5

Variability in Molluscan Species and Habitat Exploitation

A detailed analysis of the molluscan taxa recovered from the six excavated sites provides for an assessment of the intensity of human interaction with the environment, in this case at a finer-scale of analysis relative to broader economic patterns. As molluscan remains reflect ecological and environmental changes within the local environment, changes in the distribution and relative abundance of particular species at focal points within the landscape should be reflected in the archaeological record (Faulkner 2011:137–8). Investigating the relative proportion of mollusc species requires the consideration of a number of different economic and/or environmental processes. For example, taxonomic variability might indicate differential cultural selection and discard practices, and may also be a reflection of the environment from which resources were procured and associated differences in the availability of molluscs within and between specific localities (Bourke 2000:301). As such, an interpretation of successive short-term responses to changes in the local environment may be supported by chronological change in the relative frequencies of molluscan taxa (Bird and Frankel 1991; O'Connor and Sullivan 1994). An investigation of this issue is achieved here via species richness, relative abundance of taxa and the identification of habitats that were preferred or more intensively utilised by people in the past.

Methods for investigating molluscan diversity

Representing the number of taxa within a sample, species richness is a useful way of identifying whether these shell deposits reflect the exploitation of a wide range of edible species, or a greater focus in the exploitation of one or two particular taxa. As species richness is an effective measure of the classes represented within an assemblage, a relatively rich sample would contain a larger number of taxa in comparison with a relatively poor sample (Magurran 1988:1–7; Broughton and Grayson 1993; Broughton 1995; Nagaoka 2000:99, 2002). As an extension of this, similar patterns would be expected in assessing variability in the exploitation of those habitats from which the sample of molluscan taxa was drawn. As noted above, differences in the number of taxa and the habitats they come from may be indicative of a range of different processes, such as environmental changes affecting the distribution and density of the represented species via changes to the structure of the available habitats and/or the emphasis placed by people on particular species for exploitation (Faulkner 2011:141). The use of the number of species as a measure of assemblage richness has been criticised, the argument being that it is said to reflect average patterns in subsistence exploitation (for example Madsen 1993), and would therefore not be sensitive enough for the identification of subtle changes in economic activity over time. In fact, broad trends in the variation of species and habitat exploitation across the study area have already been established through survey data, based

on differences in species richness and habitat representation (Chapter 3). The time-averaged nature of open sites lends itself to the identification of broad-scale trends, as the level of chronological resolution will often not allow subtle changes to be identified.

The mollusc species included in the following analyses are based on the edible taxa recovered from the 6mm sieve, identified primarily as those large enough to provide a reasonable amount of meat for human consumption. While Rowland (1994a:122–3) has highlighted that size on its own is not an adequate criterion for differentiating between possible non-economic and economic molluscan species, there are a number of reasons for implementing this approach here. While the identification of most taxa could be made to species level, there are several instances where the level of identification could only be made to genera or family (Faulkner 2011:141). Therefore, while the level of taxonomic identification varies, none of the taxa overlaps in terms of their identification (Nagaoka 2000:100). This means, rather than over-estimation, there is a general under-estimation of species richness within these assemblages. In addition to this, from the excavated sites in this area that form the basis for the following analyses, those species identified as non-economic form such a minor component of the shell assemblage that their exclusion does not bias the results. Non-economic shell species comprise approximately 5% by weight of the total weight of shell removed from the three midden excavations in Myaoola Bay, and less than 1% by weight from the mound sites in Grindall Bay (Faulkner 2011:141–2). In addition to their relative size, the identification of taxa as being primarily economic for these analyses is in line with previous research undertaken on coastal shell deposits in northern Australia (e.g. Meehan 1982; Clarke 1994; Mitchell 1994a; Mowat 1995; Bourke 2000). An example is the detailed research undertaken by Bourke (2000:247), who largely focussed her analyses of the molluscan fauna from shell deposits in the Darwin Harbour region on the 'macro-molluscs'. This approach has been applied consistently within and between sites in this study, and enables a more accurate analysis and interpretation of variability in subsistence and the economy.

The final factor to be considered in investigating faunal assemblage richness is that variability in species richness is often strongly related to sample size (Grayson 1984:132). The relationship between sample size and the number of taxa within an assemblage is therefore required to be taken into account whenever species richness is assessed. Table 5.1 provides the correlation coefficients for the relationship between the number of taxa identified within each site and the size of the sample. In this case, sample size is determined through MNI calculations as they may more accurately reflect the relative number of individuals in a midden sample than NISP counts (see discussion below). Only one of the six sites in this sample, the midden site BMB/018, shows a strong and significant correlation between species richness and sample size. That said, Grayson (1984:121) notes that while there may be a correlation between species richness and sample size within midden assemblages, it is possible that there is no real causal relationship. Based on previous analyses that indicate the strong effect of environmental parameters on the distribution and morphology of sites in this area, this correlation may be due to this factor acting in conjunction with the structure of the exploited mollusc populations. In most cases where a correlation is noted, the cause of this relationship is much clearer. For site BMB/018, it is more than possible that the correlation is a reflection of a situation where the small number of samples contains comparatively low relative abundance values (Grayson 1984:121; Faulkner 2011:142).

Table 5.1: Correlation coefficients for the relationship between species richness (number of taxa) and sample size (MNI) by site.

Site Type	Site Code	Pearson's r	r^2	p	No. Excavation Units
Shell Midden	BMB/018	0.937	0.8771	< 0.05	4
	BMB/067b	0.706	0.4984	> 0.2	5
	BMB/084	0.356	0.2641	> 0.2	8
Shell Mound	BMB/029	0.960	0.0091	> 0.5	11
	BMB/071	0.538	0.2893	> 0.2	6
	BMB/045	0.344	0.1184	> 0.1	16

Turning to considerations in estimating the relative abundance of molluscan species, there has been considerable debate in the archaeological literature concerning the relative merits of the number of identifiable specimens (NISP) and the minimum number of individuals (MNI) as appropriate measures of relative abundance in faunal studies. The principal identified weakness of NISP relates to the potential for variation in counts of taxa within differentially fragmented assemblages, the non-independence of specimens, and the inflation of NISP counts for those taxa with a larger number of easily identifiable elements. Increased levels of disturbance and fragmentation, in combination with differing butchery patterns (Grayson 1984:20–3) affect NISP values to a large degree. On the other hand, MNI has been criticised for its difficulty in calculation relative to NISP, problems related to the uneven distribution of animal body parts within a deposit, and its increased sensitivity to sample size (Grayson 1984:20; Marshall and Pilgram 1993:262; Giovas 2009). As a result of these criticisms of both NISP and MNI, the ability to identify all elements of a given species regardless of the level of fragmentation is important. Differential breakage is a common problem affecting shell deposits, as some mollusc species are more fragile than others. For molluscan remains, even when heavily fragmented, some species will be recognisable by their sculpture, whereas increased levels of weathering, fragmentation and degradation will render some taxa unrecognisable. Increasing fragmentation levels will therefore affect the calculated abundance of species, over-inflating the NISP values of those relatively fragile species compared to the more robust species (Marshall and Pilgram 1993:266–267; Mowat 1994, 1995:77–8, 85). Mowat's (1995:83–4) experiment assessing the effects of inter-species fragmentation goes some way to resolving this issue. As the levels of fragmentation increase within the experimental sample, the number of identifiable hinges slowly decreases, thus MNI values slowly decrease. In comparison, however, NISP values increase at a much faster rate than MNI decreases. Whereas MNI may fail to achieve one-to-one correspondence through biased under counting at levels of high fragmentation, NISP generally fails at one-to-one connection between specimens and whole individuals due to the tendency for multiple counting (Marshall and Pilgram 1993:266–267). Therefore, as fragmentation increases, NISP will over-estimate the abundance of species relative to MNI.

The effects of aggregation, however, affect MNI estimates. Where MNI values are calculated for each taxon within arbitrary excavation levels, and then calculated for the entire stratum or site, the result will be lower MNI values for the larger unit. This is because there is no guarantee that all elements from each individual will be found within any arbitrary level (Grayson 1984:67; Mowat 1995:79). The effects of aggregation are offset to a certain degree in midden analysis as molluscs have only one or two complete skeletal elements. Furthermore, the use of MNI controls the effects of aggregation in midden analysis as only the diagnostic parts of each individual are counted, and each individual is in effect only counted once (Mowat 1995:83). Molluscs also have only one or two preservable body parts, so MNI values are not calculated in the same way as for vertebrate assemblages. It is generally known prior to identification and counting of molluscan material which element will be used to define the minimum number of individuals, as diagnostic elements are often very specific to the taxon being examined (Nichol and Williams 1981:90; Mowat 1995:80; Giovas 2009). The use of MNI, rather than NISP, in midden analysis is also encouraged by the observation that with many of the molluscan taxa examined, the element used to calculate MNI, such as the hinge section of bivalves, is the most robust component of the shell. As a categorical variable, the discrete nature of MNI has also been seen to be more appropriate to research questions investigating environmental change and the nature of resource exploitation, particularly when dealing with inter-site comparisons of the relative frequency of mollusc taxa (Bourke 2000:68; Mason *et al.* 1998:309, 319; 2000:757). As a result, MNI is used here as the most appropriate measure of relative abundance for molluscan material within the Point Blane Peninsula sites.

Variability in species richness, habitat and molluscan exploitation

In total, 35 molluscan taxa have been identified for the purposes of this analysis from the six excavated sites (Table 5.2), with 21 species identified from the Grindall Bay mounds and 33 species from the Myaoola Bay middens (Faulkner 2011:142). Overall species richness follows the pattern previously identified in Chapter 3, with a higher species richness recorded for the Myaoola Bay shell deposits. This pattern suggests that variability in the distribution of species between the Grindall and Myaoola Bay sites possibly relates to the differential availability of resources across the study area, reflecting the diversity of environmental conditions and the differential distribution of molluscan habitats. Differences between the species identified on the surface of the sites compared with the excavated material possibly relate to a number of factors. It has been noted by a number of researchers in other regions of northern Australia (for example Mitchell 1993, 1994a and Hiscock 1997) that there is a certain degree of temporal and spatial intra-site variability in the distribution of species. This variability relates to the formation history of the site itself, as well as to the differential preservation of molluscan taxa. Those taxa identified for the analysis of species richness from the survey data reflect the total number of taxa identified across the surface of the site, and as such provided the basis for an analysis of species richness in very broad terms. Added to this is the generally high level of fragmentation and weathering in surface samples, making identification and quantification in these contexts difficult. As such, the excavated samples provide the opportunity to investigate possible changes in species richness and those habitats exploited with a greater degree of chronological control.

Table 5.2: The presence / absence of molluscan species of possible economic origin within the six excavated sites.

			Myaoola Bay			Grindall Bay		
Family	**Taxon**	**Habitat**	**BMB/018**	**BMB/067b**	**BMB/084**	**BMB/029**	**BMB/071**	**BMB/045**
Arcidae	*Anadara antiquata*	Littoral Sand and Mud (Intertidal/marginally subtidal)	+	+	+	+	+	+
	Anadara granosa	Littoral Sand and Mud (Intertidal/marginally subtidal)		+	+	+	+	+
	Barbatia sp.	Rock/Debris in Littoral Area, Coral Reefs	+	+	+	+		
Chitonidae	Chitonidae f.	Upper Intertidal to Shallow Sub-tidal		+	+			
Corbiculidae	*Polymesoda (Geloina) coaxans*	Coastal Rivers, Streams and Estuaries	+	+	+	+	+	+
Ellobiidea	*Cassidula angulata*	Mangroves/Mud		+		+	+	+
Fissurellidae	Fissurellidae sp.	Attached to Rocks or Debris		+	+			
Haliotidae	*Haliotis* sp.	Attached to Rocks or Debris			+			
Isognomonidae	*Isognomon isognomon*	Mangroves to Under rocks in Shallow Water	+	+	+			
Mactridae	*Mactra abbreviata*	Littoral Sand	+	+		+	+	+
Muricidae	*Chicoreus* sp.	Under Rock/Rubble in Intertidal/Sub-tidal Areas		+				
	Muricidae sp.	Under Rock/Rubble in Intertidal/Sub-tidal Areas		+				
Mytilidae	*Modiolus* sp.	Sand and Mud in Shallow Water – Estuaries	+		+	+	+	+
	Mytilidae f.	Attached to Rocks or Debris			+			
	Septifer bilocularis	Attached to Rocks or Debris	+	+			+	+
Neritidae	*Nerita* sp.	Mangrove Roots/Rocks	+	+	+	+	+	+
Ostreidae	Ostreidae f.	Mangrove Roots/Rock/Debris in Sub-tidal Areas	+	+	+	+	+	+
Pinnidae	*Pinna bicolor*	Littoral Sand/Seagrass Beds			+			
Placunidae	*Placuna placenta*	Surface of Mud/Mangroves				+	+	+
Potamididae	*Cerithidea* sp.	Shallow Mud/Mangroves Roots				+		
	Telescopium telescopium	Mangroves		+	+	+	+	+
	Terebralia sp.	Mangroves	+	+	+	+	+	+
Pteriidae	*Pinctada* sp.	Attached to Substrate in Intertidal/Sub-tidal Areas	+	+	+			
Tellinidae	*Tellina* sp.	Littoral Sand and Mud	+	+	+	+	+	+

Note: + indicates presence.

