	30	22	52	2	0	2	12.90	7.69
Carditamera spp.	30	22	52	2	0	2	12.90	7.69
Pectinidae	24	0	24	0	0	0	5.96	0.00
Argopecten gibbus	24	0	24	0	0	0	5.96	0.00
Anomiidae	13	0	13	2	0	2	3.23	30.77
Anomia simplex	13	0	13	2	0	2	3.23	30.77
Noetidae	9	2	11	0	0	0	2.73	0.00
Noetia ponderosa	9	2	11	0	0	0	2.73	0.00
Cardiidae	4	0	4	0	0	0	0.99	0.00
Trachycardium mericatum	4	0	4	0	0	0	0.99	0.00
Chamidae	2	0	2	0	0	0	0.50	0.00
Arcinella sp.	2	0	2	0	0	0	0.50	0.00
TOTAL BIVALVIA	**198**	**93**	**291**	**17**	**4**	**21**	**72.21**	14.43
GASTROPODA								
Crepidulididae			22			1	10.92	4.55
Crepidula plana			2			1	0.99	50.00
Crepidula fornucata			20			0	9.93	0.00
Cerithiidae			12			0	5.96	0.00
Cerithium spp.			7			0	3.47	0.00
Ceritheda costata			5			0	2.48	0.00
Trochidae			12			0	5.96	0.00
Tegula sp.			12			0	5.96	0.00
Olividae			8			0	3.97	0.00
Oliva sp.			8			0	3.97	0.00
Naticidae			1			1	0.50	0.00
Lunatia heros			1			1	0.50	0.00
Muricidae			1			0	0.50	0.00
Nassarius sp.			1			0	0.50	0.00
TOTAL GASTROPODA			**56**			**2**	**27.79**	**3.57**
TOTAL		**n =**	**347**	**specimens**			**100.0**	**11.41**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **46 - Padre Island Natl Seashore, Texas**

Latitude: 26.10 degrees north Date Collected: July 17, 2000

Longitude: 97.12 degrees west Province Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Donacidae	269	169	438	42	41	83	70.19	37.90
Donax variabilis	269	169	438	42	41	83	70.19	37.90
Mactridae	181	1	182	40	0	40	29.17	43.96
Mulinia lateralis	181	0	181	40	0	40	29.01	44.20
Rangia cuneata	0	1	1	0	0	0	0.16	0.00
Carditidae	2	2	4	0	0	0	0.64	0.00
Caditamera floridana	2	2	4	0	0	0	0.64	0.00
TOTAL BIVALVIA	**452**	**172**	**624**	**82**	**41**	**123**	**100.00**	**39.42**
TOTAL		**n =**	**624**	**specimens**			**100.0**	**39.42**

*Includes total valves for symmetrical or nearly symmetrical species

Location: **47 - Brazos Inlet, Texas**

Latitude: 26.07 degrees north | Date Collected: July 17, 2000

Longitude: 97.16 degrees west | Province: Gulf-Louisianian

Taxon	Specimens R Valve*	Specimens L Valve	Specimens Total	Number Drilled R Valve*	Number Drilled L Valve	Number Drilled Total	Relative Abundance (%)	Drilling Frequency (%)
BIVALVIA								
Macttridae	73	200	273	2	3	5	48.84	3.66
Rangia cuneata	9	162	171	0	0	0	30.59	0.00
Mulinia lateralis	64	38	102	2	3	5	18.25	9.80
Arcidae	68	141	209	27	29	56	37.39	53.59
Anadara ovalis	57	139	196	25	27	52	35.06	53.06
Barbatia candida	11	2	13	2	2	4	2.33	61.54
Noetidae	10	52	62	2	0	2	11.09	6.45
Noetia ponderosa	10	52	62	2	0	2	11.09	6.45
Ostreidae	5	0	5	0	0	0	0.89	0.00
Crassostrea virginica	5	0	5	0	0	0	0.89	0.00
Donacidae	4	0	4	1	0	1	0.72	50.00
Donax variabilis	4	0	4	1	0	1	0.72	50.00
Lucinidae	0	1	1	0	0	0	0.18	0.00
Anadontia alba	0	1	1	0	0	0	0.18	0.00
Pectinidae	1	0	1	0	0	0	0.18	0.00
Argopecten gibbus	1	0	1	0	0	0	0.18	0.00
Veneridae	0	1	1	0	0	0	0.18	0.00
Chione elevata	0	1	1	0	0	0	0.18	0.00
Cardiidae	0	1	1	0	0	0	0.18	0.00
Trachycardium muricatum	0	1	1	0	0	0	0.18	0.00
TOTAL BIVALVIA	**161**	**396**	**557**	**32**	**32**	**64**	**99.64**	**29.25**
GASTROPODA								
Crepidulididae			1			0	0.36	0.00
Crepidula plana			1			0	0.36	0.00
TOTAL GASTROPODA			**1**			**0**	**0.36**	**0.00**
TOTAL		**n =**	**558**	**specimens**			**100.0**	**22.90**

*Includes total valves for symmetrical or nearly symmetrical species