Title:

Investigating Shellfish Deposition and Landscape History at the Natia Beach Site, Fiji

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Abstract:

The relationship between environmental variation and subsistence practices is a central point of discussion in much Oceanic archaeology. While human predation can significantly reduce prey populations, environmental variation also contributes to reductions in prey abundance, possibly leading to increased human competition and resource scarcity. At the Natia Beach Site, Nacula Island, Fiji, geoarchaeological evidence suggests that coastal progradation began soon after initial occupation of the coastal plain. Additionally, at approximately 650 BP a marked increase in clay and silt deposition occurred. Changes in coastal geomorphology may be explained by landscape response to regional Mid-Holocene sea level fall combined with human induced soil erosion due to upland settlement. Smaller scale environmental changes associated with climate variability may have also played a role. Additionally, landscape change appears to have had a measurable impact on local nearshore mollusks that are sensitive to high levels of water turbidity. Minor evidence of human exploitation is observable in this shellfish assemblage, although changes in predation pressure may have allowed shellfish populations to recover. Increased ceramic diversity and fortified settlements also appear at approximately 650 BP on Nacula and other parts of Fiji. The suite of changes at Natia may be explained by processes of regional and local environmental changes, and human adaptation in terms of subsistence, spatial organization, and competition.

1. Introduction

Over the last 20 years archaeologists and other scholars in Oceania have increasingly explored the relationship between environmental variability and cultural change (e.g., Finney 1985; Field 2004; Nunn 2000a, 2000b; O'Connell and Allen 1995; Allen 1992a, 1992b, 1998; Anderson and Walter 2002), as have archaeologists in other regions (e.g., Raab and Larson 1997; Kennett and Kennett 2000; Richerson et al. 2001; deMenocal 2001). While Oceanic populations certainly modified their environments (e.g., Allen 2003; Sand 2002; Athens 1997; Spriggs 1985, 1997), regional climatic phenomena and local environmental change also significantly altered ecological conditions on Oceanic islands. Explanations of human cultural adaptation, diversification, and relatedness should therefore consider the possible influence of environmental variables on variation in human behavior and the archaeological record. Our research on Nacula Island, Fiji, discussed here includes a preliminary assessment of the effects of landscape change on local island conditions and hypotheses accounting for variation in subsistence practices.

Despite over 30 years of debate on the character of prehistoric Pacific subsistence practices (e.g., Groube 1971; Kirch 1997; Clark and Anderson 2001; Davidson and Leach 2001), the significance of marine resources to prehistoric diet throughout the Pacific Islands is well attested archaeologically (e.g. Kirch and Dye 1979; Kirch 1982; Rolett 1989; Allen 2002, 2003; Fitzpatrick and Kataoka 2005). Determining the causes of change in the kind and importance of marine resources in prehistoric subsistence regimes is complicated as the structure of particular marine animal populations can be affected by human and non-human induced environmental change, complex ecological relationships, and human and non-human predation. Changes in human population density, site activity, and spatial organization may also play a role in predation intensity (Braje et al. 2007). Accounting for many of these factors, archaeologists increasingly apply models drawn from evolutionary ecology, (e.g., Charnov 1976; Stephen and Krebs 1986) to examine temporal and spatial shifts in subsistence practices (e.g., Broughton 1994, 1999; Allen 2003; Allen et al. 2001; Grayson 2001; Nagaoka 2001, 2002; Cannon 2003; Morrison and Hunt in 2007; Morrison and Addison in press).

The prey choice model, as developed in foraging theory, is particularly useful for explaining subsistence variation. The model measures changes in foraging efficiency by predicting that foragers choose prey with the highest return rate upon encounter. Low ranked prey items will be included in the diet when the abundance of higher ranked items begins to decline. In archaeological studies, prey body size is generally used as a proxy for energetic return rate (Broughton 1994, 1995; Butler 2001; Byers and Broughton 2004). Consequently, declining foraging efficiency should be indicated in the archaeological record by a decrease in large bodied prey relative to smaller prey and a widening of the diet breadth resulting in increased species diversity. Other measures of foraging efficiency include changes in the mean size and age of prey items.

Heavy predation can lead to a decline in foraging rates as high ranked prey items decrease in abundance. Such impacts of human predation on Pacific marine mollusks have been demonstrated by Anderson (1981), and Swadling (1976, 1986). At Black Rocks Point, New Zealand, Anderson (1981) documented a reduction in shell size and an increase in the exploitation of small bodied mollusk species relative to larger prey. Swadling (1986) also showed mean shell size reductions in species recovered from the Reef/Santa Cruz Islands. Archaeologists working in England (Mannino and Thomas 2001, 2002), South Africa (Jerardino 1997), and Mozambique (deBoer et al. 2000) have documented changes in species composition, mean shell size, abundance, and age, all generally due to human predation or environmental variables.

While human predation can significantly affect prey characteristics, environmental changes may also result in habitat modifications that have both positive and negative impacts on prey populations. On Tikopia Island in the southwest Pacific, Kirch and Yen (1982) documented the transformation of a saltwater bay into a brackish lake due to shoreline progradation, dune development, and possibly tectonic uplift. A consequence of this environmental transformation was a substantial reduction in the abundance of sand dwelling mollusks, such as *Anadara*, and *Periglypta* species (Kirch and Yen 1982:293). In Tonga, Spennemann (1987) also measured impacts to *Anadara* populations due to altered water quality from geomorphologic change.

In the following analysis we apply the prey choice model and demonstrate that variation in the Natia Beach shellfish assemblage in western Fiji (Figure 1) is not explained exclusively by human predation. We show that local landscape changes at Natia Beach likely associated with both natural environmental processes and cultural factors led to increased terrigeneous deposition on the coastal plain and nearshore environment. Changes in the local landscape negatively affected shellfish that are sensitive to high amounts of fine grained sediment. Finally, we suggest that contemporaneous changes in human spatial organization and competition may have been key variables influencing shellfish deposition and predation intensity at Natia Beach. The next section presents an overview of the natural environment of the Fijian islands including environmental changes that populations would have experienced over Fiji's prehistory. We then discuss the Natia Beach site, including its geomorphology and prehistoric chronology. These sections provide a background for the subsequent shellfish analysis and discussion.

2. Environmental Context

Fiji lies within the southern tropics of the central Pacific and consists of over 300 islands dominated by the islands of Viti Levu (10,388 km^2) and Vanua Levu (5,587 km^2) together comprising almost 90% of the archipelago's land area. Resting on the Indo-

Australian plate, the archipelago exhibits a diverse geology, and because of fairly complex tectonic activity in the area, both emergence and subsidence are active processes across the islands (Nunn 1998a; Dickinson 2001; Dickinson et al. 1994, 1999). There is also considerable spatial variation in Fiji's physical environment with wet and dry sides of the archipelago generated by the southeasterly trade winds, topographically influenced climate differences, and different biotic communities across the volcanic, coralline, and limestone island types.

Field data combined with computer models indicate that relative sea level in the equatorial Pacific decreased 1-3 meters between c. 5000-1500 yr BP as a result of hydro isostatic drawdown related to oceanic equatorial siphoning (Mitrovica and Peltier 1991; Nunn 1995; Pirazzoli and Montaggioni 1988; Fletcher and Jones 1996; Grossman et al. 1998; Dickinson 2001). Paleoshoreline researchers in Eastern Fiji have documented a number of post-mid Holocene emergent shoreline features that fall within the hypothesized 1-3 meter range of the Mid Holocene high stand of the sea (Dickinson 2001: Table 1, 222-225). Other localized changes in relative sea level may be caused by tectonic activity (e.g., Dickinson and Green 1998). However, the low lying island of Viwa located close to the Yasawa chain does not show evidence of significant post-mid Holocene subsidence or uplift (Dickinson 2001:224).

Using paleoclimate data from various world regions, Nunn (2000a, 2000b) has investigated temporal variation in the environment of Fiji and other islands in the Pacific. Nunn has argued that the transition between the Little Climatic Optimum (LCO, 1250-700 BP) and the Little Ice Age (LIA, 700-200 BP) (Fagan 2000) influenced coastal landscapes and had dramatic negative effects on subsistence resources and socio-cultural development among island populations (Nunn 2000a; Nunn 2000b; Nunn and Britton 2001). Cooler air and water temperatures and a sea level fall of up to 1 meter have been key factors in the destruction of reef ecosystems and subsequent cultural changes (Nunn and Britton 2001: 9-13). However, Gehrels (2001:244-245) has argued that Nunn's data do not precisely establish a clear relationship between sea level and climate if all height and age uncertainties are taken into consideration. Regardless, Nunn's research has led archaeologists to productively address the role climate variability has played in altering the lifeways of ancient island societies.

Recently Allen (2006) has questioned the appropriateness of using paleoclimate proxy data from the northern hemisphere to reconstruct past climate patterns and their local environmental effects in the central Pacific. Reviewing multiple ice cores from several widespread locations, Dunbar (2000:73) also notes 'the disparity between these records does not support globally synchronous warming during the thirteenth century (Medieval Warm Period) or cooling during the Little Ice Age'. More spatially resolute proxy paleoclimatic data drawn from studies of long lived coral fossils suggests the climatic patterns documented during the LCO and LIA in the temperate Northern Hemisphere data do not correlate well for the tropical central Pacific (Allen 2006: 521; Cobb et al. 2003: 275**)**. The coral proxy data suggest that while much of the world was experiencing warmer weather at times during the LCO, the central Pacific appeared to be cool and dry. Moreover, the central Pacific was likely warm and wet at times during the LIA.