Table 5.2 (continued): The presence / absence of molluscan species of possible economic origin within the six excavated sites.

			Myaoola Bay			Grindall Bay		
Family	**Taxon**	**Habitat**	**BMB/018**	**BMB/067b**	**BMB/084**	**BMB/029**	**BMB/071**	**BMB/045**
Trochidae	*Euchelus atratus*	Shallow Water		+				
	Monodonta labio	Shallow Water	+					
	Trochus sp.	Shallow Water		+	+	+		
Turbinidae	*Turbo cinereus*	Shallow Water		+	+			
Veneridae	*Circe* sp.	Littoral Sand		+	+			
	Dosinia mira	Littoral Sand				+		
	Gafrarium sp.	Littoral Muddy Sand	+	+	+			
	Marcia hiantina	Littoral Sand	+	+	+	+	+	+
	Pitar sp.	Littoral Sand			+			
	Placamen calophyllum	Littoral Sand	+	+		+	+	+
	Tapes sp.	Littoral Sand			+			
Volutidae	*Melo amphora*	Lower Intertidal and Sub-tidal Sand/Mud		+				
Total No. Taxa			**16**	**26**	**24**	**18**	**15**	**15**

Note: + indicates presence.

Myaoola Bay Midden Sites

BMB/018: Species richness, habitat exploitation and relative abundances

Sixteen molluscan species in all were identified within the four units excavated in BMB/018. As previously noted, BMB/018 is possibly representative of short-term or ephemeral occupation, and it is not relevant to assess variation in species richness and habitat exploitation between arbitrary excavation units within approximately 10cm of cultural deposit. More importantly, within this context, it is still possible to assess the relative importance of the habitats from which the 16 species were gathered. Table 5.3 details the number and percentage of the 16 species from this site by habitat, along with the total MNI counts for each of these species, and the volume-corrected relative abundance estimates (MNI/cm^3). Species richness per habitat and the corrected relative abundance of species from each habitat are graphed in Figure 5.1. While changes in the number of taxa and the focus on habitats exploited through time cannot be assessed for BMB/018, there appears to be a more intensive focus on those species gathered from shallow areas, and those species from sand and mud flats. The site is located in an area that prior to the phases of beach-ridge development that created the present-day landscape would have resembled a headland. The area would have been predominantly a rocky coastline with some mangrove-fringed sand and mudflat areas in small, relatively protected embayments. The pattern of species and habitat richness possibly reflects the structure of the habitats within this locality at the time of site deposition approximately 3000 years ago. While richness of exploited species varies between patches, there appears to be near equal emphasis in exploitation in terms of the number of individuals gathered from within the dominant habitat areas.

Table 5.3: BMB/018, number and percentage of species, MNI values and MNI density estimates (MNI/cm³) for molluscan habitats.

Molluscan Habitats	No. of Taxa	%	Habitat MNI	% MNI	MNI/cm³
Shallow Water	4	25.00	408	51.78	0.00185
Sand/Mud Flats	7	43.75	370	46.95	0.00168
Mangroves	3	18.75	7	0.89	0.00003
Estuarine	2	12.50	3	0.38	0.00001
Totals	**16**		**788**		

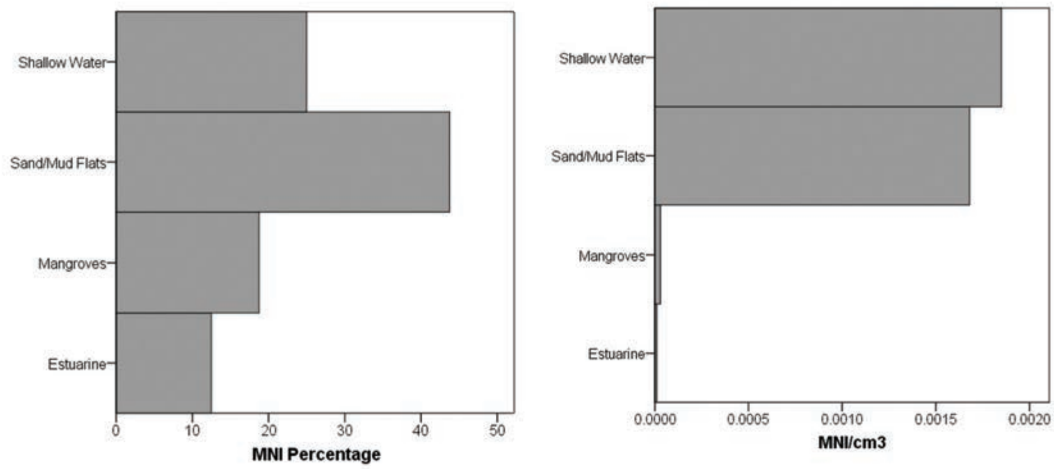

Figure 5.1: BMB/018, percentages of the number of taxa and volume-corrected MNI estimates (MNI/cm³) per habitat.

Both Grayson (1984:134) and Mowat (1995:76) have noted that the tendency in archaeological assemblages is for few species to be very abundant, while most are represented by small numbers of individuals. It is therefore appropriate to investigate the abundance of the species from the site relative to the description of species and habitat richness, as this enables the specific focus of exploitation within the site to be examined. Table 5.4 details the MNI counts and percentages for the 16 species from this site and the corrected relative abundance estimate (MNI/cm³), with the MNI percentages and abundance estimates for the three dominant species graphed in Figure 5.2. For this analysis, those species contributing greater than 5% by MNI to the overall assemblage are viewed as being dominant. Three species, at 18.8% of the total species richness, make up 91.2% by MNI of the assemblage from BMB/018. *Septifer bilocularis* is the highest-ranking species by percentage of the total MNI (48.7%) and by the corrected density estimate. *Septifer bilocularis* is found attached to hard-substrate areas within the shallow water habitat zone. In rank order, this species is followed by *Pinctada* sp. (34.8% MNI) and *Gafrarium* sp. (7.7% MNI) which collectively comprise 42.5% of the assemblage by MNI. Both of these species are found within sand and mudflat habitats. This pattern further emphasises the point made earlier, that while there is variation in species richness between exploited patches, there appears to be similar intensity of exploitation within the dominant habitat areas. It is also suggestive of the structure and distribution of molluscan resources within these habitats, which directly reflects the relative abundance of each species.

Table 5.4: BMB/018, MNI values and volume-corrected MNI estimates (MNI/cm^3) for all molluscan species (species above dashed line at > 5% MNI viewed as dominant).

Economic Molluscan Species	Habitat Category	MNI	% MNI	Density (MNI/cm^3)	Rank Order
Septifer bilocularis	Shallow Water	384	48.73	0.00175	1
Pinctada sp.	Sand/Mud Flats	274	34.77	0.00125	2
Gafrarium sp.	Sand/Mud Flats	61	7.74	0.00028	3
Marcia hiantina	Sand/Mud Flats	26	3.30	0.00012	4
Barbatia sp.	Shallow Water	17	2.16	0.00008	5
Nerita sp.	Mangroves	5	0.63	0.00002	6
Monodonta labio	Shallow Water	4	0.51	0.00002	7
Mactra abbreviata	Sand/Mud Flats	4	0.51	0.00002	7
Ostreidae f.	Shallow Water	3	0.38	0.00001	9
Tellina sp.	Sand/Mud Flats	2	0.25	0.00001	10
Placamen calophyllum	Sand/Mud Flats	2	0.25	0.00001	10
Polymesoda (Geloina) coaxans	Coastal Rivers/Estuaries	2	0.25	0.00001	10
Anadara granosa	Sand/Mud Flats	1	0.13	0.00001	13
Isognomon isognomon	Mangroves	1	0.13	0.00001	13
Terebralia sp.	Mangroves	1	0.13	0.00001	13
Modiolus sp.	Coastal Rivers/Estuaries	1	0.13	0.00001	13
Total		**788**			

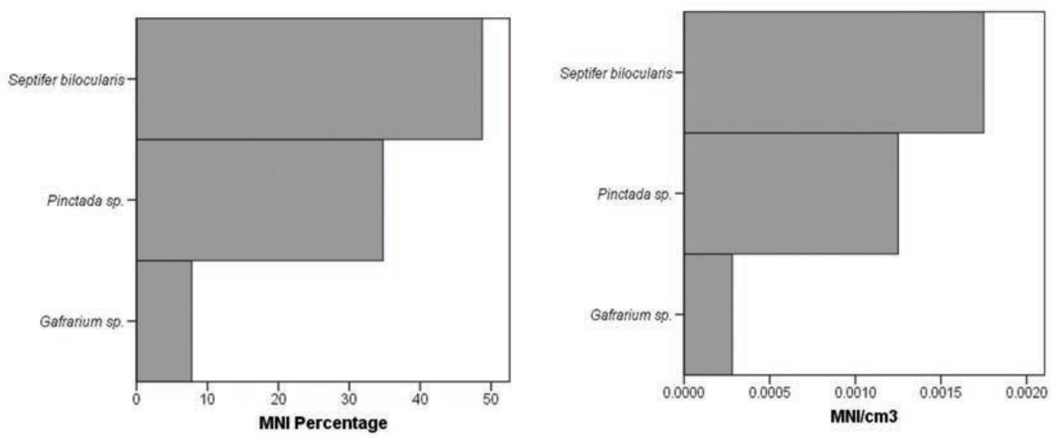

Figure 5.2: BMB/018, dominant molluscan species by MNI percentages and volume-corrected MNI (MNI/cm^3).

BMB/067b: Species richness, habitat exploitation and relative abundances

Twenty-six molluscan species were identified within the five excavation units analysed in BMB/067b. While it was not possible to isolate phases in occupation within this site based on the available radiocarbon determinations, any changes through time should be reflected by analysing variation in species richness, habitat exploitation and relative abundance estimates by excavation unit (Table 5.5). As the differences in radiocarbon dates from the surface and base of the site are significantly different, this approach enables broad scale patterns in the economy to be observed. While there is degree of variation in species richness between excavation units, with a decrease in the number of species exploited apparent in the upper units, correlation coefficients (r_s = 0.821, p > 0.05, n = 5) suggest that the relationship between species richness and excavation unit is not significant. This indicates that, given minor variation, there is a certain level of consistency in overall species richness within the site through time.

Table 5.5: BMB/067b, number of species, the percentage of the total number of species and number of species for molluscan habitats by excavation unit.

Excavation Unit	No. Species	% of Total	Shallow Water	Sand/Mud Flats	Mangroves	Estuarine
1	17	65.38	8	5	3	1
3	18	69.23	5	10	2	1
5	20	76.92	7	8	4	1
7	25	96.15	10	10	4	1
9	20	76.92	7	9	3	1
Totals	**26**		**10**	**10**	**5**	**1**

Of the 26 economic species within the site, 10 (38.5%) each come from the shallow water and sand/mud flat habitats, with five (19.2%) from the mangrove zone and only one (3.9%) gathered from coastal river/estuarine areas. This indicates that the shallow water and sand/mud flat areas were the dominant environmental zones within the area during deposition of the site. Species richness and relative abundance estimates by excavation unit are again used to determine whether there were any shifts in the focus of exploitation within and between these habitats through time. Table 5.5 details the number and percentage of species within each excavation unit by habitat. Spearman's rank correlation (r_s) is used to test the relationship between habitat species richness and excavation unit with the exception of the estuarine habitat, as there is no change in the number of species by excavation unit. Correlation coefficients calculated for these three habitats indicate that, as with overall species richness, the relationship between habitat species richness and excavation unit is not significant. In other words, there is little variation in the number of species exploited within the shallow water ($r_s = 0.103$, $p > 0.2$, $n = 5$), sand/mud flat ($r_s = 0.410$, $p > 0.2$, $n = 5$), or mangrove ($r_s = 0.369$, $p > 0.2$, $n = 5$) habitat areas through time. As a contrast, Table 5.6 details the MNI of species within each excavation unit by habitat.

Table 5.6: BMB/067b, MNI values and volume-corrected MNI estimates (MNI/cm^3) for species from molluscan habitats by excavation unit.

Excavation Unit	Volume (cm^3)		Shallow Water	Sand/Mud Flats	Mangroves	Estuarine
1	13000	MNI	51	140	12	4
		MNI/cm^3	0.00392	0.01077	0.00092	0.00031
3	31000	MNI	99	193	2	1
		MNI/cm^3	0.00319	0.00623	0.00007	0.00003
5	34000	MNI	86	237	37	1
		MNI/cm^3	0.00253	0.00697	0.00109	0.00003
7	31000	MNI	90	272	26	1
		MNI/cm^3	0.00290	0.00877	0.00084	0.00003
9	46000	MNI	90	256	22	2
		MNI/cm^3	0.00196	0.00557	0.00048	0.00004

Testing the combined, volume-corrected species relative abundance estimates from the four habitat areas by excavation unit again suggests that there is not a strong relationship. As these results are an approximate temporal measure, they suggest that for the shallow water ($r_s = -0.900$, $p > 0.1$, $n = 5$), sand/mud flat ($r_s = -0.600$, $p > 0.2$, $n = 5$), mangrove ($r_s = -0.200$, $p > 0.2$, $n = 5$) and coastal river/estuarine habitats ($r_s = -0.205$, $p > 0.2$, $n = 5$), there is no significant change in the focus of exploitation through time. Regardless of the comparative level or intensity of use between these habitat zones, exploitation within each habitat remains consistent throughout the period of occupation. These results combined with the lack of change in species richness per habitat through time, suggests that there may have been little environmental alteration

related particularly to these habitats within the immediate landscape during this period. If this interpretation of environmental stability were correct, then little to no change in the abundance of the dominant species through time would be expected. Table 5.7 details the MNI counts and percentages for the 16 species from this site, volume-corrected relative abundance estimates (MNI/cm^3), and the rank order by MNI. Four species, at 15.4% of the total number in the site, make up 78.5% by MNI of the assemblage. *Anadara granosa* is the highest-ranking species by percentage of the total MNI (31.9%) and by the corrected density estimate. In rank order, this species is followed by *Marcia hiantina* (21.1% MNI), *Septifer bilocularis* (17.02% MNI) and *Gafrarium* sp. (8.5% MNI). Three of these top four ranked species, *Anadara granosa*, *Marcia hiantina* and *Gafrarium* sp., are all found in the sand and mudflats within the intertidal/subtidal zone, and collectively comprise 61.5% by MNI of the total assemblage. In contrast, *Septifer bilocularis* is found attached to hard-substrate areas within the shallow water habitat zone. In order to address possible variation in the relative abundance of the dominant molluscan species within the site over time, Table 5.8 and Figure 5.3 present the MNI values for these four taxa corrected for volume (MNI/cm^3).

Table 5.7: BMB/067b, MNI values and corrected MNI estimates (MNI/cm^3) for all molluscan species (species above dashed line at > 5% MNI viewed as dominant).

Economic Molluscan Species	Habitat Category	MNI	% MNI	MNI/cm^3	Rank Order
Anadara granosa	Sand/Mud Flats	518	31.94	0.00334	1
Marcia hiantina	Sand/Mud Flats	342	21.09	0.00221	2
Septifer bilocularis	Shallow Water	276	17.02	0.00178	3
Gafrarium sp.	Sand/Mud Flats	137	8.45	0.00088	4
Terebralia sp.	Mangroves	78	4.81	0.00050	5
Trochus sp.	Shallow Water	57	3.51	0.00037	6
Tellina sp.	Sand/Mud Flats	44	2.71	0.00028	7
Anadara antiquata	Sand/Mud Flats	26	1.60	0.00017	8
Ostreidae f.	Shallow Water	24	1.48	0.00016	9
Muricidae sp.	Shallow Water	18	1.11	0.00012	10
Chitonidae f.	Shallow Water	17	1.05	0.00011	11
Pinctada sp.	Sand/Mud Flats	16	0.99	0.00010	12
Barbatia sp.	Shallow Water	13	0.80	0.00008	13
Nerita sp.	Mangroves	9	0.55	0.00006	14
Polymesoda (Geloina) coaxans	Coastal Rivers/Estuaries	9	0.55	0.00006	14
Telescopium telescopium	Mangroves	8	0.49	0.00005	16
Turbo cinereus	Shallow Water	5	0.31	0.00003	17
Mactra abbreviata	Sand/Mud Flats	4	0.25	0.00003	18
Melo amphora	Sand/Mud Flats	4	0.25	0.00003	18
Cassidula angulata	Mangroves	3	0.18	0.00002	20
Chicoreus sp.	Shallow Water	3	0.18	0.00002	20
Circe sp.	Sand/Mud Flats	3	0.18	0.00002	20
Placamen calophyllum	Sand/Mud Flats	3	0.18	0.00002	20
Euchelus atratus	Shallow Water	2	0.12	0.00001	24
Isognomon isognomon	Mangroves	2	0.12	0.00001	24
Fissurellidae sp.	Shallow Water	1	0.06	0.00001	26
Total		**1622**			

Table 5.8: BMB/067b, MNI and corrected MNI values for the dominant species by excavation unit.

Excavation	Volume	*Anadara granosa*		*Marcia hiantina*		*Septifer bilocularis*		*Gafrarium* sp.	
Unit	(cm^3)	MNI	MNI/cm^3	MNI	MNI/cm^3	MNI	MNI/cm^3	MNI	MNI/cm^3
1	13000	77	0.00592	40	0.00308	37	0.00285	18	0.00139
3	31000	89	0.00287	65	0.00210	66	0.00213	23	0.00074
5	34000	110	0.00324	84	0.00247	49	0.00144	14	0.00041
7	31000	147	0.00474	76	0.00245	53	0.00171	19	0.00061
9	46000	95	0.00207	77	0.00167	71	0.00154	63	0.00137

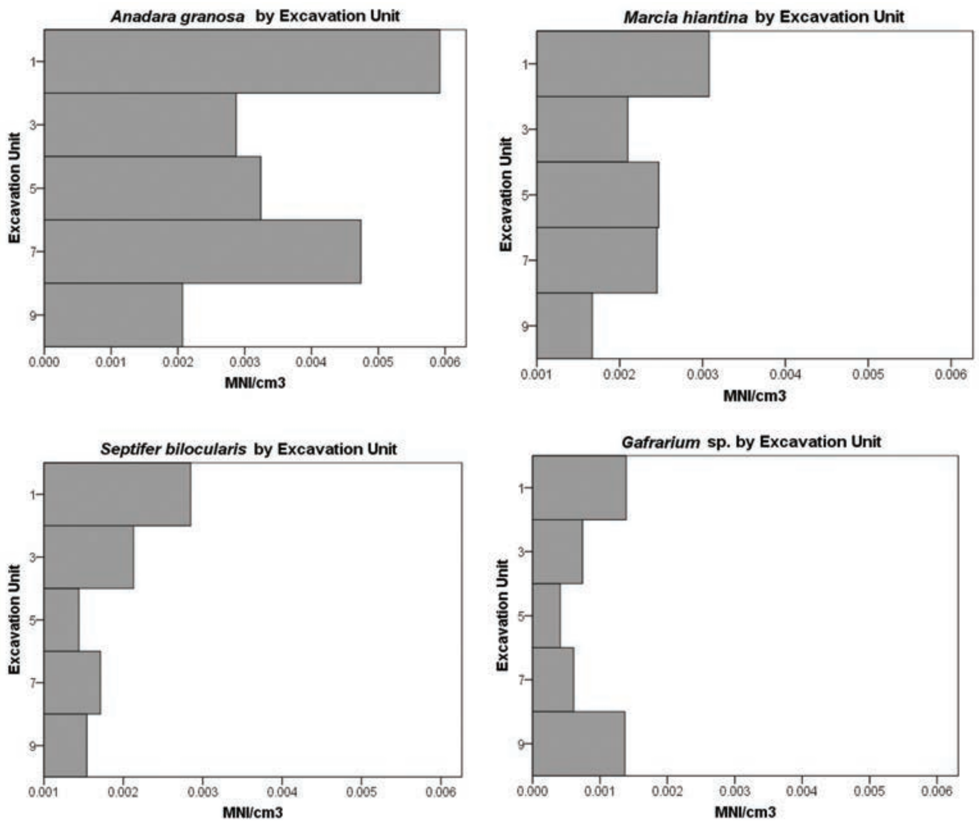

Figure 5.3: BMB/067b, corrected MNI values (MNI/cm^3) for the dominant species by excavation unit.

Correlation coefficients calculated on the volume-corrected MNI counts indicate that the differences in the relative abundance of *Anadara granosa* (r_s = -0.600, p > 0.2, n = 5), *Marcia hiantina* (r_s = -0.700, p > 0.2, n = 5), *Septifer bilocularis* (r_s = -0.700, p > 0.2, n = 5) and *Gafrarium* sp. (r_s = -0.300, p > 0.2, n = 5) by excavation unit, and by extension through time, are not statistically significant. In combination with the analysis of overall species richness and species richness by habitat, the primary focus of molluscan exploitation within this site appears to remain relatively consistent throughout. This is reflected in the fact that there is no real change in the abundance of the four dominant species through time, indicating that there is no shift in those species that were the focus of exploitation.

BMB/084: Species richness, habitat exploitation and relative abundances

Twenty-four molluscan taxa in all were identified within the eight units excavated in BMB/084. In order to address the extent of possible variations through time in species and habitat richness, the data are analysed by excavation unit, with excavation units 1 and 2 combined for this analysis due to the comparatively small volumes of these units. Species richness for BMB/084 by excavation unit is detailed in Table 5.9, along with the percentages of the total number of economic species identified within the site.

Table 5.9: BMB/084, number of species, the percentage of the total number of species and number of species for molluscan habitats by excavation unit.

Excavation Unit	No. Species	% of Total	Shallow Water	Sand/Mud Flats	Mangroves	Estuarine
1 / 2	19	79.17	4	10	3	2
3	13	56.52	3	7	2	1
4	17	70.83	5	7	4	1
5	17	70.83	5	9	2	1
6	18	75.00	4	9	3	2
7	18	75.00	6	6	4	2
8	18	75.00	6	9	2	1
Total No. of Species	**24**		**8**	**10**	**4**	**2**

The number of economic species identified per excavation unit appears to remains stable. Spearman's correlation coefficient ($r_s = 0.478$, $p > 0.1$, $n = 7$) suggest that the relationship between species richness and excavation unit is neither strong nor significant. This indicates there is a high degree of consistency in the level of species richness throughout the deposit. Of the 24 economic species within the site, eight (33.3%) come from the shallow water habitat, 10 (41.7%) from the sand/mud flat habitat, with four (16.7%) from the mangrove zone and two (8.3%) gathered from coastal river/estuarine areas. This indicates that the shallow water and sand/mud flat areas were the dominant and consistently available environmental zones within the area. This broad patterning may mask a certain level of variability within the deposit. It was noted during the course of the excavation that there was a change in the dominant taxa between the two stratigraphic units, which also relate to the variability in radiocarbon ages available from this deposit. As such, consistency in species richness may not be indicative of environmental changes within the area, or shifts in the focus of exploitation. To investigate this aspect further, species richness and relative abundance estimates by excavation unit are used to determine whether there were any shifts in the focus of exploitation between these habitats through time. Table 5.9 also details the number and percentage of species within each excavation unit by habitat. In line with overall species richness within the site, the number of economic species identified for each habitat per excavation unit remains relatively stable. Spearman correlation results for the sand and mudflats ($r_s = -0.243$, $p > 0.5$, $n = 7$), mangroves ($r_s = -0.019$, $p > 0.5$, $n = 7$) and the coastal rivers and estuaries ($r_s = 1.000$, $p > 0.5$, $n = 7$), indicate that there is not a significant relationship between species richness and excavation unit for these habitats. In comparison, there appears to be a decrease in species richness throughout the deposit for the shallow water habitat ($r_s = 0.771$, $p < 0.05$, $n = 7$). This may signify a slight restructuring of shell beds within this zone or of this habitat zone itself, affecting the diversity of available resources.