Significantly, these new data suggest global climatic trends may have had quite negative effects on local resources and human subsistence in the central Pacific. Regarding marine ecosystems, Allen notes that a marked temperature increase registered in the coral data around 700 BP may have damaged the region's coral reefs (Allen 2006:18). Sudden changes in sea temperature, as well as ocean salinity can lead to coral bleaching potentially resulting in large scale coral reef death (Wilkinson et al. 1999; Gardner et al. 2003; Allen 2006). Recent coral bleaching events and subsequent habitat destruction in various oceans have been correlated with warmer than average sea surface temperatures (SST) during the powerful El

Niño season of 1997-1998 (McPhaden 1999; Wilkinson 2000; Garpe et al. 2006). Nunn (2000b) has noted that the transition period between the LCO and the LIA (approximately 700 BP) was a time of heightened ENSO frequency. El Niño years may also include increased storminess in Fiji as historical data on hurricane frequencies in the archipelago indicate that storm events are more likely to occur during periods of low pressure associated with El Niño (Field 2003).

Hydrological studies in Fiji on ENSO-related storms demonstrate that cyclones during El Niño years produce higher amounts of stream discharge with subsequent flooding (Terry et al. 1998, 2001). Substantial amounts of precipitation over brief time periods results in soil saturation and hazardous stream overwash (Terry et al. 2001: 276-279). Higher rainfall rates may have led to elevated amounts of sedimentation resulting in increased water turbidity and loss of lagoon organisms sensitive to water quality (Nunn 2000a: 723).

The review of paleoenvironmental variability in the central Pacific presented above suggests a number of relevant environmental processes potentially affecting coastal landscapes and marine environments occurred over the course of Fijian prehistory. Natural processes associated with sea level change and climatic fluctuation as well as cultural factors related to settlement expansion and agricultural intensification may be measured by investigating the history of local landscape change at Natia Beach. Coastal reconfigurations can lead to negative effects on nearshore areas with consequences for the people who rely on these environments for subsistence. The next section introduces the Natia Beach site and subsequent sections present the shellfish assemblage data and analyses conducted to assess the effects of human predation and environmental change.

3. The Natia Beach Site

The Natia Beach Site is located on Nacula Island in the northern Yasawas Islands of western Fiji (see Figure 1). The Yasawa Islands were colonized approximately 2800 BP, perhaps 200 years after some of the first human habitation in other islands of Fiji. The cultural sequence at Natia Beach and the other Yasawa Islands includes a ceramic tradition beginning with Lapita pottery and subsequent ceramic change up to the historic era. Artifact assemblages also include a variety of lithic tools, subsistence artifacts such as fishhooks, shell scrapers, as well as personal ornaments. Archaeological sites in the islands are found on beach terraces, caves, in the uplands and in defensive locations, either on fortified hilltops or as settlements surrounded by annular ditches (see Cochrane 2004 for overview).

Natia is a large coastal beach terrace just east of Nacula village. A hand-driven auger was used to core the subsurface of the beach terrace in an attempt to locate accessible buried cultural deposits and obtain sediment samples. The possibility that cultural deposits here are inundated by the water table or capped by thick colluvium makes coring an effective method to locate areas where excavation will be most profitable. Thirty two cores were placed at variable distances along three transects (A-C) perpendicular to the beach and running approximately 360 m inland. Five 1 x 1 m test units were placed in the vicinity of transect A (Figure 2) approximately 160 to 230 m from beach. Two of these test units (1 and 2) were excavated into stratigraphically mixed deposits and a third (test unit 3) was abandoned due to extensive colluvium. Test units 4 and 5 were excavated into undisturbed, stratified cultural deposits with no evidence of a nearby stream cross-cutting or disrupting of the sediments (Figures 3 and 4). Artifacts including pottery, shellfish remains, formal lithic tools, flakes and cores, and shell ornaments were found across all excavation levels in test units 4 and 5 down to 190 cm below the ground surface (base of excavation level 19). There is no evidence from artifact size and matrix grain-size distributions, water-worn artifacts, or artifact orientations to suggest the deposits in test units 4 and 5 are in secondary context. There is also no evidence for living floors, dumping events, or discrete cultural features. We consider the shell and artifact assemblages from test units 4 and 5 to be samples of a horizontally more expansive deposit as identified in the auger cores (see section 3.2). Future field work will attempt to more precisely define this deposit's boundaries. All shell and cultural remains from test units 4 and 5 were recovered using 1/8 inch (4 mm) screen mesh. All of the excavated shell remains, ceramics, faunal material, and other artifacts were collected and analyzed at the University of Hawaii, Mānoa.

3.1 Cultural Chronology at Natia Beach

Both ceramics and anthropogenic shell were recovered from excavation level 19 (180-190 cmbs) in both test units 4 and 5. Carbon residue on a sherd from level 15 (140-150 cmbs) in test unit 5 (AA-60255) returned an AMS-derived date range of 2380-2170 cal. BP at 2 σ (see Cochrane 2004 for AMS data and calibration procedures). Thus the early human activities associated with levels 16-19 possibly date to several hundred year prior with the deepest cultural deposits likely dating to approximately 2800 BP considering similar dates for the earliest cultural deposits at other sites in the Yasawa Islands in similar geographic settings (Cochrane 2004). Ceramics recovered from excavation levels 16-19 in both test pits are plain, precluding relative dating of the deepest deposits through changes in ceramic surface treatment.

Carbon residue on a sherd from level 7 (60-70 cmbs) in test unit 5 produced an AMS derived date (AA-60256) of 710-590 cal. BP at 2 σ and marks the final deposition of Layer II (see next section). Ceramics deposited above this AMS date in levels 1-6 from both test units exhibit a range of surface treatments typically associated with the last 500-600 years of Fijian prehistory, including different forms of incising, appliqué and molding (Cochrane 2004).

3.2 Geomorphologic Change at Natia Beach

Sedimentary analysis of test unit 4 and 5 deposits demonstrates an increase in the amount of fine-grained clay and silt particles in Layer I (see Figure 4), signifying a change in the source and environment of deposition at Natia relative to deeper layers. Sediment samples collected from each distinct layer in the archaeological cores were analyzed to explore the subsurface stratigraphy of the Natia Beach coastal terrace and topographic mapping with an auto level was conducted to establish the relationship between geomorphic features and the present sea level (Figure 5). Sediment samples were described by standard morphological characteristics such as, depth and thickness, texture (contribution of sand, silt and clay), color and mottling, structure, and class.

The auger and topographic data reveal a sequence of coastal deposition dominated by coarse-grained marine sands until approximately 155 m inland where an 80 cm thick silty clay loam deposit is located, first identified in Auger 15 (Figure 5). The silty clay loam corresponds to Layer I in test units 4 and 5. Underneath the silty clay loam, a sandy anthropogenic deposit bearing dense shell was encountered. This is Layer II in the test units and seems to be present between the 155 and 190 m marks in the vicinity of the transects. As augering continued inland, the silty clay loam became thicker, reaching close to 3 meters at 220 meters from the shoreline. Sediment particle size analysis (section 6.1, below) was conducted to explore variation in the source, transport agent, and depositional environment of the Natia Beach coastal terrace.

4. Shellfish Analysis Methods

The quantitative shellfish analyses are based on the assemblages found in Layers I-IV in Test Units 4 and 5 (Figure 4). To mitigate the poor representation of small samples associated with 10 cm excavation levels, the excavation levels from both test units 4 and 5 were aggregated into analytic units (Zones A-E) based on stratigraphic context and the need to create analytic units that balance both the generation of adequate sample sizes and the examination of meaningful chronological variation (Table 1).

While Test Units 4 and 5 are only approximately 5 meters apart, shell discard patterns can be highly variable leading to spatial differences in the stratigraphic coherence of assemblages recovered from separate units. As a consequence, it was necessary to assess possible biases arising from the combination of the test unit 4 and 5 assemblages. All analyses were first performed on the assemblages recovered from the separate excavation units. When no significant differences in the analytical results were discovered treating the units separately, assemblages were then combined to create larger analytic units. All analyses were also tested for correlations with sample size (following Grayson 1984).

Shell remains were quantified using weight (grams), MNI, and NISP (Table 2). The relationship between MNI and weight was examined by performing regression analysis for the seven most abundant species in the assemblages (Table 3). The results suggest that for each excavation level MNI and weight are strongly correlated and therefore provide comparable results. While MNI and weight measurements both have their strengths and weaknesses for shell analysts (see Mason et al. 1998; Glassow 2000; Claassen 1998; 2000), we have chosen to use MNI for the analyses in this study. While shell weights can be useful for certain types of analysis, they may be problematic when modeling the potential impact of predation on populations of prey species. Different age and size classes in a taxon vary by shell weights, so a gross weight of shell remains per taxon can hide a great deal of potentially valuable information. MNI was calculated by counting the umbo fragments for bivalves and the apices for gastropods. The shellfish analysis and identifications were conducted by Morrison using shell manuals for Fiji and the Pacific region (e.g., Cernohorsky 1972; Kay 1979; Abbott and Dance 1982) and a reference collection for Fiji created by Morrison and housed at the University of Hawai`i, Mānoa. Specimens were identified to lowest possible taxonomic level (see Table 2)

Inspection of taxa only identified to genus suggests two main reasons for the low taxonomic specificity. First, taxa with high degree of speciation such as *Cypraea, Chiton*, and *Conus* are generally only identifiable with confidence by color and patterns on the shell which rarely survive in archaeological contexts. Abbott and Dance (1982) report over 40 species of the genus *Cypraea* in the Indo-Pacific region most of which are differentiated by color and patterning. Secondly, the majority of taxa identified only to the genus level are small individual fragments contributing minute amounts to the overall recovered remains. For example *Arca sp., Diodora sp., Cerithium sp., Drupa sp., Nassarius sp., Neritina sp, Oliva sp., Patella sp., Tectus sp., Theodux sp, Trachycaridum sp., and Tridacna sp.,* all only contribute 5 or less MNI to the assemblage. Excluding *Nerita sp.*, taxa identified only to genus make up less than 7% of the assemblage.

4.1 Taphonomic Factors

Analysis of shell fragmentation can provide important information regarding pre-depositional alterations associated with shell processing and tool manufacture (e.g., Keegan et al. 2003) and post depositional processes affecting shell preservation and recovery (Mannino and Thomas 2001). As differential processing of shell material can lead to dissimilar recovery rates throughout an assemblage, we assessed shell fragmentation for the seven most abundant species and the entire assemblage. Fragmentation was assessed by comparing the ratio of NISP to MNI throughout the assemblage (see Fitzpatrick 2003; Keegan et al. 2003). A value of 1 indicates that all identified shells are whole and both NISP and MNI are therefore equal. Increasing values document higher degrees of fragmentation in the assemblage.