Table 5.10 presents MNI and volume-corrected MNI of species within each excavation unit by habitat. This pattern of relative abundance by habitat contrasts with that of species richness by habitat, and reinforces the point that, at least within this site, little change in the number of species exploited is not an accurate reflection of the intensity of habitat exploitation. While there appeared to be minor variability in the number of species exploited from the shallow water habitat (Figure 5.4), relative abundance estimates remain consistent throughout the deposit ($r_s = 0.036$, $p > 0.5$, $n = 7$). The relative abundance estimates from the coastal river/estuarine habitat are not presented graphically at this scale, but there is not a significant relationship with excavation unit for this habitat ($r_s = -0.468$, $p > 0.2$, $n = 7$) or for the sand/mud flat habitat ($r_s = -0.3219$, $p > 0.5$, $n = 7$). The correlation coefficients for the relationship between excavation unit and the relative abundance of mangrove species suggest that the increase in species from this habitat is significant ($r_s = -0.786$, $p < 0.05$, $n = 7$), particularly near the surface of the site (excavation units 1 and 2). There is a dramatic jump in relative abundance for this habitat area in the upper portion of the deposit, and while this may suggest a reorganisation in the structure of the mangrove zone in the

area and/or an increase in the abundance of species in this zone in the recent past, this process did not apparently affect the diversity of resources within this habitat zone. Interestingly, this increase in mangrove species does not appear to have occurred at the expense of the other habitat zones, as there is no significant difference in the relative abundance estimates for the other three identified habitats.

Table 5.10: BMB/084, MNI values and volume-corrected MNI estimates (MNI/cm^3) for species from molluscan habitats by excavation unit.

Excavation Unit	Volume (cm^3)		Shallow Water	Sand/Mud Flats	Mangroves	Estuarine
1 / 2	4750	MNI	29	64	166	7
		MNI/cm^3	0.01347	0.02157	0.09153	0.00157
3	5500	MNI	17	47	16	5
		MNI/cm^3	0.00309	0.00855	0.00291	0.00091
4	8250	MNI	24	23	79	1
		MNI/cm^3	0.00291	0.00279	0.00958	0.00012
5	8500	MNI	27	99	30	13
		MNI/cm^3	0.00318	0.01165	0.00354	0.00153
6	7250	MNI	22	74	22	6
		MNI/cm^3	0.00303	0.01021	0.00303	0.00083
7	8000	MNI	44	78	12	10
		MNI/cm^3	0.00550	0.00975	0.00150	0.00125
8	8250	MNI	45	34	12	1
		MNI/cm^3	0.00546	0.00412	0.00146	0.00012

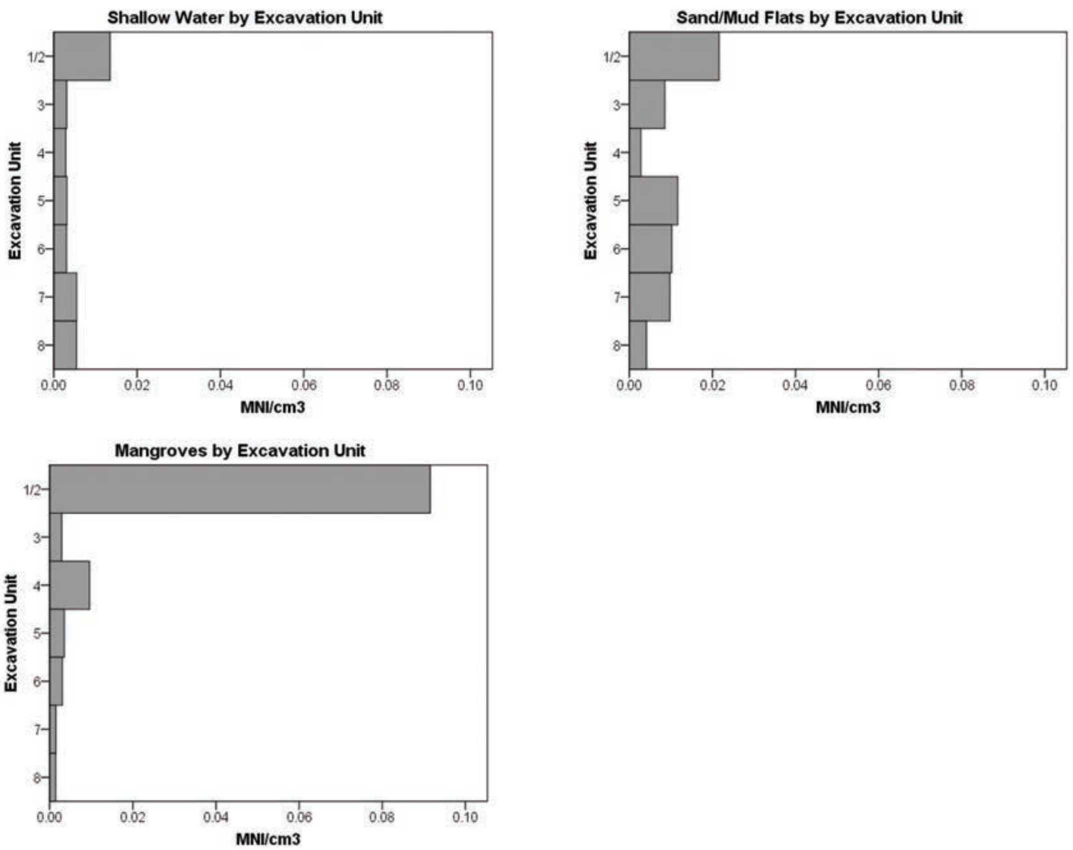

Figure 5.4: BMB/084, corrected MNI values (MNI/cm^3) for molluscan habitat by excavation unit.

Again, this type of variation in habitat exploitation throughout the site should be reflected in the relative abundance of the dominant species. Table 5.11 details the MNI counts and percentages for the 24 species from this site and a relative density estimate (MNI/cm^3). Four species, at 16.7% of the total number of species in the site, make up 76.9% by MNI of the assemblage from BMB/084. *Marcia hiantina* is the highest-ranking species by percentage of the total MNI (29.0%) and by the corrected density estimate. In rank order, this species is followed by *Isognomon isognomon* (27.8% MNI), Mytilidae f. (14.4% MNI) and *Gafrarium* sp. (5.7% MNI). Two of these top four ranked species, *Marcia hiantina* and *Gafrarium* sp., are found in the sand and mudflats within the intertidal/subtidal zone, and collectively comprise 33.5% by MNI of the total assemblage. In contrast, species from the Mytilidae family are found attached to hard-substrate areas within the shallow water habitat zone, and *Isognomon isognomon* is generally found within mangrove forests. Table 5.12 and Figure 5.5 present the MNI values for these four species corrected for volume (MNI/cm^3).

Table 5.11: BMB/084, MNI values and MNI density estimates (MNI/cm^3) for all molluscan species (species above dashed line at > 5% MNI viewed as dominant).

Economic Molluscan Species	Habitat Category	MNI	% MNI	Density (MNI/cm^3)	Rank Order
Marcia hiantina	Sand/Mud Flats	292	29.00	0.00578	1
Isognomon isognomon	Mangroves	280	27.81	0.00555	2
Mytilidae f.	Shallow Water	145	14.40	0.00287	3
Gafrarium sp.	Sand/Mud Flats	57	5.66	0.00113	4
Modiolus sp.	Coastal Rivers/Estuaries	39	3.87	0.00077	5
Trochus sp.	Shallow Water	36	3.57	0.00071	6
Terebralia sp.	Mangroves	28	2.78	0.00055	7
Nerita sp.	Mangroves	27	2.68	0.00054	8
Pinctada sp.	Sand/Mud Flats	16	1.59	0.00032	9
Anadara granosa	Sand/Mud Flats	14	1.39	0.00028	10
Circe sp.	Sand/Mud Flats	10	0.99	0.00020	11
Barbatia sp.	Shallow Water	9	0.89	0.00018	12
Ostreidae f.	Shallow Water	7	0.70	0.00014	13
Pinna bicolor	Sand/Mud Flats	7	0.70	0.00014	13
Tapes sp.	Sand/Mud Flats	7	0.70	0.00014	13
Pitar sp.	Sand/Mud Flats	6	0.60	0.00012	16
Tellina sp.	Sand/Mud Flats	6	0.60	0.00012	16
Turbo cinereus	Shallow Water	5	0.50	0.00010	18
Anadara antiquata	Sand/Mud Flats	4	0.40	0.00008	19
Polymesoda (Geloina) coaxans	Coastal Rivers/Estuaries	4	0.40	0.00008	19
Fissurellidae sp.	Shallow Water	3	0.30	0.00006	21
Haliotis sp.	Shallow Water	2	0.20	0.00004	22
Telescopium telescopium	Mangroves	2	0.20	0.00004	22
Chitonidae f.	Shallow Water	1	0.10	0.00002	24
Total		**1007**			

Table 5.12: BMB/084, MNI and corrected MNI values for the dominant species by excavation unit.

Excavation	Volume	*Marcia hiantina*		*I. isognomon*		*Mytilidae* f.		*Gafrarium* sp.	
Unit	(cm^3)	MNI	MNI/cm^3	MNI	MNI/cm^3	MNI	MNI/cm^3	MNI	MNI/cm^3
1 / 2	4750	42	0.00884	161	0.03389	26	0.00547	13	0.00274
3	5500	35	0.00636	12	0.00218	10	0.00182	6	0.00109
4	8250	17	0.00206	70	0.00849	19	0.0023	0	0.00000
5	8500	78	0.00918	27	0.00318	20	0.00235	10	0.00118
6	7250	60	0.00828	9	0.00124	13	0.00179	1	0.00014
7	8000	50	0.00625	1	0.00013	35	0.00438	18	0.00225
8	8250	10	0.00121	0	0.00000	22	0.00267	9	0.00109

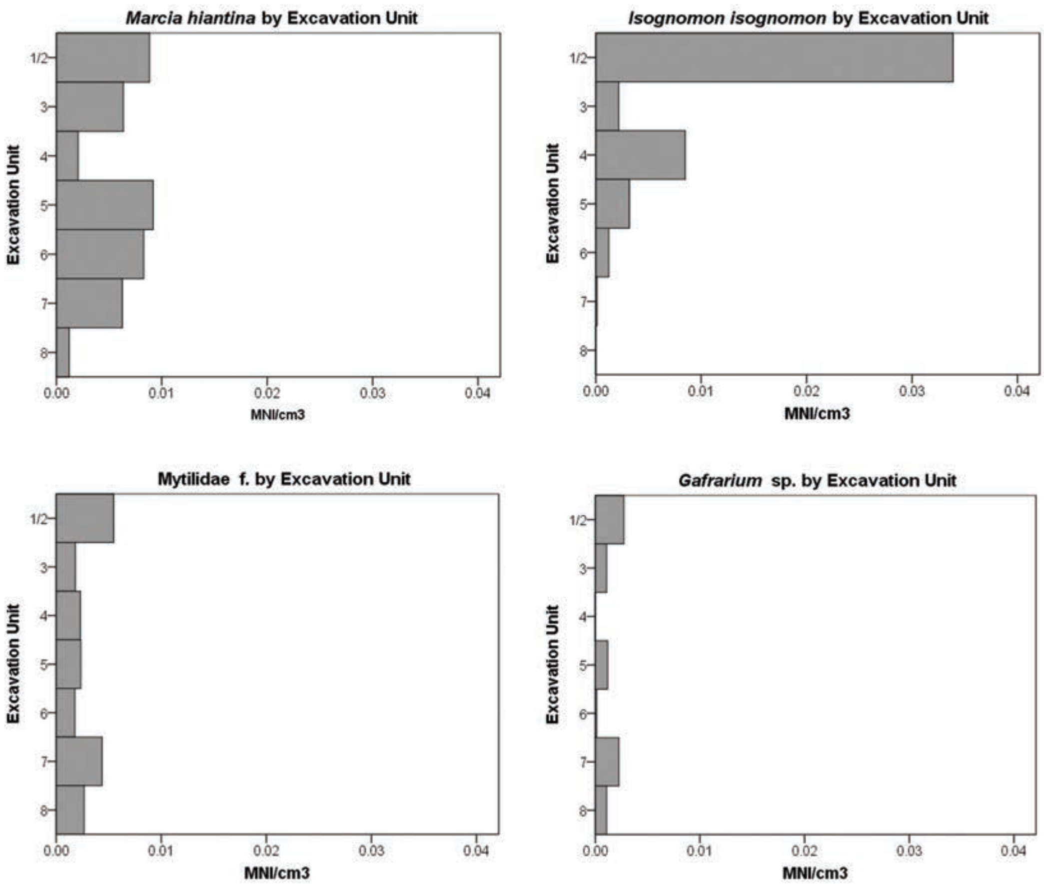

Figure 5.5: BMB/084, corrected MNI values for the dominant species by excavation unit.

In testing the relationship between relative abundance estimates of these dominant species by excavation unit, for *Marcia hiantina* (r_s = -0.500, $p > 0.2$, $n = 7$), Mytilidae f. (r_s = 0.000, $p > 0.5$, $n = 7$) and *Gafrarium* sp. (r_s = -0.162, $p > 0.5$, $n = 7$) correlation coefficients indicate that there is not a significant change through time in the level of exploitation for these species within the site. In comparison, the results of Spearman's correlations for *Isognomon isognomon* (r_s = -0.893, $p < 0.01$, $n = 7$) suggests that there is a significant change through time in relative abundance, supported by the observably large jump in the relative abundance estimates in the upper excavation units closer to the surface of the site. The dramatic difference in the relative abundance estimates for this species reinforces this picture of increased exploitation in the more recent past. As with the pattern of habitat relative abundance discussed previously, even with the highly increased level of *Isognomon isognomon* exploitation, there does not appear to be a corresponding decrease in the exploitation of the other three dominant species within the site. This may relate to a restructuring of habitats within the area, although the lack of a decrease in those dominant species from the sand/mud flat and shallow water habitats would suggest otherwise. Rather, the patterns of molluscan exploitation within this site are probably more indicative of a restructuring of the shell-beds within the mangrove zone itself, affecting the distribution, density and overall availability of species from this habitat.

Myaoola Bay midden site comparison

Given that the degree of variability or homogeneity in resource exploitation within the Myaoola Bay midden sites has been characterised on an individual basis, it is useful to compare these sites given that there are distinct differences in site chronologies and position within the landscape (Table 5.13). While there is a degree of variability across the Myaoola Bay sites, varying in species

richness between 16 and 26, these differences are not statistically significant (χ^2 = 2.455, *d.f.* = 3, $p > 0.2$). Chi-square results also indicate that species richness per habitat in the Myaoola Bay sites are not significantly different (χ^2 = 1.668, *d.f.* = 6, p = 0.948, Cramer's V = 0.112). As species richness relates to the structure and productivity of resources within the local area, reflecting the number of species available for exploitation, little would have appeared to change through time on this exposed coastline of Myaoola Bay.

Table 5.13: Myaoola Bay sites, overall species richness and the frequency of species per habitat area.

Site	Approx.	Total Species	Shallow Water		Sand/Mud Flats		Mangroves		Estuarine	
Code	Age cal BP	Richness	No.	%	No.	%	No.	%	No.	%
BMB/018	2953	16	4	25.00	7	43.75	3	18.75	2	12.50
BMB/067	1518 - 592	26	10	38.46	10	38.46	5	19.23	1	3.85
BMB/084	424 - Modern	24	8	33.33	10	41.67	4	16.67	2	8.33

While these results may suggest a certain degree of homogeneity between these sites in terms of the number of species exploited, they are not indicative of the overall level or intensity of exploitation between environmental patches. To this end, Table 5.14 details the MNI and percentage MNI of species by each habitat zone. To investigate whether the differences in the relative abundance of species per habitat in the Myaoola Bay middens, a chi-square statistic was used, the results of which indicate that the Myaoola Bay sites are significantly different (χ^2 = 789.088, *d.f.* = 6, p = 0.000, Cramer's V = 0.340) in terms of relative abundance per habitat.

Table 5.14: Myaoola Bay sites, MNI and percentage MNI of species per habitat area.

Site	Approx.	Shallow Water		Sand/Mud Flats		Mangroves		Estuarine	
Code	Age cal BP	MNI	%	MNI	%	MNI	%	MNI	%
BMB/018	2953	408	51.78	370	46.95	7	0.89	3	0.38
BMB/067	1518 - 592	416	25.65	1098	67.69	99	6.1	9	0.55
BMB/084	424 - Modern	208	20.66	419	41.61	337	33.47	43	4.27

Differences in the structure of the landscape between the three locations on the peninsula in which these sites are located explain the variability in the intensity of exploitation of species from these four habitat zones. When viewed in their chronological sequence, these differences may indicate larger scale processes of landscape alteration and environmental variability through time on this section of the coastline. While the sand/mud flat areas remain consistently exploited through time and by location, there is a gradual decrease in the use of species from the hard-substrate, shallow water zone. This shift in these species is also related to a corresponding increase in mangrove species exploitation, and to a lesser degree, those species inhabiting the coastal rivers and estuaries. Following the rapid phase of sea level rise, culminating and stabilising at a high-stand of approximately 2.5m above present 5000 years ago, gradual changes to the shoreline would have occurred, largely resulting from the slow sea level regression and increased sedimentation from the coastal rivers and streams. These processes would have seen a gradual restriction of the shallow water habitats, and an expansion of other habitats, particularly the mangrove forests. The shallow nature of near-shore areas around the Point Blane Peninsula may also explain the consistency of sand and mud flat species over the last 3000 years in the Myaoola Bay sites (Faulkner 2011:143–4).

Grindall Bay shell mound sites

BMB/029: Species richness, habitat exploitation and relative abundances

Eighteen molluscan taxa in all were identified from the 11 excavation units analysed for BMB/029. As this site is situated within the most northerly of the mound clusters, and possibly represents part of the earliest phase of mollusc exploitation within this area following sea level stabilisation and initial progradation, the extent of possible variations through time in species and habitat richness are important. Species richness for BMB/029 by excavation unit is detailed in Table 5.15, along with the percentages of the total number of economic species identified within the site. Spearman's correlation coefficient (r_s = -0.140, p > 0.5, n = 11) suggests that the relationship between species richness and excavation unit is neither strong nor significant. Therefore, the level of species richness appears to remain consistent throughout the occupation of the site.

Table 5.15: BMB/029, number of species, the percentage of the total number of species and number of species for molluscan habitats by excavation unit.

Excavation Unit	No. Species	% of Total	Shallow Water	Sand/Mud Flats	Mangroves	Estuarine
1	9	50.00	1	3	4	1
3	11	61.11	1	5	4	1
5	9	50.00	1	4	3	1
7	14	77.78	2	5	5	2
9	8	44.44	1	3	2	2
11	11	61.11	3	3	4	1
13	8	44.44	1	3	4	0
15	9	50.00	1	5	3	0
17	8	44.44	1	4	3	0
19	12	66.67	2	6	4	0
21	9	50.00	1	4	3	1
Total No. of Species	**18**		**3**	**7**	**6**	**2**

Of the 18 economic species within the site, three (16.7%) come from the shallow water habitat, seven (38.9%) from the sand/mud flat habitat, six (33.3%) from the mangrove zone and two (11.1%) gathered from coastal river/estuarine areas. This suggests that the mangrove fringing sand/mud flat areas and the mangroves themselves were the dominant and consistently available environmental zones within the area during the period of site deposition. Given patterns of landscape change and reorganisation following sea level rise, particularly with environmental change coinciding with progradation in these types of former shallow embayments, the emphasis on resources from these two habitat zones is not surprising. It would be expected that these habitats would dominate this type of coastline during the late Holocene. As such, the lower numbers of species exploited from hard-substrate, near shore areas and coastal rivers and estuaries reflects the differential availability and distribution of both of these habitat areas. Species richness and relative abundance estimates by excavation unit are used here to investigate possible shifts in the focus of exploitation between these habitats through time. Differences in the number of species by excavation unit are not significant for the shallow water zone (r_s = 0.116, p > 0.5, n = 11), sand and mud flats (r_s = 0.242, p > 0.2, n = 11), mangroves (r_s = -0.298, p > 0.2, n = 11) or coastal river/estuarine species (r_s = -0.544, p > 0.05, n = 11). Therefore, patterns in the number of economic species identified for each habitat through time (excavation unit) remains relatively stable.

While habitat richness appears to have remained consistent, there may well have been changes in the intensity of exploitation within these habitat zones, possibly reflecting further changes within the immediate surrounds relating to environmental processes. Therefore, the relative abundances of species per habitat need to be addressed. While there was little variation in species richness per habitat, the patterns are quite different when taking relative abundance into account (Table 5.16). There is not a significant or strong relationship between relative abundance of species from the shallow water zone and excavation unit ($r_s = -0.292$, $p > 0.2$, $n = 11$). On the other hand, there appears to be a significant relationship between relative abundance per habitat and excavation unit for the sand/mud flat habitat ($r_s = -0.600$, $p < 0.05$, $n = 11$), the mangroves ($r_s = -0.620$, $p < 0.05$, $n = 11$) and coastal river/estuarine habitat ($r_s = -0.739$, $p < 0.01$, $n = 11$). The level of significance from the estuarine habitat needs to be placed in context, as it is only a minor resource exploited within this site, and comparatively, this increase does not affect the overall economic structure.

Table 5.16: BMB/029, MNI values and volume-corrected MNI estimates (MNI/cm^3) for species from molluscan habitats by excavation unit.

Excavation Unit	Volume (cm^3)		Shallow Water	Sand/Mud Flats	Mangroves	Estuarine
1	7500	MNI	1	120	19	1
		MNI/cm^3	0.00013	0.01600	0.00253	0.00013
3	7500	MNI	1	164	51	1
		MNI/cm^3	0.00013	0.02187	0.00680	0.00013
5	10000	MNI	7	129	67	1
		MNI/cm^3	0.00070	0.01290	0.00670	0.00010
7	7500	MNI	2	302	17	2
		MNI/cm^3	0.00027	0.04027	0.00227	0.00027
9	7500	MNI	3	211	4	2
		MNI/cm^3	0.00040	0.02813	0.00053	0.00027
11	12500	MNI	3	291	11	1
		MNI/cm^3	0.00024	0.02328	0.00088	0.00008
13	10000	MNI	2	228	9	0
		MNI/cm^3	0.00020	0.02280	0.00090	0.00000
15	12500	MNI	1	102	13	0
		MNI/cm^3	0.00008	0.00816	0.00104	0.00000
17	10000	MNI	1	47	9	0
		MNI/cm^3	0.00010	0.00470	0.00090	0.00000
19	5000	MNI	2	29	6	0
		MNI/cm^3	0.00040	0.00580	0.00120	0.00000
21	17500	MNI	2	16	13	1
		MNI/cm^3	0.00011	0.00091	0.00074	0.00006

The significance for the increasing abundance of species from both the sand/mud flats and the mangroves is more indicative of economic activity. The general increase in relative abundance for these habitat zones, regardless of the level of significance attributed to these figures, relates to two main factors. There may be variations in the intensity of discard within the site through time, and/or the density of resources and general availability of species from these areas related to changes to the environment. As the Garangarri site cluster probably represents the earliest period of mound building within this system, variations in habitat exploitation may also relate to the

ongoing process of progradation at the time, and the gradual establishment and proliferation of the sand/mud flat zone. As such, the dominance of mangrove species, and sand/mud flat species in particular, in terms of the number of taxa represented and relative abundance would be expected.

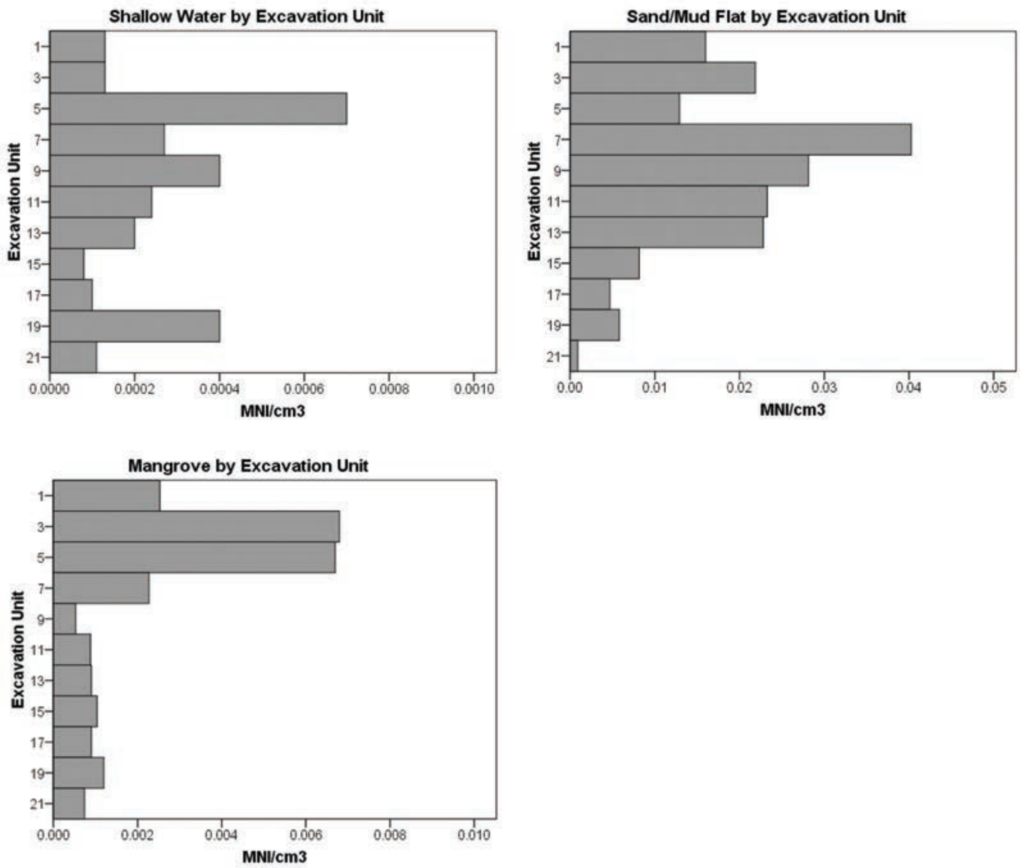

Figure 5.6: BMB/029, corrected MNI values (MNI/cm^3) for molluscan habitat by excavation unit (note differences in scale).