Results (Table 4) suggest that in general fragmentation is higher in larger more robust species and is likely related to shell processing rather than post-depositional taphonomic factors. The lower fragmentation rate of both smaller less robust gastropods and the entire assemblage indicates that differential shell fragmentation alone does not account for the patterns documented in the assemblage.

To determine if shell recovery was a product of post-depositional taphonomy associated with sediment acidity, we measured the pH level of the four stratigraphic Layers in Test Unit 4 (see Linse 1992; Raiswell 2001). An auto-calibrated digital pH meter was used following guidelines in Jackson (1973). Measurements for each sample were continually taken until a standard error of 0.1 was achieved (following Stein 1992). All values were either neutral (7.7-7.9) or very slightly alkaline (8.0-8.1) and indicate that sediment pH had very little effect on shell preservation.

5. Investigating Human Impacts

5.1 Taxonomic Evenness of the Shellfish Assemblage

Overall taxonomic evenness was assessed to test the hypothesis that evenness increases as foragers seek to offset declining foraging efficiency as predicted by the prey choice model. Shannon's Evenness Index was used to calculate evenness (e.g., Grayson 1984; Claassen 1999; Grayson and Delpech 1998). This index is calculated as:

$$\text{Evenness} = -\sum (p_i \log[p_i])/ \log(\text{NTAXA})$$

(where p_i is the proportional contribution of each item).

Results suggest that there are larger evenness values in Zone A and Zone E (Table 5), but the trend is not significant (r_s = -0.4, p = 0.505). Evenness is not correlated with sample size ($r_s =$ -0.7, p = 0.188).

5.2 Large Versus Small Bodied Prey Species

To investigate human impacts to mollusk species at Natia Beach we compared the contribution of the three most abundant large bodied species, *Trochus niloticus*, *Anadara antiquata*, and *Turbo crassus,* to the three most abundant small bodied prey, *Turbo cinereus*, *Nerita sp*., and *Planaxis sulcatus.* These prey items constitute a large proportion (69.2%) of the Natia Beach assemblage and are also common mollusk remains found in other Fijian archaeological contexts (e.g., Szabo 2001). We utilize a simple equation to create comparative abundance indices between large and small prey called the Large Abundance Index:

$$\text{Large AI} = \sum \text{MNI large taxon} / \sum [\text{MNI large taxon} + \text{MNI small taxon}]$$

We use Cochran's test of linear trend to test for a significant tendency in the relationship between large and small bodied prey (see Zar 1996; Cannon 2001). Cochran's test of linear trend is a chi square test comprised of three components: a traditional chi square test which examines the overall relationship between the two variables, the variation as a result of a linear trend, and the departure from the linear trend (see e.g., Nagaoka 2002). The results indicate a statistically significant difference in the contribution of the small to large bodied mollusks across Zones A-E (X^2 = 40.49, p = 0.00), but this difference is not the result of a significant linear trend (X^2_{trend} = 0.00, p = 1.00). The AI values are not significantly correlated with sample size (r_s = -0.6, p = 0.285). Inspection of the Large AI values (Figure 6, Table 5) suggest that early foragers (Zone E deposits) relied more on larger prey species and shifted to a greater contribution of smaller species during Zones D-B. However, in the last 650 years represented by Zone A, a renewed emphasis on large species is evident in the assemblage.

Inspection of the large abundance index suggests similarities between shellfish foraging patterns in both Zones E and A. The high AI index values for Zone E and A demonstrate that larger shellfish were harvested during these time periods when compared to Zones D-B. A possible explanation accounting for the abundance of large shellfish species recovered in Zones A and E is that changes in human population density and spatial organization led to less intense exploitation of the nearby marine environment adjacent to Natia Beach resulting in the rebound of previously exploited large species populations. In this scenario, initial population density at Natia was likely low during the first settlement of the Natia Beach Coastal Plain (Zone E), and subsequent shellfish exploitation and resource pressure was not intense. As population density increased during Zones D-B predation pressure increased with subsequent effects on large shellfish species. However, after 650 BP (Zone A), large species are again represented in ratios similar to Zone E suggesting the possibility of a period of ecological recovery perhaps due to decreased predation pressure as human populations were no longer settled adjacent to the coast. However, it is noteworthy that a subsequent decrease in species diversity usually signifying expansion of foraging diet breadth does not accompany the increased use of large species. It is possible that shellfish deposition during zone A was too low to adequately encompass the diversity of shellfish in the foraging regime therefore making diversity measurements ambiguous. In order to explore differential shellfish deposition at Natia, we calculated the density of shellfish recovered by analytic zone.

5.3 Changes in Shellfish Density

Inspection of Table 2 indicates that shellfish dramatically decrease in Layer I which post-dates approximately 650 BP and is associated with a new depositional environment at Natia. In both test units Layer I accounts for about 30% of excavated matrix volume, but contain less than 4% of the total amount of shell. To explore temporal variation in shellfish abundance relative to excavation volume, density of shellfish MNI per m^3 was calculated for each stratigraphic zone following Allen (1992a) (Figure 7).

Inspection of shellfish density demonstrates that when considering the assemblage as a whole density increases after initial low counts in Zone E. Density values in zones E and A are similar suggesting very low levels of shellfish exploitation and deposition during these time periods. Decreased deposition of shell remains in general may reflect settlement reorganization and subsequent lower human population density in the area. Results from the large abundance index also support this hypothesis. Additionally, investigations at an upland fortified habitation site on Nacula suggest changes in human spatial organization. This upland site was initially inhabited approximately 500 BP and represents a trend toward late prehistoric habitation of defensive sites throughout the Yasawa and Mamanuca Islands (Cochrane 2004, Cochrane et al. 2007). However, the decreased shell deposition may not be a simple function of decreased human presence at Natia Beach after 650 BP as 69% of the total ceramic assemblage (3,048 sherds) for test units 4 and 5 is deposited in Zone A (data in Cochrane 2004). The increase in ceramic deposition in Zone A may reflect differences in activities at Natia over time.

5.4 Mean Shell Size

To assess the possible effects of human predation and environmental change on species size, measurements were made on samples of two abundant bivalve species: *Anadara antiquata* and *Atactodea striata*. Shell length was measured with digital calipers as the longest axis along the posterior/anterior dimension of the shell. Small samples of these bivalves recovered from Zone A precludes their comparison with the other zones; only 9 individual *Anadara antiquata* and no *Atactodea Striata* specimens were recovered from Zone A attesting to the low degree of shell deposition after 650 BP.

Size results for *Atactodea striata* across Zones B-E (Figure 8) do not reveal any significant changes through time suggesting that foraging and environmental change had no impact on *A. striata* size (ANOVA, F = 1.41, sig. = .241). Additionally, the size distributions are normal and mean size is not significantly correlated with sample size (r_s = 0.8, sig. = 0.2). However, analysis of the mean size of *Anadara antiquata* species demonstrates significant increase in *Anadara antiquata* mean size (60.2 mm) in Zone C compared to the earlier zone E (51.8 mm) (ANOVA, F = 3.18, sig.= 0.027, Tukey's test sig = 0.014) (Figure 9). Size distributions are normal and mean size is not significantly correlated with sample size (r_s = 0.4, sig. = 0.6).

An increase in the size of *Anadara* over time may be related to decreased density of shell beds. Pathansai and Soong (1958) demonstrated that a negative relationship exists between *Anadara* density and growth rate. Broom (1982) also found that weight of *Anadara granosa* specimens negatively correlated with bed density. If the increased size of *Anadara* from Zone E to Zone C is explained by a decrease in shell bed density, we suggest the change in shell bed density may be influenced by environmental factors associated with habitat alteration. This is plausible as other researchers have noted that shellfish living in unfavorable environmental conditions may contain larger and more mature individuals due to population thinning and increased nutrient availability (Spennemann 1987: 91; Mannino and Thomas 2001: 1112; Keegan et al. 2003: 1613). For example, Kirch and Yen (1982) suggest that at Tikopia increased terrestrial deposition may have led to substantial reductions in shellfish abundance resulting from high water turbidity. A similar argument has been made by

Spennemann (1987) when analyzing abundance on *Anadara* remains in Tonga. We now turn to evidence for landscape change at Natia Beach and document a decrease in the abundance of mollusk species that are sensitive to high levels of water turbidity.

6. Investigating Environmental Change

6.1 Particle Size Distribution Analysis

Particle size distribution analysis is often used to explore the history of coastal progradation and landform evolution in island settings (e.g., Allen 1998; Scudder 2001). We analyzed sediments taken from test unit 4 (Tables 6 and 7) using both dry sieves and the pipette technique for silt and clay outlined in Folk (1980). The augering data, topographic mapping, and particle size distribution analysis drawn from sediment samples in test unit 4 reveal the following sequence of landform development at Natia:

(1) Layer V, the basal layer in both excavation units 4 and 5 (largely unexcavated except for some matrix in test unit 5) is made up of lithified calcareous rock, an abundance of naturally occurring non-anthropogenic shell and small amounts of pottery sherds. The presence of minor amounts of silt inclusions in the matrix suggests fluvial activity near a marine environment. This deposit represents initial use of the Natia Beach site.

(2) Layer IV and Layer III are composed predominately of medium to fine sand with a slight contribution of gravel, silt, and clay sized particles. The presence of anthropogenic shell and increased pottery indicates that by this time human use of the Natia Beach coastal terrace had increased. The contribution of clay and silt particles (approximately 20-25%) indicates that coastal progradation had begun by this time. An AMS (AA-60255) date of 2380-2170 cal. BP at 2 standard deviations was recovered from the upper half of Layer IV.