Turning to the relative abundance of the dominant taxa within the site, Table 5.17 details the MNI counts and percentages for the 18 species from this site and a relative density estimate (MNI/cm^3). Three species, at 16.7% of the total number of species in the site, make up 91.3% by MNI of the assemblage from BMB/029. By far, *Anadara granosa* is the highest-ranking species by percentage of the total MNI (68.1%) and by the corrected density estimate. In rank order, this species is followed by *Marcia hiantina* (13.48% MNI) and *Placuna placenta* (9.8% MNI). Two of these top three ranked species, *Anadara granosa* and *Marcia hiantina*, are found in the sand and mudflats within the intertidal/subtidal zone, and collectively comprise 81.6% by MNI of the total assemblage (Faulkner 2009:827). *Placuna placenta*, which occurred in dense horizontal lenses or bands throughout the deposit, is generally found within the mangroves.

Table 5.17: BMB/029, MNI values and MNI density estimates (MNI/cm³) for all molluscan species (species above dashed line at > 5% MNI viewed as dominant).

Economic Molluscan Species	Habitat Category	MNI	% MNI	Density (MNI/cm³)	Rank Order
Anadara granosa	Sand/Mud Flats	1288	68.08	0.01198	1
Marcia hiantina	Sand/Mud Flats	255	13.48	0.00237	2
Placuna placenta	Mangroves	185	9.78	0.00172	3
Anadara antiquata	Sand/Mud Flats	76	4.02	0.00071	4
Ostreidae f.	Shallow Water	21	1.11	0.00020	5
Nerita sp.	Mangroves	16	0.85	0.00015	6
Dosinia mira	Sand/Mud Flats	10	0.53	0.00009	7
Cassidula angulata	Mangroves	7	0.37	0.00007	8
Polymesoda (Geloina) coaxans	Coastal Rivers/Estuaries	6	0.32	0.00006	9
Telescopium telescopium	Mangroves	6	0.32	0.00006	9
Tellina sp.	Sand/Mud Flats	6	0.32	0.00006	9
Mactra abbreviata	Sand/Mud Flats	3	0.16	0.00003	12
Terebralia sp.	Mangroves	3	0.16	0.00003	12
Modiolus sp.	Coastal Rivers/Estuaries	3	0.16	0.00003	12
Barbatia sp.	Shallow Water	2	0.11	0.00002	15
Cerithidea sp.	Mangroves	2	0.11	0.00002	15
Trochus sp.	Shallow Water	2	0.11	0.00002	15
Placamen calophyllum	Sand/Mud Flats	1	0.05	0.00001	18
Total		**1892**			

Table 5.18 and Figure 5.7 present the MNI values for these three species corrected for volume (MNI/cm³) per excavation unit. Investigating variability in relative abundance estimates by excavation unit for *Marcia hiantina* (r_s = -0.273, $p > 0.2$, $n = 11$) indicates that the differences observed here are not significant. In other words, there is not a significant change through time in the level of exploitation for this species within the site. In comparison, the Spearman's correlation coefficients suggests that there is a highly significant change through time (excavation unit) in the relative abundance of *Anadara granosa* (r_s = -0.491, $p < 0.05$, $n = 11$) and *Placuna placenta* (r_s = -0.647, $p < 0.02$, $n = 11$) (Faulkner 2009:827).

Table 5.18: BMB/029, MNI and corrected MNI values for the dominant species by excavation unit.

Excavation	Volume	*Anadara granosa*		*Marcia hiantina*		*Placuna placenta*	
Unit	(cm³)	MNI	MNI/cm³	MNI	MNI/cm³	MNI	MNI/cm³
1	7500	108	0.01440	10	0.00133	16	0.00213
3	7500	119	0.01587	9	0.00120	48	0.00640
5	10000	106	0.01060	18	0.00180	62	0.00620
7	7500	256	0.03413	40	0.00533	12	0.00160
9	7500	158	0.02107	51	0.00680	3	0.00040
11	12500	231	0.01848	57	0.00456	8	0.00064
13	10000	202	0.02020	17	0.00170	4	0.00040
15	12500	60	0.00480	28	0.00224	11	0.00088
17	10000	27	0.00270	14	0.00140	7	0.00070
19	5000	13	0.00260	6	0.00120	3	0.00060
21	17500	8	0.00046	5	0.00029	11	0.00063

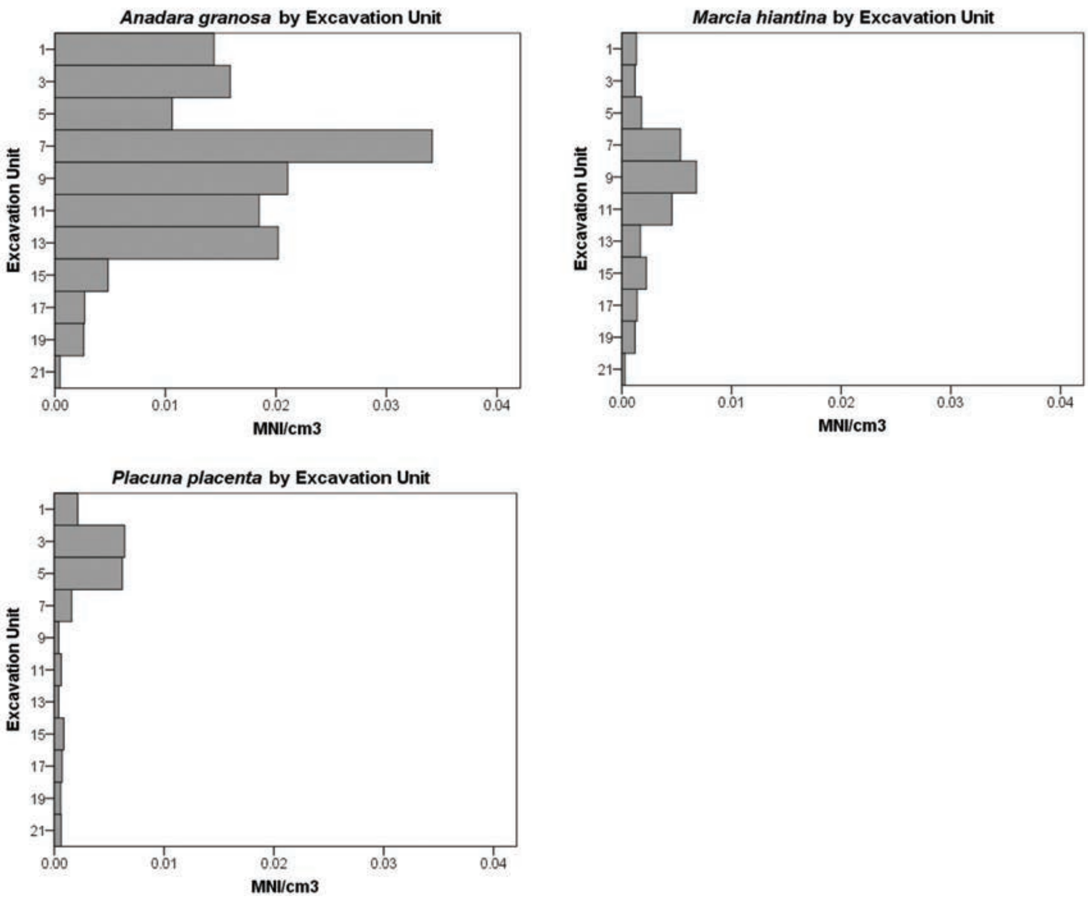

Figure 5.7: BMB/029, corrected MNI values for the dominant species by excavation unit.

It is still highly probable that this increase in *Anadara granosa* is tied strongly to those processes of landscape alteration noted earlier. The proliferation of this species probably kept pace with these changes as the sand/mud flat areas enlarged through progradation. *Anadara granosa* then became the primary focus of exploitation within this locality. While the sand/mud flats were an important resource to start with, as evidenced by the similar relative abundance estimates between *Marcia hiantina* and *Anadara granosa* for the lower portions of the deposit, it is evident that the increasing abundance of *Anadara granosa* in the environment created the stronger emphasis on this species within the area during the latter periods of occupation.

BMB/071: Species richness, habitat exploitation and relative abundances

Fifteen molluscan taxa were identified within the seven excavation units analysed for BMB/071. This site is situated within a large mound and midden cluster approximately 2km south of the Garangarri cluster. As such, it is possibly representative of ongoing use of this area following the initial phase of exploitation characterised by site BMB/029. Overall species richness within the site varies through time (Table 5.19), the Spearman's correlation coefficient (r_s = -0.880, p > 0.05, n = 6) suggests that the relationship between species richness and excavation unit is significant. While there appears to be an increase in species richness by excavation unit, between the lower and upper portions of the deposit there is an increase of only one species. It is therefore difficult to place too much emphasis on the significance of this increase in overall species richness. Turning to possible shifts in habitat exploitation, of the 15 economic species within the site, two (13.3%) come from the shallow water habitat, six (40.0%) from the sand/mud flat habitat, five (33.3%) from the mangrove zone and two (13.3%) gathered from coastal river/estuarine areas. This

pattern is very similar to that found within BMB/029, and suggests that the mangrove fringing sand/mud flat areas and the mangroves themselves were the dominant habitats available during the period of occupation in the area. Again, the lower numbers of species exploited from hard-substrate, near shore areas and coastal rivers and estuaries reflects the differential distribution of these habitat areas relative to the two more dominant habitats.

Table 5.19: BMB/071, number of species, the percentage of the total number of species and number of species for molluscan habitats by excavation unit.

Excavation Unit	No. Species	% of Total	Shallow Water	Sand/Mud Flats	Mangroves	Estuarine
1	12	80.00	2	4	4	2
3	12	80.00	2	5	4	1
5	12	80.00	1	5	4	2
7	10	66.67	2	4	4	0
9	11	73.33	1	5	4	1
11	9	60.00	1	3	4	1
Total No. of Species	**15**		**2**	**6**	**5**	**2**

Comparing the number of species by excavation unit shows that there are not significant differences for the shallow water zone (r_s = -0.683, $p > 0.1$, $n = 6$), sand and mud flats (r_s = -0.309, $p > 0.5$, $n = 6$) and coastal rivers/estuaries (r_s = -0.525, $p > 0.1$, $n = 6$). As there is no change in species richness throughout the excavation for the mangrove zone, this habitat was not tested. Therefore, patterns in the number of economic species identified for each habitat through time remains relatively stable. The minor variations in habitat species richness noted between excavation units for the shallow water and coastal river/estuarine habitats, while not significant themselves, may have contributed to the significant results for overall site species richness. Figure 5.8 graphs the corrected MNI values by excavation unit and the mean MNI for each excavation unit for each habitat, and Table 5.20 details the MNI and volume-corrected MNI of species within each excavation unit by habitat. While there was little variation in species richness per habitat, the relative abundance estimates for species from these habitats again highlights greater variability in the level of exploitation.

Differences in the mean volume-corrected MNI by excavation unit are significant for the shallow water zone (r_s = -0.841, $p < 0.05$, $n = 6$) and mangroves (r_s = 1.000, $p < 0.01$, $n = 6$). In contrast, the decrease in the corrected MNI estimates by excavation unit is significant for the sand and mudflats (r_s = -0.029, $p > 0.5$, $n = 6$), as is the slight increase for the coastal rivers/estuaries zone (r_s = -0.609, $p > 0.1$, $n = 6$). As with the patterns identified for BMB/029 from the Garangarri site cluster, the decrease in the exploitation of mangrove species probably reflects variation in this particular habitat zone related to progradation and the expansion of the sand/mud flat zone. The progressive build-up of fine sediment (silt and mud) in the intertidal zone, particularly within the mangroves, encourages the establishment of beach ridges. As the ridge develops, the mangrove fringe is killed off and eventually re-establishes on the seaward edge of the new ridge (Chappell 1982:74; Woodroffe *et al.* 1985b:25). The decrease in species from the mangrove zone may relate to the process described above, while the availability of species that inhabit the other three habitats, in particular the mangrove fringing intertidal flats, remained relatively stable.

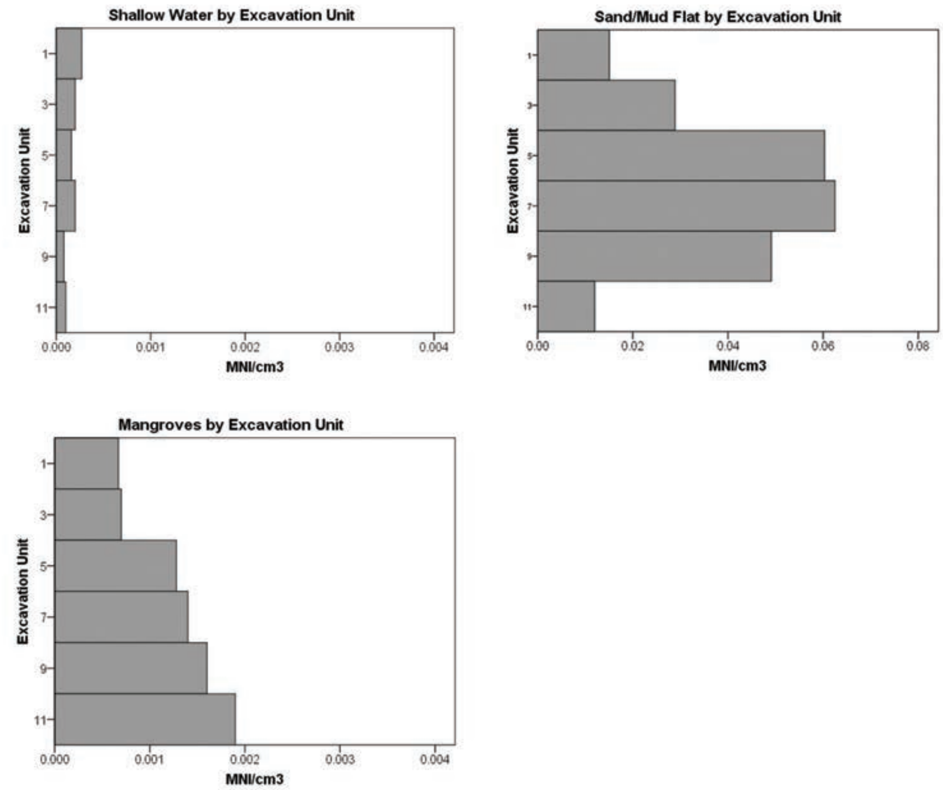

Figure 5.8: BMB/071, corrected MNI values (MNI/cm³) for molluscan habitats by excavation unit (note differences in scale).

Table 5.20: BMB/071, MNI values and volume-corrected MNI estimates (MNI/cm³) for species from molluscan habitats by excavation unit.

Excavation Unit	Volume (cm³)		Shallow Water	Sand/Mud Flats	Mangroves	Estuarine
1	7500	MNI	2	113	5	2
		MNI/cm³	0.00027	0.01507	0.00067	0.00027
3	10000	MNI	2	289	7	1
		MNI/cm³	0.00020	0.02890	0.00070	0.00010
5	12500	MNI	2	754	16	2
		MNI/cm³	0.00016	0.06032	0.00128	0.00016
7	10000	MNI	2	625	14	0
		MNI/cm³	0.00020	0.06250	0.00140	0.00000
9	12500	MNI	1	614	20	1
		MNI/cm³	0.00008	0.04912	0.00160	0.00008
11	10000	MNI	1	120	19	1
		MNI/cm³	0.00010	0.01200	0.00190	0.00010

Table 5.21 details the MNI counts and percentages for the 15 species from this site and a relative density estimate (MNI/cm³). Table 5.22 and Figure 5.9 present the MNI values for the two dominant species corrected for volume (MNI/cm³). These two species, at 13.3% of the total number of species in the site, make up 94.80% by MNI of the assemblage from BMB/071. *Anadara granosa* dominates the molluscan assemblage from this site; it is the highest-ranking species by percentage of the total MNI (87.5%) and by the corrected density estimate. The only other species to make up greater than 5% by MNI is *Mactra abbreviata* at 7.3% (both species are found in sand/mudflat areas). The Spearman's test of the relationship between the relative abundance estimates by excavation unit for *Anadara granosa* ($r_s = -0.086$, $p > 0.5$, $n = 6$) and *Mactra abbreviata* ($r_s = -0.116$, $p > 0.5$, $n = 6$) indicates that the differences observed above are not significant. In other words, there is not a significant change through time in the

level of exploitation for these species within the site (see Figure 5.9). The sheer dominance of *Anadara granosa* within this site indicates that this species was the primary focus of exploitation within this locality. This suggests that, regardless of whatever changes to the landscape were occurring within this area during the span of occupation of this site, such as the possible changes to the mangrove areas noted previously, the sand and mud flat areas remained reasonably stable (Faulkner 2009:827). By extension, the abundance and apparent reliability of *Anadara granosa* as a resource within this consistently available habitat area saw this species become the focal point within the economy.

Table 5.21: BMB/071, MNI values and MNI density estimates (MNI/cm^3) for all molluscan species (species above dashed line at > 5% MNI viewed as dominant).

Economic Molluscan Species	Habitat Category	MNI	% MNI	Density (MNI/cm^3)	Rank Order
Anadara granosa	Sand/Mud Flats	2286	87.49	0.03658	1
Mactra abbreviata	Sand/Mud Flats	191	7.31	0.00306	2
Placuna placenta	Mangroves	40	1.53	0.00064	3
Anadara antiquata	Sand/Mud Flats	19	0.73	0.00030	4
Nerita sp.	Mangroves	19	0.73	0.00030	4
Marcia hiantina	Sand/Mud Flats	15	0.57	0.00024	6
Cassidula angulata	Mangroves	11	0.42	0.00018	7
Telescopium telescopium	Mangroves	10	0.38	0.00016	8
Septifer bilocularis	Shallow Water	5	0.19	0.00008	9
Polymesoda (Geloina) coaxans	Coastal Rivers/Estuaries	5	0.19	0.00008	9
Ostreidae f.	Shallow Water	5	0.19	0.00008	9
Tellina sp.	Sand/Mud Flats	2	0.08	0.00003	12
Modiolus sp.	Coastal Rivers/Estuaries	2	0.08	0.00003	12
Placamen calophyllum	Sand/Mud Flats	2	0.08	0.00003	12
Terebralia sp.	Mangroves	1	0.04	0.00002	15
Total		**2613**			

Table 5.22: BMB/071, MNI and corrected MNI values for the dominant species by excavation unit.

Excavation Unit	Volume (cm^3)	*Anadara granosa*		*Mactra abbreviata*	
		MNI	MNI/cm^3	MNI	MNI/cm^3
1	7500	105	0.01400	5	0.00067
3	10000	267	0.02670	16	0.00160
5	12500	701	0.05608	46	0.00368
7	10000	516	0.05160	104	0.01040
9	12500	589	0.04712	20	0.00160
11	10000	108	0.01080	0	0.00000

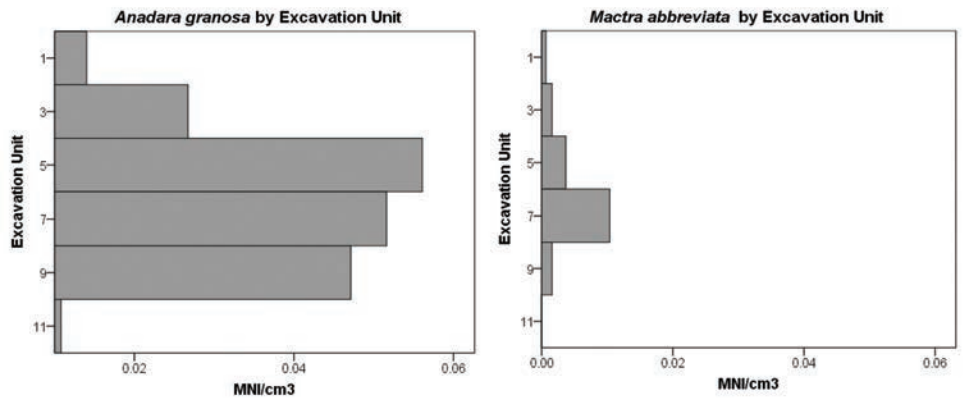

Figure 5.9: BMB/071, corrected MNI values for the dominant species by excavation unit.

BMB/045: Species richness, habitat exploitation and relative abundances

Fifteen molluscan taxa in all were identified within the 16 excavation units analysed for BMB/045. The differences in radiocarbon dates from the surface, middle and base of the site are not statistically significant, which suggests that there was extremely rapid rate of deposition, given the 1m depth of deposit within the excavated area. Any changes through time in economic activity within the site should be reflected by analysing variation in species richness, habitat exploitation and relative abundance estimates by excavation unit. Species richness for BMB/045 by excavation unit is detailed in Table 5.23, with the percentages of the total number of economic species identified within the site. While there is a certain degree of variation in species richness between excavation units, ranging between four and eleven species per unit, the Spearman's correlation coefficient (r_s = -0.074, $p > 0.5$, $n = 16$) suggest that the relationship between species richness and excavation unit is neither strong nor significant. This again indicates that there was a certain level of consistency in the number of species exploited within this site through time. Of the 15 economic species within the site, three (20.0%) come from the shallow water habitat, six (40.0%) from the sand/mud flat habitats, four (26.7%) from the mangrove zone and only two (13.3%) from coastal river/estuarine areas. In line with the other Grindall Bay sites, this suggests that the sand/mud flats were the dominant environmental zone within the area during site deposition.

Species richness and relative abundance estimates by excavation unit are again used to determine whether there were any shifts in the focus of exploitation between these habitats through time. A Spearman's rank correlation is used to test the relationship between habitat species richness and excavation unit with the exception of the estuarine habitat, as the number of species by excavation unit remains constant. These results show that there is not a significant relationship between species richness and excavation unit throughout the deposit for the shallow water zone (r_s = -0.031, $p > 0.5$, $n = 16$), mangroves (r_s = 0.428, $p > 0.05$, $n = 16$) and estuary habitat (r_s = -0.082, $p > 0.5$, $n = 16$). In contrast, there appears to be a general increase in the number of species exploited from the sand/mud flats within the site, as the relationship between species richness from this habitat area and excavation unit is significant (r_s = -0.565, $p < 0.05$, $n = 16$).

Table 5.23: BMB/045, number of species, the percentage of the total number of species and number of species for molluscan habitats by excavation unit.

Excavation Unit	No. Species	% of Total	Shallow Water	Sand/Mud Flats	Mangroves	Estuarine
1	8	53.33	1	5	2	0
3	11	73.33	2	6	2	1
5	8	53.33	1	6	1	0
7	7	46.67	0	6	1	0
9	6	40.00	0	5	1	0
11	6	40.00	0	5	1	0
13	8	53.33	1	5	2	0
15	8	53.33	1	5	2	0
17	9	60.00	1	4	3	1
19	10	66.67	2	5	3	0
21	5	33.33	1	2	2	0
23	4	26.67	1	3	0	0
25	7	46.67	1	3	2	1
27	10	66.67	1	5	3	1
29	9	60.00	1	5	3	0
31	7	46.67	0	5	2	0
Total	**15**		**3**	**6**	**4**	**2**

As a contrast, Table 5.24 details the MNI of species within each excavation unit by habitat. Testing the combined, volume-corrected species relative abundance estimates from the four habitat areas suggests that there is not a significant relationship between relative abundance and excavation unit for any of the four habitats. The Spearman's correlation coefficients indicate that for the shallow water ($r_s = 0.121$, $p > 0.5$, $n = 16$), sand/mud flat ($r_s = -0.465$, $p > 0.05$, $n = 16$), mangrove ($r_s = -0.398$, $p > 0.1$, $n = 16$) and estuarine habitats ($r_s = 0.108$, $p > 0.5$, $n = 16$), there is not a significant change in the focus of exploitation through time. Regardless of the comparative level or intensity of exploitation between these habitat zones, exploitation within each habitat remains consistent throughout the occupation of this site. While the number of species from the sand/mud flats does change significantly throughout the deposit, the relative abundance estimates of species from this habitat indicates that any change in the level of exploitation from this area is not significant. This pattern possibly indicates a slight change in the structure and density of shell-beds within this zone.