3) Sediment samples drawn from Layer II show a large increase in the amount of both fine grained silt and clay and a decrease in gravel and sand sized sediment suggesting a change in the environmental context at Natia from one dominated by wave and wind transport of calcareous material to an environment associated with low energy fine-grained terrigenous deposition. Inspection of the topographic profile (see Figure 5) also shows the presence of swales near augers 12 and 14, which may indicate paleo-beach dunes.
4) The abrupt boundary between Layer II and Layer I marks the end of the primary anthropogenic shell bearing deposit at Natia with a single AMS (AA-60256) assay of 710- 590 cal. BP at 2 standard deviations dating this abrupt change. Layer I contains no sand with the majority of particles being silt sized. A well developed A-horizon provides evidence for landscape stability at Natia over the last few centuries.
5) The presence of predominately coarse grained marine deposits underneath a thin (approximately 40 cm in most places) weakly developed loamy sand in all auger deposits less than 155 m from the present shoreline suggest a sequence of beach progradation likely related to a change in the sediment budget at Natia.

6.2 A Change in Shellfish Habitat

The particle size analysis and archaeological core data demonstrate progradation of the Natia beach terrace as well as a substantial increase in terrestrial deposition during the period of human activity at the site. As such changes in coastal geologic settings can have variable and sometimes negative impacts on the different environments inhabited by particular prey species we examined the abundance of species whose habitats would likely be negatively impacted by increased sediment discharge and subsequent higher turbidity in the nearshore marine environment. Research on habitat preference for the intertidal bivalve *Atactodea* *striata* shows preference for a habitat of coarse grained soft sediment particles, and that low species density is correlated with high percentages of silt and clay particles (Baron and Clavier 1992). Furthermore, species of the family Veneridae also prefer coarse grained sand substrates and are know to be very sensitive to high silt contents and temperature fluctuations (Keegan et al. 2003:1612).

In the Natia Beach assemblage, the only species of Veneridae recovered is the intertidal bivalve *Gafrarium tumidum*. While Spennemann (1987) has classified *Gafrarium tumidum* as a brackish water shellfish, recent research by Baron et al. (1993) from New Caledonia demonstrates that density of *Gaffrarium tumidium* was considerably higher in an environment with very coarse grained sand and low mud content compared to a habitat consisting of fine to medium sand with medium mud content. Additional research by Baron and Clavier (1992) did not record a preference of the species for muddy habitats. As *Gafrarium tumidum* is a short siphon suspension feeder sensitive to fine sediment contents greater than approximately 20%, high fine-grained particle content limits its abundance (Baron and Clavier 1992: 112). Analysis of the relative contribution of *Atactodea striata* and *Gafrarium tumidum* to the assemblage may therefore track changes in the nearby marine environment, particularly the changing abundance of silt and clay particles. The comparison was conducted using the *Atactodea-Gafrarium* Abundance Index formula:

$$\textit{Atactodea-Gafrarium}\ \mathrm{AI} = (\sum \mathrm{MNI}\ \textit{Atactodea striata} + \sum \mathrm{MNI}\ \textit{Gafrarium tumidum}) / \sum (\mathrm{MNI\ total\ assemblage})$$

The results demonstrate that both *Atactodea striata* and *Gafrarium tumidum* declined in both relative and absolute abundance in the assemblage ($X^2 = 21.43$, $X^2_{trend} = 7.51$, $p = 0.000$ (Table 8, Figure 10), particularly after approximately 650 BP in Zone A and during the onset of coastal progradation after Zone E. The AI values are not correlated with sample size (r_s = 0.7; p = 0.188). In fact, no specimens of *Atactodea striata* were recovered in post 650 BP deposits.

7. Discussion

The Natia Beach shellfish assemblage provides a valuable opportunity to study long term patterns in marine mollusk use in the western Fijian Islands. Since an array of research has successfully explained prehistoric human impacts to shellfish and other nearshore resources using evolutionary ecology and foraging theory (Swadling 1976; Botkin 1980; Anderson 1981; Raab 1992; Jerardino 1997; Mannino and Thomas 2001, 2002; Braje et al. 2007; Morrison and Hunt 2007; Morrison and Addison in press), we began by investigating variation in shellfish deposition using the prey choice model.

First we compared the relative abundance of large and small bodied prey species and found a significant increase in the relative proportion of large species recovered from Zone A post dating 650 BP, compared to the immediately preceding zones. Higher relative abundance of large bodied mollusk species in both analytic Zones A (post 650 BP) and E (approx 2300 BP) suggest changes in the exploitation of marine habitats perhaps due to changes in settlement or site activity. Recent research on California's Channel Islands by Braje et al. (2007) documents a similar pattern of shellfish recovery they suggest may be related to changes in local population levels and settlement locations.

It is also possible that as mollusk returns decreased, foragers began exploiting new habitats not previously affected by human predation pressure. As Zone E represents initial exploitation of the nearby nearshore ecosystem at Natia, similar foraging patterns identified in Zone A may indicate the exploitation of similar marine environments. A model based on central place foraging formulated by Bird and Bliege Bird (1997) and Bird et al. (2002)

predicts that as the distance foragers travel from a central location increases, field processing of larger shellfish species with heavier shells will also increase. If foragers began to move into new unexploited shell beds at increasing distances from the Natia Beach coastal plain, field processing may have led to differential transportation and deposition of shell material, complicating comparisons of midden remains from our different analytic zones.

Changes in spatial organization around 500 BP as suggested by increased upland settlement on Nacula and elsewhere in the Yasawas may explain decreased predation pressure and shell deposition at the Natia Beach site. Additional archaeological evidence from the western Fijian islands suggests variation in human behavior and settlement patterns possibly related to changes in the environment and human competition. Analyzing pottery assemblages from the Yasawa Islands (including Nacula), Cochrane (2004) identified increasing diversity in jar rim styles (sensu Dunnell 1978) dating to approximately 500 BP and suggested that this increasing diversity is explained by a decreasing spatial scale of cultural transmission among populations (cf. Neiman 1995). A similar contraction in the spatial dimension of cultural transmission was identified through chemical provenance analysis linking western Fijian ceramic clays to source areas (Cochrane and Neff 2006). Defensive habitation sites also appear to increase in the western islands by approximately 500 BP (Cochrane 2004), a pattern identified in other areas of Fiji (e.g., Field 2004; Best 1993; Kumar et al. 2006) and under similar conditions in nearby Samoa (Pearl 2004). Increased upland settlement and less reliance on the nearby marine environment at Natia could have led to the regeneration of large bodied shellfish species as suggested by the AI analysis, however shell density is quite low making reliable assessments difficult.

We also measured shell size for *Anadara antiquata* and *Atactodea striata* in the pre-650 BP deposits (Zones E to B) as sample sizes in the uppermost Zone A were small. Only *Anadara antiquata* exhibits significant size differences, an increase in size from Zone E to

Zone B, possibly explained by a decrease in shell bed density. Overall, these changes in assemblage composition are not conclusively explained through human predation and may be better accounted for by environmental change.

Spennemann (1987) has documented a decrease in *Anadara antiquata* remains on prehistoric Tongatapu as well as fluctuations in mean size which he interprets as related to increased brackish water from landscape changes caused by the regional late Holocene sea level decline and local tectonic activity. Kirch and Yen (1982:296-297) have also noted decreases in *Anadara* abundance related to increased terrestrial erosion and landscape changes. Changes in *Anadara* size and landscape reconfiguration at Natia may reflect a similar geologic history. However, differentiating changes in taxa size resulting from natural processes and human predation is difficult as both can occur simultaneously (Leach and Davidson 2001:150).

While the sediment particle size analysis, topographic mapping, and auger data reveal a sequence of coastal progradation, increased terrigeneous sedimentation and subsequent landscape change at Natia, the exact causes of these geomorphologic changes are probably due to a variety of factors. Debate regarding the nature of landscape changes in island environments in the past have generally centered on whether human or natural factors such as climate change or sea level fluctuations are responsible for the recorded landscape alterations (e.g., Nunn 1998; Spriggs 1985, 1997). Nunn (1991:1) notes that the effects of non human processes on island landscapes have generally been ignored in favor of explanations that focus on human impacts. In contrast, Spriggs has investigated the role of agricultural clearing in denuding hillsides and accelerating slope erosion (Spriggs 1997; see also Kirch 1983). Finally, Allen (1997) has presented a well balanced analysis of landscape changes on the windward coast of Oahu in the Hawaiian Islands, assessing the role of both cultural and natural factors.

The sediment particle size analysis above suggests that extensive progradation of the coastal plain occurred since initial occupation as early as 2800 BP. An increase in silt and clay particles and a decrease in calcareous deposition occurred continuously throughout the sequence at Natia. An AMS (AA-60255) date of 2380-2170 cal. BP at 2 standard deviations recovered from the upper half of Layer IV suggests that retreat of the mid Holocene high-stand of the sea may have played a role in landscape change at Natia as the timing fits well within the chronology of hydroisostatic sea level drawdown (e.g., Grossman et al. 1998; Dickinson 2001).

The cessation of calcareous particles and increase in silt and clay that occurs during Layer I (post dating 650BP) may be the result of increased slope erosion from agricultural activity or an increase in upland settlement or both. Dickinson et al. (1998) have argued that a similar process may explain the formation of massive dunes at Sigatoka on the southern coast of Viti Levu, Fiji. As previously mentioned, evidence from a hilltop fortification above Natia Beach demonstrates increased upland activity around the same time. Additional increases in upland settlement late in prehistory have been documented on other islands in the Yasawas (Cochrane 2004) and elsewhere in Fiji (Field 2003).

Higher frequency of ENSO events may have also been a causal factor in the increased clay and silt deposition after 650 BP. Increased storminess and subsequent precipitation would result in higher rainfall levels, subsequent runoff, and water turbidity in the nearshore environment (Crabbe and Smith 2005). Sedimentary evidence from the Sigatoka dunes on Viti Levu also suggests the possibility of increased ENSO events after 1000 BP leading to landscape changes and dune development (Anderson et al. 2006). Recent research in the Sigatoka Valley on Viti Levu (Field 2003, 2004) suggests that increased environmental variability resulting from amplified ENSO events influenced the development of warfare and other competitive strategies by approximately 500 BP.

Regardless of the specific causes of the landscape changes at Natia, increased soil runoff and coastal landscape reconfiguration can lead to negative effects on marine organisms living in nearby ecosystems. Spriggs (1997:99) has suggested that human induced soil erosion would have had negative effects on the availability of marine resources leading to more reliance on agricultural intensification. The intertidal bivalves *Atactodea striata* and *Gafrarium tumidum*, although abundant in earlier strata, decreased in both relative and absolute abundance in Layer I. This decrease is likely a result of more silt and clay particles in the nearshore environment resulting from increased terrigenous deposition at Natia Beach.

When discussing the secondary environmental effects of increased precipitation, Nunn (2000a) has suggested that high amounts of water turbidity resulting from increased soil runoff would have led to a decline in lagoon organisms. Working in the Caribbean region, Keegan et al. (2003) have also argued that increased rainfall after AD 950 led to heavier river flow leading to increased fine grained clay and silt deposition in the inshore environment with negative effects on the Veneridae species. Similar environmental processes in Fiji may have also affected human competitive strategies ultimately leading to changes in spatial organization and interaction (see Cashdan 1992).

Further excavation of archaeological deposits as well as landscape analyses in the area is necessary to conduct additional tests of our hypotheses and address possible spatial differences in shellfish deposition. One alternative explanation is that shellfish deposition continued in other areas at Natia Beach after 650 BP. However, our surface and subsurface surveys failed to locate shell deposits less than 155 meters from the present shoreline.

Finally, the results of our analysis should be treated somewhat cautiously as the samples are small relative to the excavated volume. Replication of these patterns through excavation and analysis of archaeological sites with higher densities of shellfish deposition is therefore necessary. Analyses of other faunal remains and plant resources will greatly facilitate our understanding of subsistence patterns in general and possible broad shifts in the preference of reef-based versus other animal resources or plant foods. If marine resources were indeed diminishing we might expect an increase in the use of domesticated animals. Our excavations at Natia (or indeed the Yasawa Islands as a whole [Cochrane 2004]) have failed to locate significant amounts of terrestrial fauna in archaeological deposits. Understanding terrestrial animal use is a goal of future research. By focusing first on links between environmental variation, use of marine resources, and human competition we hope to open new avenues of research in Fijian and Oceanic prehistory.

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Figure Captions for 'Shellfish Use at the Natia Beach Site' by Morrison and Cochrane

Figure 1. Western Fiji showing Nacula Island and the Natia Beach site. Island names are italicized. Island groups are in plain font.

Figure 2**.** Natia Beach Site, view to southwest. Excavations placed on the coastal flat behind the beach to the right of the small headland. Nacula village is to the left of the headland. White line shows approximate location of Transect A.

Figure 3**.** Natia Beach, Transect A showing location of Test Units 4 and 5. Top of figure shows plan view and bottom shows profile.

Figure 4**.** Excavation Profiles for Test Units 4 and 5 at Natia Beach.

Figure 5. Transect B elevation profile with subsurface core profiles (core width not to scale). Transect B is 20 m east and parallel to transect A (see figures 2 and 3).

Figure 6. Plot of Large Abundance Index for large vs. small bodied mollusks in test units 4 and 5 at Natia Beach (Y1-15).

Figure 7. Plot of density (MNI) per 1 meter^3 excavation volume per zone.

Figure 8. Box plots describing size of *Atactodea striata* by Analytical Zone, Test Units 4 and 5, Natia Beach Site (Y1-15).

Figure 9. Box plots describing size of *Anadara antiquata* by Analytical Zone, Test Units 4 and 5, Natia Beach Site (Y1-15).

Figure 10. Plot of *Atactodea* and *Gafrarium* Abundance Index at Natia Beach (Y1-15).

Table 1. Relationship between Excavation Levels, Strata, and Analytic Zones in Test Units 4 and 5, Natia Beach Site (Y1-15)

Excavation Level	Stratum	Analytic Unit	cm below surface	Associated Date
Unit 4 Lvl. 1-6 Unit 5 Lvl. 1-6	I	Zone A	0-60	--
Unit 4 Lvl. 7-8 Unit 5 Lvl. 7-8	II	Zone B	60-80	710 - 590 cal. BP at 2 σ (AA-60256)
Unit 4 Lvl. 9-10 Unit 5 Lvl. 9-10	III	Zone C	80-100	--
Unit 4 Lvl. 11-12	III	Zone D	100-120	--
Unit 4 Lvl. 13-19	IV	Zone E	120-190	2380 - 2170 cal. BP at 2 σ (AA-60255)

Table 2. Data for Mollusk Species Recovered from Test Units 4 and 5 at the Natia Beach Site (Y1-15).

	Zone A			Zone B			Zone C			Zone D			Zone E		
Species	Wt (g)	MNI	NISP	Wt (g)	MNI	NISP	Wt (g)	MNI	NISP	Wt (g)	MNI	NISP	Wt (g)	MNI	NISP
Anadara antiquata	172.4	9	14	875.9	26	141	1596.3	42	157	640.3	22	80	717.2	30	82
Anadara sp.	3	1	1	--	--	--	--	--	--	--	--	--	--	--	--
Arca avellana	--	--	--	--	--	--	3.8	4	6	2.9	2	4	2.2	1	1
Arca sp.	--	--	--	2.8	1	1	--	--	--	--	--	--	--	--	--
Atactodea striata	--	--	--	132.2	140	288	190.9	175	329	105.2	91	168	136.1	104	192
Barbatia sp.	29.9	5	14	122.2	17	75	89.3	19	98	83.7	9	57	63.8	11	48
Cerithium columna	3.9	1	1	8.98	7	7	36.7	22	22	13.0	4	4	3.2	1	1
Cerithium sp.	--	--	--	--	--	--	6.4	3	3	--	--	--	--	--	--
Chama sp.	7	1	1	36.7	1	1		--	--	--	--	--	--	--	--
Chiton sp.	--	--	--	16.5	4	15	47.1	7	50	13.9	2	15	8.2	3	4
Codakia tigerina	4.8	1	3	269.2	11	79	137	5	27	194.4	5	33	170.2	9	35
Conus sp.	3.1	1	1	57.4	7	9	88.8	13	15	27.3	2	4	31.2	3	3
Cymatium sp.	--	--	--	--	--	--	3.5	2	2	3.8	1	1	--	--	--
Cypraea sp.	9.2	1	1	8.1	3	4	38.0	7	7	23.3	3	3	43.6	2	2
Diodora sp.	2.7	1	1	4.4	3	3	2.0	2	2		--	--	--	--	--
Drupa sp.	--	--	--	8.6	2	2	13.5	36	36		--	--	--	--	--
Gafrarium tumidum	11.2	3	3	150.4	18	40	211	28	56	90.4	12	24	121.8	17	25
Lambis lambis	155.5	3	4	321.6	6	14	227.9	4	12	100.7	2	6	188.6	5	22
Planaxis sulcatus	16.5	18	18	151.2	206	209	181.9	183	183	69.7	69	70	65.9	37	37
Nassarius sp.	3.2	2	2	--	--	--	--	--	--	--	--	--	--	--	--
Nerita sp.	86.8	16	16	181.4	120	156	328.2	185	219	148.7	79	91	198.2	88	113
Neritina sp	--	--	--	--	--	--	--	--	--	--	--	--	2.3	1	1
Oliva sp.	--	--	--	--	--	--	10.0	1	1	--	--	--	--	--	--
Patella sp.	--	--	--	--	--	--	1.8	1	1	3	1	1	--	--	--
Peristernia sp.	--	--	--	5.5	3	3	--	--	--	--	--	--	--	--	--
Polincies sp.	--	--	--	9.2	3	3	--	--	--	--	--	--	--	--	--
Rhinoclavis sp.	--	--	--	7.6	5	5	--	--	--	--	--	--	--	--	--
Strombus gibberulus gibberulus	4.3	1	1	--	--	--	16.0	1	1	--	--	--	--	--	--
Strombus sp.	9.6	3	3	8.3	2	2		--	--	2.4	1	1	7.7	1	1
Tectus pyramis	5.0	1	1	22.5	2	4	70.9	4	4	6.3	3	3	--	--	--
Tectus sp.	--	--	--	7.0	2	3	--	--	--	--	--	--	--	--	--

Tellina palatum	2.5	1	1	8.0	2	11	21.5	5	15	18.1	2	14	48.2	5	12
Tellina remies	--	--	--	--	--	--	13.1	1	5		--	--	--	--	--
Thais hippo	--	--	--	22.9	1	1	25.0	2	2	4.8	1	2			
Thais sp.	11.8	1	1	--	--	--	--	--	--	--	--	--	11.5	4	4
Thais tuberosa	--	--	--	39.0	1	1	12.7	1	1	--	--	--	30.6	1	1
Trachycaridum sp.	--	--	--	--	--	--	3.8	2	2	--	--	--	--	--	--
Tridacna crocea	--	--	--	125.7	4	8	13.7	2	2	25.8	1	1	9.8	3	2
Tridacna maxima	178.5	2	3	--	--	--	--	--	--	--	--	--	--	--	--
Tridacna sp.	--	--	--	49.0	1	14	--	--	--	--	--	--	--	--	--
Trochus niloticus	220.6	7	11	1102.3	27	59	2561.4	37	129	675.6	19	64	798	28	91
Trochus sp.	--	--	--	22.1	7	19	--	--	--	34.6	4	7	43.0	7	18
Turbo cinereus	65.2	21	27	342.7	175	267	795.3	359	432	464.4	224	242	287.42	126	145
Turbo crassus	4.0	1	1	269.6	6	10	1111.2	27	127	414.4	7	30	588.2	20	65
Turbo sp.	80.8	8	23	348.3	9	59	--	--	--	363.2	4	49	108.6	5	36
Total	1091.5	109	152	4737.28	822	1513	7865.4	1183	1949	3532.7	572	976	3685.52	512	941

Table 3. Relationship between weight and MNI across excavation levels for seven of the most prevalent taxa at the Natia Beach Site (Y1-15).

Species	r_2	significance	n of excavation levels
Anadara antiquata	0.915	0.000	21
Gafrarium tumidum	0.953	0.000	19
Nerita sp.	0.993	0.000	23
Planaxis sulcatus	0.919	0.000	18
Trochus niloticus	0.902	0.000	20
Turbo cinereus	0.994	0.000	23
Turbo crassus	0.862	0.000	23

Table 4. Fragmentation for seven of the most prevalent taxa at the Natia Beach Site (Y1-15). Fragmentation is calculated as NISP/MNI.

Species	Zone A	Zone B	Zone C	Zone D	Zone E
Anadara antiquata	4.55	5.42	3.74	3.63	2.73
Gafrarium tumidum	1.0	2.22	2.0	2.0	1.47
Nerita sp.	1.0	1.3	1.18	1.15	1.28
Planaxis sulcatus	1.0	1.0	1.0	1.01	1.0
Trochus niloticus	1.67	2.19	3.49	3.37	3.25
Turbo cinereus	1.39	1.53	1.2	1.1	1.15
Turbo crassus	3.14	4.6	4.7	7.18	3.8
Entire assemblage	1.43	1.84	1.65	1.71	1.84

Table 5. Large Abundance Index and Evenness analysis by zone, Natia Beach Site (Y1-15).

	Statistic	
Zone	Large Abundance Index	Shannon's Evenness Index
A	0.236	0.809
B	0.105	0.641
C	0.127	0.640
D	0.114	0.614
E	0.237	0.719

Table 6. Sediment Characteristics for Samples taken from Test Unit 4, Natia Beach Site (Y1-15)

Zone	Layer	% Sand	% Silt	% Clay	pH	Colour	Soil Texture Class
A	Ia	0	69.66	30.34	7.72	10 YR 3/2	Silty clay loam; strong columnar and blocky
A	I	0	58.18	41.82	7.70	10 YR 3/2	Silty clay; strong columnar
B	II	49.18	31.36	19.46	7.94	7.5 YR 3/2	Sandy loam; structureless
C, D	III	76.56	10.28	13.16	8.01	10 YR 3/2	Loamy sand; structureless
E	IV	77.90	18.64	3.46	8.17	10 YR	Sand; structureless

Table 7. Particle size distribution by % of total weight from Test Unit 4, Natia Beach Site (Y1-15).

		Particle Size Classes (mm)											
Zone	Layer	4	2	1	0.5	0.25	0.125	0.625	0.0312	0.0156	0.0078	0.0039	< 0.0039
A	Ia	0	0	0	0	0	0	0	24.15	16.10	16.10	13.31	30.34
A	I	0	0	0	0	0	0	0	14.24	11.7	20.12	12.12	41.82
B	II	0	2.05	3.12	8.80	14.5	13.8	6.91	9.30	4.76	8.65	8.65	19.46
C,D	III	1.95	1.33	5.89	17.46	20.23	15.55	7.35	6.80	1.88	5.82	2.58	13.16
E	IV	2.43	1.72	5.54	13.62	18.06	15.91	6.39	14.23	4.87	3.94	9.74	3.55

Table 8. Abundance Indices for *Atactodea-Gafrarium* by zone, Natia Beach Site, (Y1-15).

	Statistic
Zone	*Atactodea- Gafrarium* Abundance Index
A	0.028
B	0.192
C	0.239
D	0.18
E	0.236

Figure1

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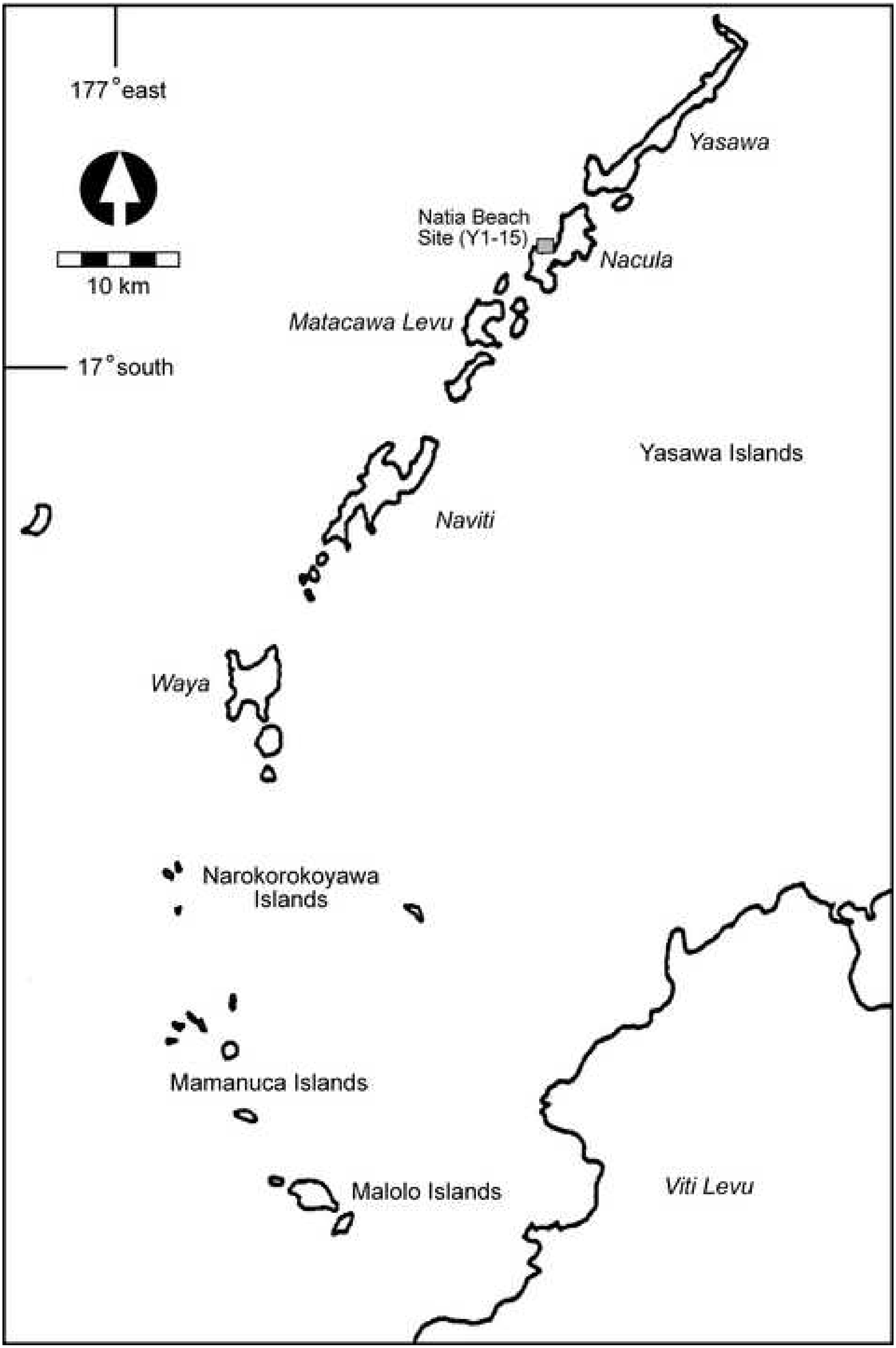

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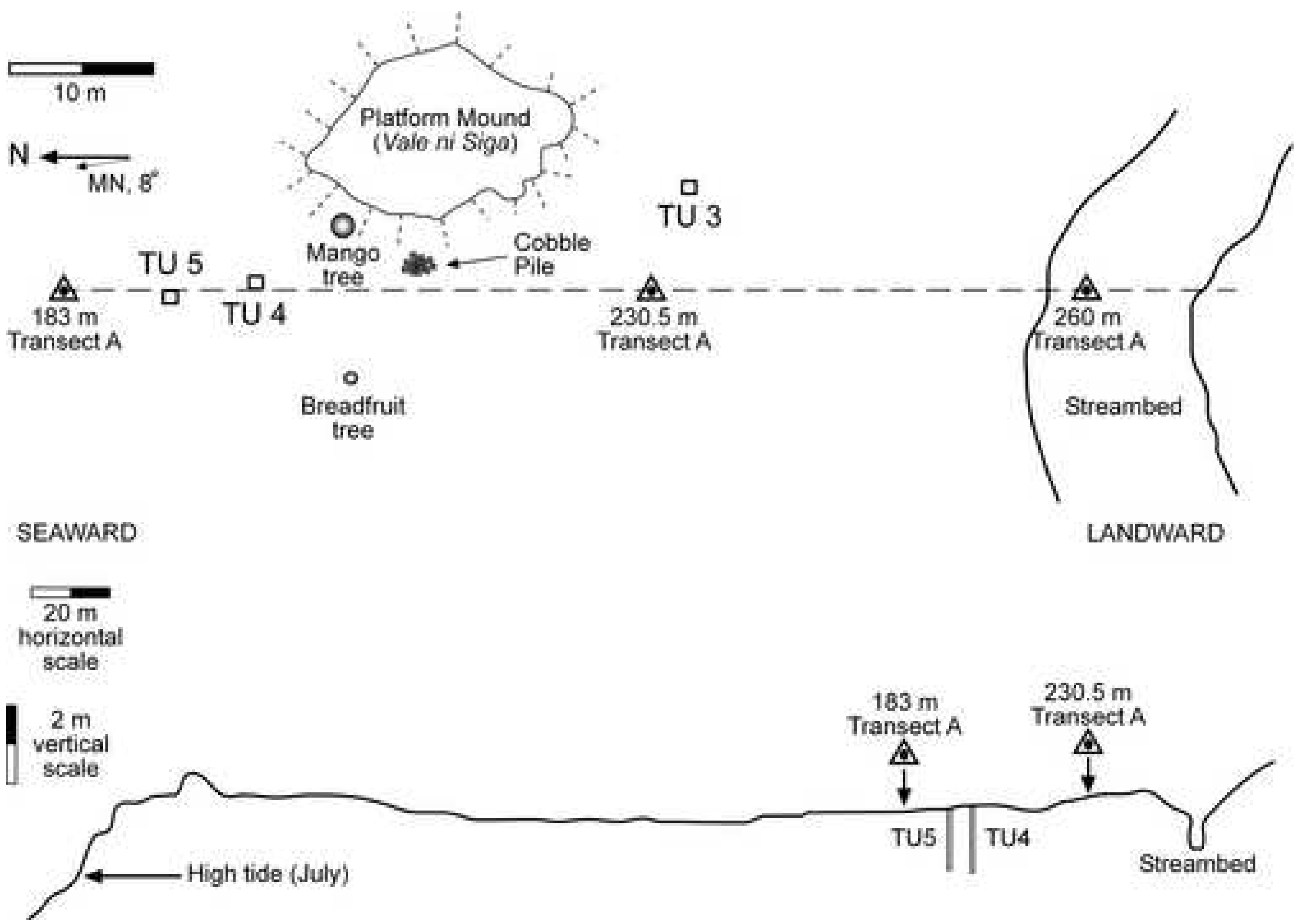

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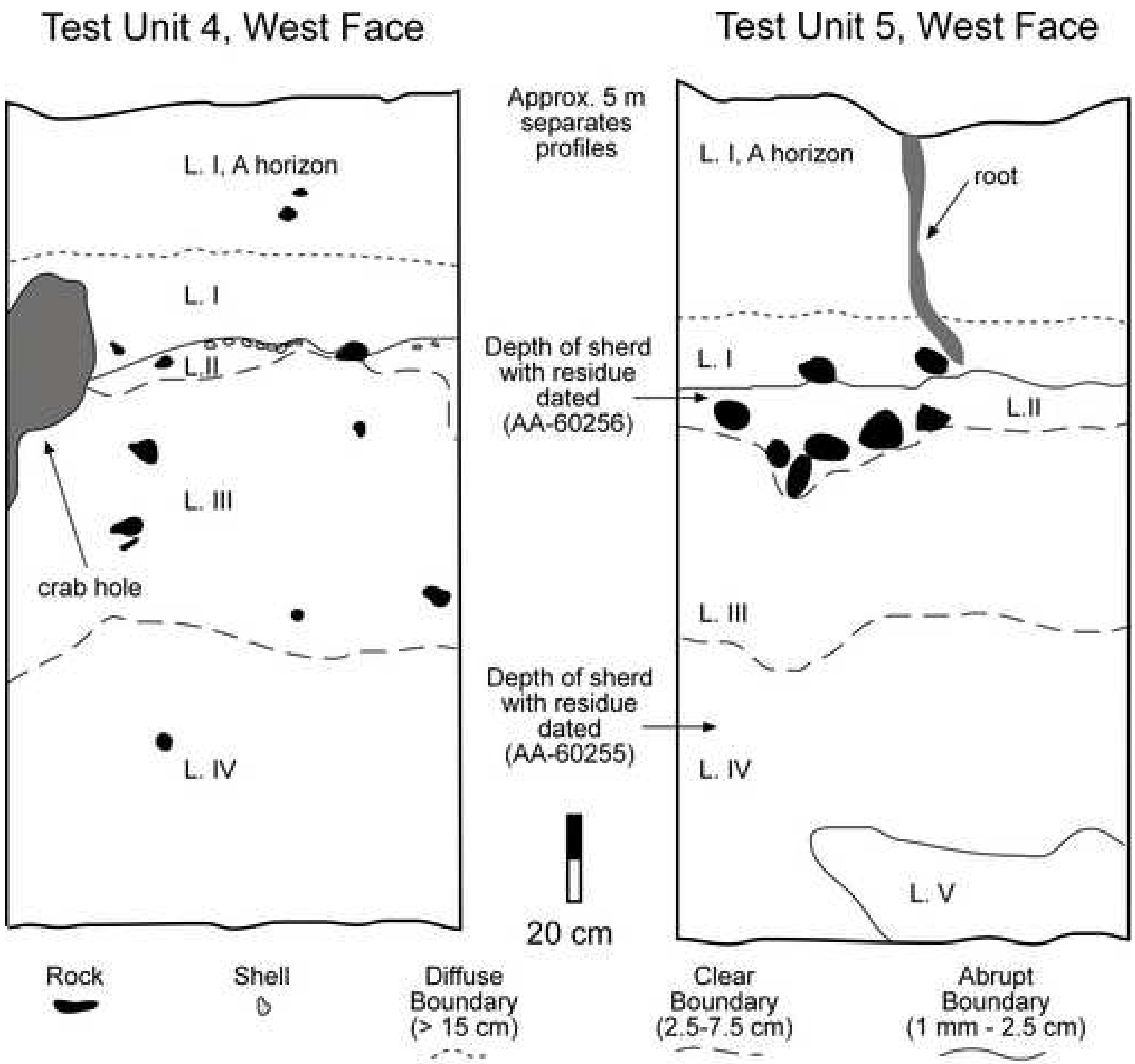

L. I, A: clay loam, strong columnar and blocky, <5% subangular pebbles, 10YR 3/2

L. I: silty clay, strong columnar, 10YR 3/2

L. II: sandy clay loam, structureless, abundant shell, 7.5YR 3/2

L. III: loamy sand, structureless, 10YR 3/2

L. IV: sand, structureless, 7.5YR 4/1 (lower boundary unexcavated)

L. V: lithified sand with silt inclusions (unexcavated)

Figure5
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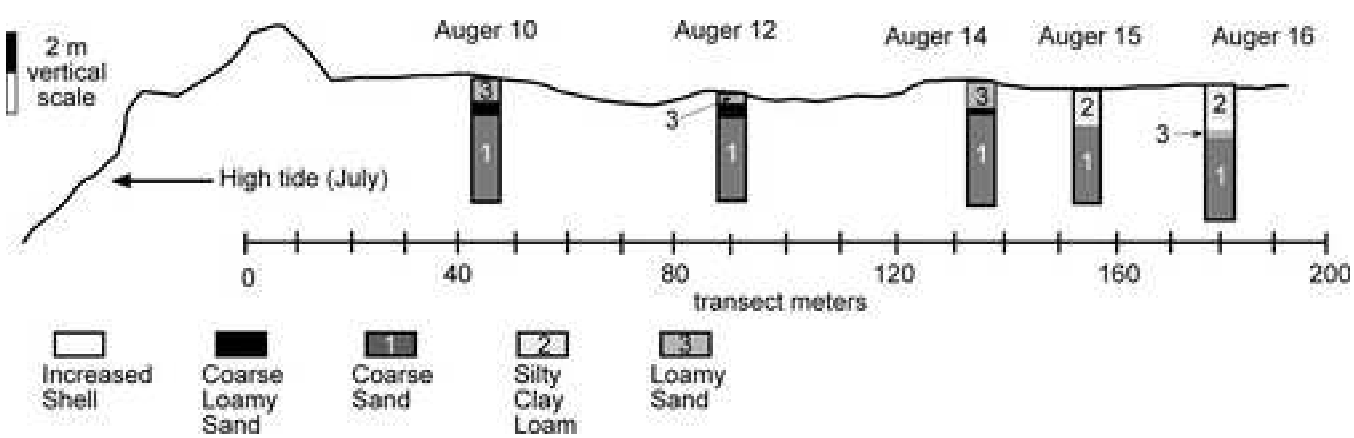

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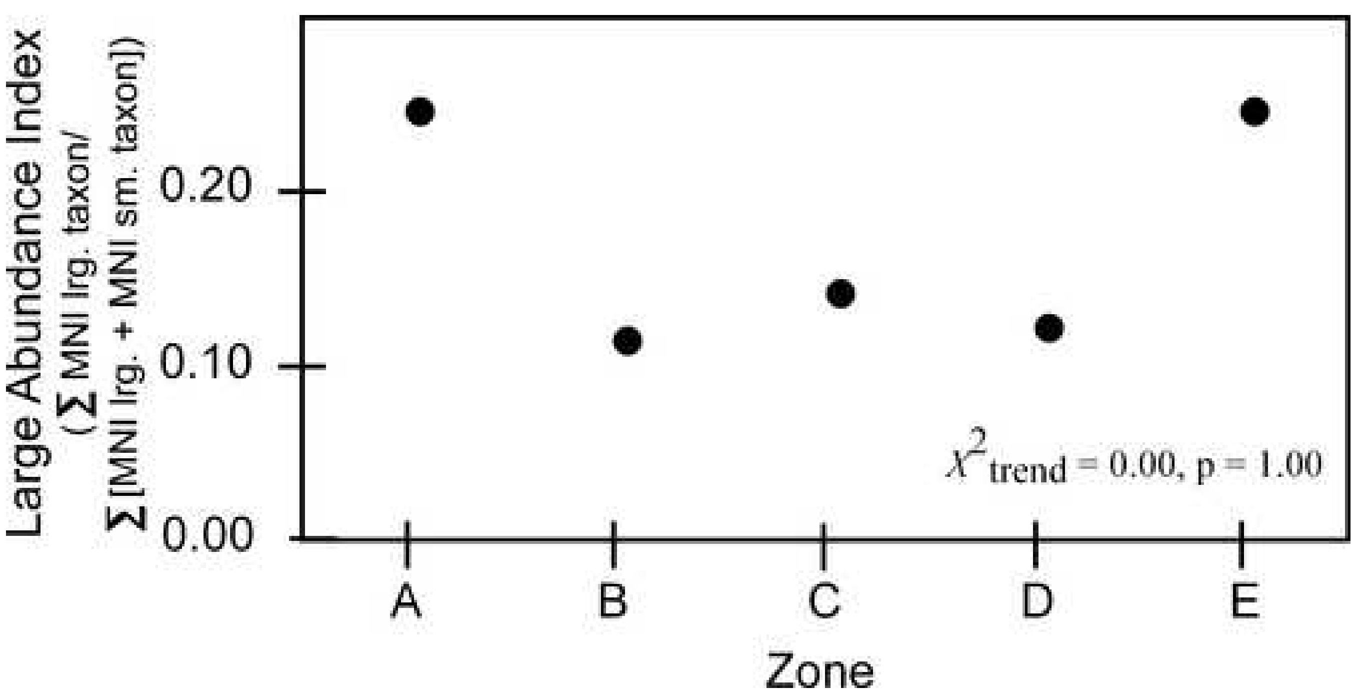

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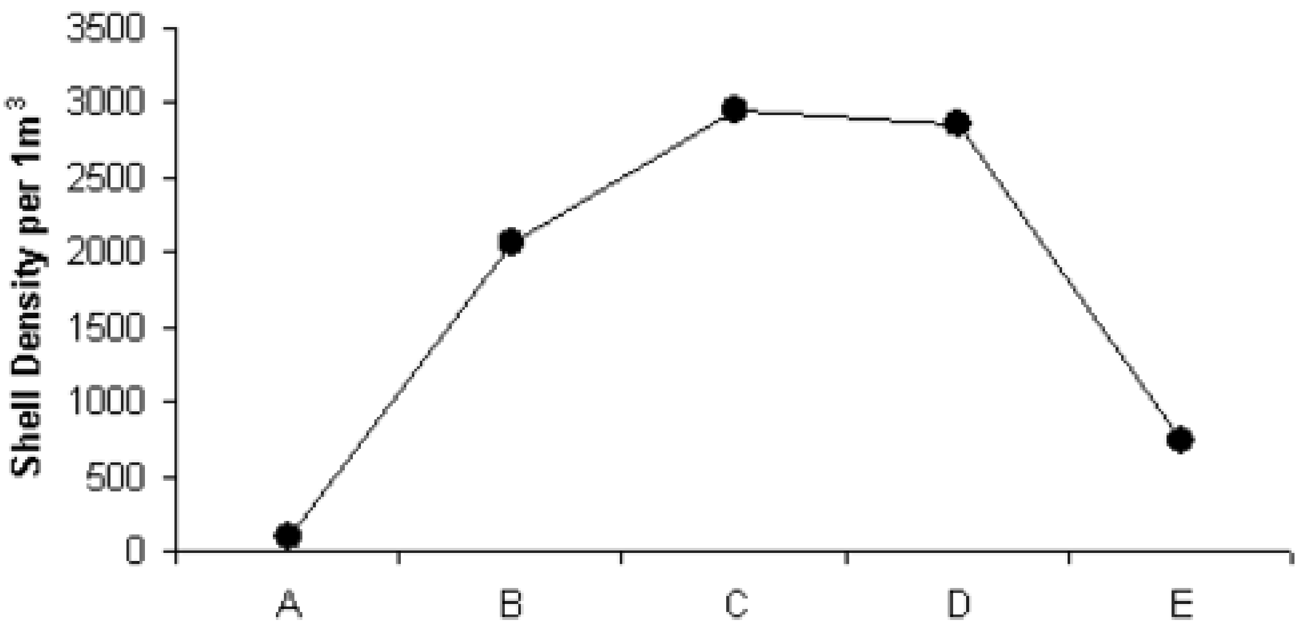

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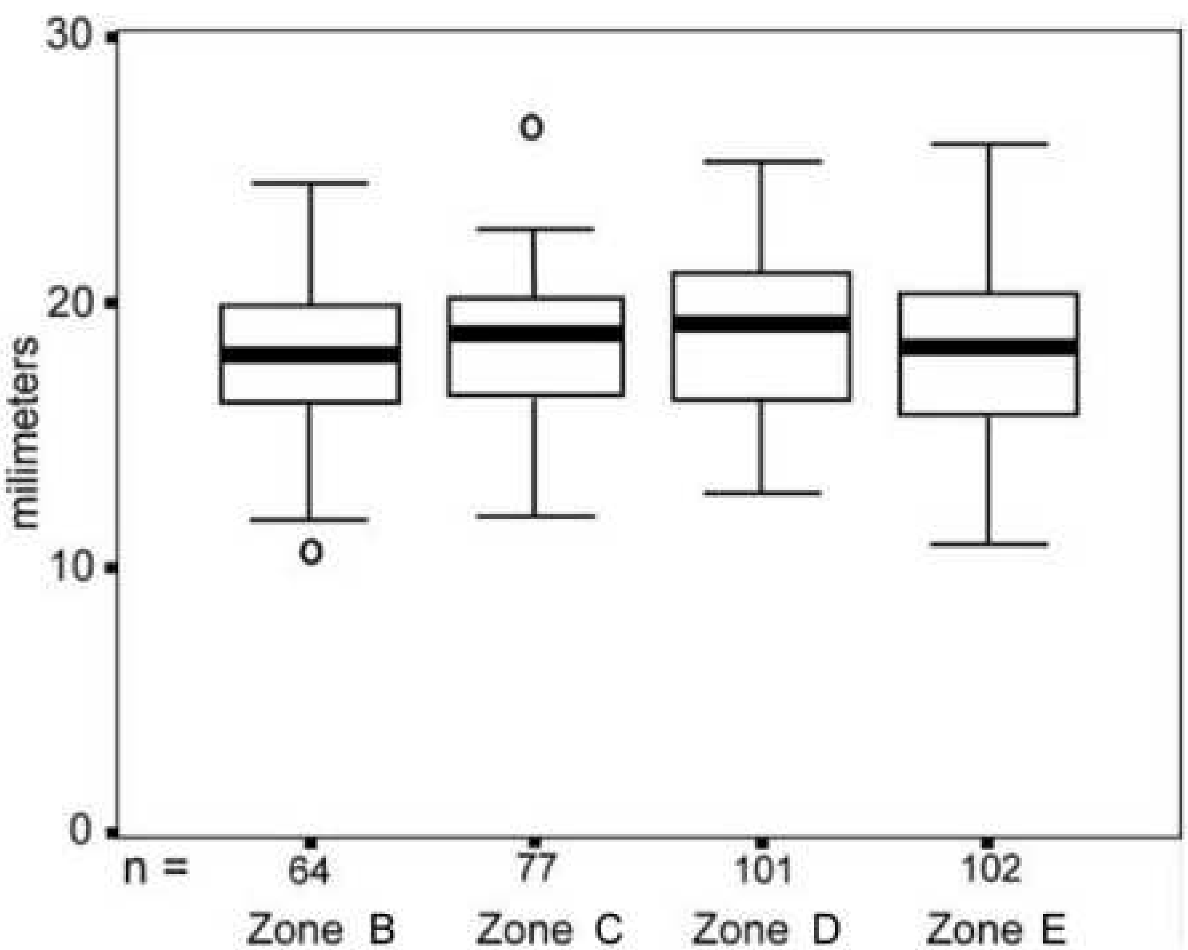

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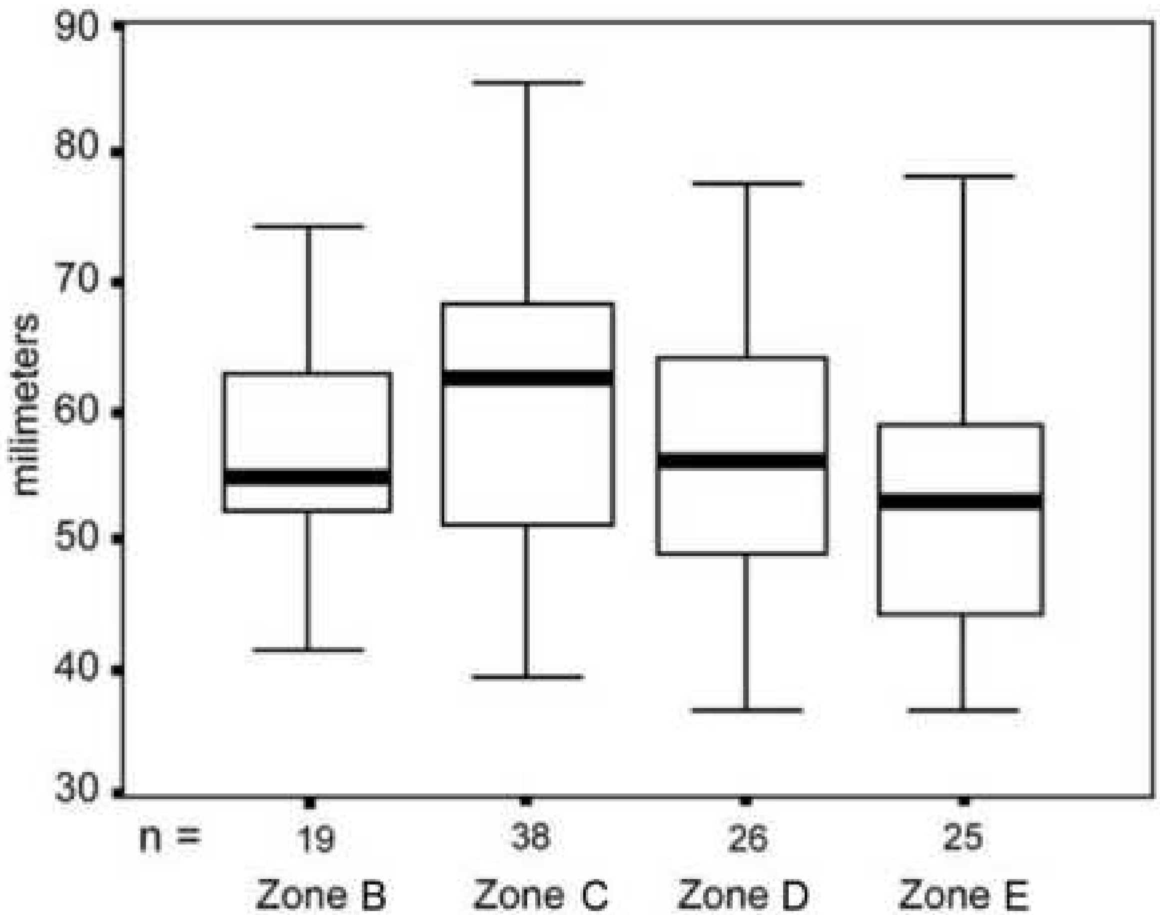

Figure10

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