Table 5.24: BMB/045, MNI values and volume-corrected MNI estimates (MNI/cm^3) for species from molluscan habitats by excavation unit.

Excavation Unit	Volume (cm^3)		Shallow Water	Sand/Mud Flats	Mangroves	Estuarine
1	5000	MNI	1	87	8	0
		MNI/cm^3	0.00020	0.01740	0.00160	0.00000
3	5000	MNI	1	172	24	1
		MNI/cm^3	0.00020	0.03440	0.00480	0.00020
5	5000	MNI	0	200	25	0
		MNI/cm^3	0.00000	0.04000	0.00500	0.00000
7	5000	MNI	0	213	2	0
		MNI/cm^3	0.00000	0.04260	0.00040	0.00000
9	7500	MNI	0	251	8	0
		MNI/cm^3	0.00000	0.03347	0.00107	0.00000
11	12500	MNI	0	176	6	0
		MNI/cm^3	0.00000	0.01408	0.00048	0.00000
13	7500	MNI	1	231	11	0
		MNI/cm^3	0.00013	0.03080	0.00147	0.00000
15	10000	MNI	0	223	14	0
		MNI/cm^3	0.00000	0.02230	0.00140	0.00000
17	10000	MNI	2	180	2	0
		MNI/cm^3	0.00020	0.01800	0.00020	0.00000
19	10000	MNI	1	218	2	1
		MNI/cm^3	0.00010	0.02180	0.00020	0.00010
21	7500	MNI	2	121	1	0
		MNI/cm^3	0.00027	0.01613	0.00013	0.00000
23	7500	MNI	0	110	2	0
		MNI/cm^3	0.00000	0.01467	0.00027	0.00000
25	7500	MNI	1	128	3	1
		MNI/cm^3	0.00013	0.01707	0.00040	0.00013
27	7500	MNI	1	236	5	1
		MNI/cm^3	0.00013	0.03147	0.00067	0.00013
29	7500	MNI	2	166	31	0
		MNI/cm^3	0.00027	0.02213	0.00413	0.00000
31	10000	MNI	0	156	7	0
		MNI/cm^3	0.00000	0.01560	0.00070	0.00000

Table 5.25 details the MNI counts and percentages for the 16 species from this site, volume-corrected relative abundance estimates (MNI/cm³), and the rank order by MNI. Only two species, at 13.3% of the total number of species in the site, make up 91.4% by MNI of the assemblage from BMB/045. *Anadara granosa* is by far the highest-ranking species by percentage of the total MNI (74.2%) and by the corrected density estimate. In rank order, this species is followed by *Mactra abbreviata* at 17.2% by MNI (Faulkner 2009:827). These two top ranked species are found in the sand and mudflats within the intertidal/subtidal zone.

Table 5.25: BMB/045, MNI values and MNI density estimates (MNI/cm³) for all molluscan species (species above dashed line at > 5% MNI viewed as dominant).

Economic Molluscan Species	Habitat Category	MNI	% MNI	Density (MNI/cm³)	Rank Order
Anadara granosa	Sand/Mud Flats	2253	74.21	0.01802	1
Mactra abbreviata	Sand/Mud Flats	523	17.23	0.00418	2
Cassidula angulata	Mangroves	116	3.82	0.00093	3
Pitar sp.	Sand/Mud Flats	32	1.05	0.00026	4
Tellina sp.	Sand/Mud Flats	32	1.05	0.00026	4
Placuna placenta	Mangroves	22	0.72	0.00018	6
Placamen calophyllum	Sand/Mud Flats	16	0.53	0.00013	7
Telescopium telescopium	Mangroves	13	0.43	0.00010	8
Anadara antiquata	Sand/Mud Flats	12	0.40	0.00010	9
Ostreidae f.	Shallow Water	10	0.33	0.00008	10
Modiolus sp.	Estuarine	3	0.10	0.00002	11
Barbatia sp.	Shallow Water	1	0.03	0.00001	12
Chicoreus sp.	Shallow Water	1	0.03	0.00001	12
Nerita sp.	Mangroves	1	0.03	0.00001	12
Polymesoda (Geloina) coaxans	Estuarine	1	0.03	0.00001	12
Total		**3036**			

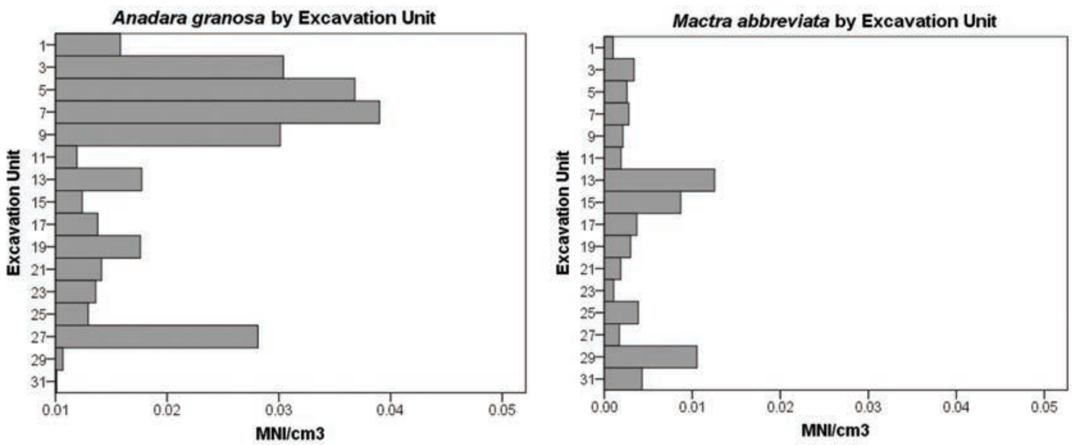

Figure 5.10: BMB/045, volume-corrected MNI values for the dominant species by excavation unit.

Figure 5.10 and Table 5.26 present the MNI values for these two species corrected for volume (MNI/cm³) by excavation unit. Spearman's correlation coefficients indicate that the differences in the relative abundance of *Anadara granosa* (r_s = -0.635, p < 0.01, n = 16) and *Mactra abbreviata* (r_s = 0.265, p > 0.2, n = 16) by excavation unit, and by extension through time, are not statistically significant (Faulkner 2009:827). In combination with the analysis of overall species richness and species richness by habitat, the primary foci of molluscan exploitation within this site appears to remain relatively consistent throughout the period of occupation.

Table 5.26: BMB/045, MNI and corrected MNI values for the dominant species by excavation unit.

Excavation Unit	Volume (cm³)	*Anadara granosa*		*Mactra abbreviata*	
		MNI	MNI/cm³	MNI	MNI/cm³
1	5000	79	0.01580	5	0.00100
3	5000	152	0.03040	17	0.00340
5	5000	184	0.03680	13	0.00260
7	5000	195	0.03900	14	0.00280
9	7500	226	0.03013	16	0.00213
11	12500	149	0.01192	24	0.00192
13	7500	133	0.01773	94	0.01253
15	10000	124	0.01240	87	0.00870
17	10000	138	0.01380	37	0.00370
19	10000	176	0.01760	30	0.00300
21	7500	106	0.01413	14	0.00187
23	7500	102	0.01360	8	0.00107
25	7500	97	0.01293	29	0.00387
27	7500	211	0.02813	13	0.00173
29	7500	80	0.01067	79	0.01053
31	10000	101	0.01010	43	0.00430

Grindall Bay mound site comparison

The analysis of the three Grindall Bay shell mounds suggests a certain level of homogeneity in resource exploitation through time and space, particularly when the emphasis on *A. granosa* in Grindall Bay is considered relative to the increased level of molluscan diversity noted in the three Myaoola Bay middens. That said, the degree of difference or similarity in resource and habitat exploitation in these sites needs to be established. Table 5.27 presents overall species richness and habitat species richness per site. As total species richness varies between 15 and 18 across the three sites, it is apparent that there is only a very low level of species richness variability, which is not statistically significant (χ^2 = 0.189, *d.f.* = 4, $p > 0.5$). Species richness by habitat for the Grindall Bay mounds follows this overall pattern, with chi-square results indicating that in the Grindall Bay mound sites the number of species exploited per habitat do not differ significantly (χ^2 = 0.395, *d.f.* = 6, $p = 0.999$, Cramer's V = 0.064).

Table 5.27: Grindall Bay sites, overall species richness and the frequency of species per habitat area.

Site Code	Approx. Age cal BP	Total Species Richness	Shallow Water		Sand/Mud Flats		Mangroves		Estuarine	
			No.	%	No.	%	No.	%	No.	%
BMB/029	2287 – 1912	18	3	16.67	7	38.89	6	33.33	2	11.11
BMB/071	1483 – 1192	15	2	13.33	6	40.00	5	33.33	2	13.33
BMB/045	584 – 539	15	3	20.00	6	40.00	4	26.67	2	13.33

Analysis of the three individual sites suggests that while this level of homogeneity may accurately reflect the availability of economic species within each habitat zone, there are quite strong differences in the level of habitat exploitation. To assess these differences between the sites, Table 5.28 details the MNI and percentage MNI of species by each habitat zone. In investigating differences in the relative abundance of species per habitat by site, chi-square results indicate that there is a high level of significance in the level of exploitation per habitat across the Grindall Bay sites (χ^2 = 177.251, *d.f.* = 6, $p = 0.000$, Cramer's V = 0.108).

Table 5.28: Grindall Bay sites, MNI and percentage MNI of species per habitat area.

Site Code	Approx. Age cal BP	Shallow Water		Sand/Mud Flats		Mangroves		Estuarine	
		MNI	%	MNI	%	MNI	%	MNI	%
BMB/029	2287 – 1912	25	1.32	1639	86.63	219	11.58	9	0.48
BMB/071	1483 – 1192	10	0.38	2515	96.25	81	3.10	7	0.27
BMB/045	584 – 539	12	0.40	2868	94.50	151	4.98	4	0.13

The main differences between the sites in Grindall Bay lie in comparing the two dominantly exploited habitats. There is a general increase in the exploitation of the sand and mud flat habitats in this area, whereas the shallow water and estuarine habitats remain consistently low between sites and throughout time. Although the level of exploitation within the sand and mud flats is at a high level throughout the period of occupation in Grindall Bay, the increase in taxa exploited from this habitat zone through time corresponds with a decrease in mangrove species. Therefore, while there is a degree of variability within and between the Grindall Bay shell mounds, in line with the patterns identified for the Myaoola Bay middens, changes through time are a reflection of broader environmental processes acting within this former shallow embayment. Variations in habitat exploitation relate to the ongoing process of progradation within the area through time, and the gradual establishment and proliferation of the sand/mud flat zone, generally at the expense of exploitation within the mangroves. As the process of progradation reached its limit within the area close to 500 years ago this pattern slowly changed, with a slight increase in mangrove species corresponding with slight decrease in sand/mud flat species. This final shift might reflect the relative stabilisation of sedimentary infilling within this area, and the stabilisation of mangrove distribution close to its present extent at the mouth of Grindall Bay (Faulkner 2011:144–5).

Differences in the dominant exploited species

Variations in the pattern of habitat exploitation relate primarily to micro- and macro-environmental changes through time, reflected within both the specific site locality and broader Myaoola and Grindall Bay areas. The composition of the dominant molluscan taxa by site and area (Table 5.29) is also a reflection of the effects of these processes. Species composition by rank varies markedly between the Myaoola Bay midden sites (BMB/018, BMB/067 and BMB/084). While several species occur consistently within these deposits, such as *Marcia hiantina*, *Septifer bilocularis* and *Gafrarium* sp., as previously discussed for each site, differences in species ranking relates specific habitat distribution and dominance within a given location. Variations in species composition within this area reflect broader environmental change, with changing conditions affecting the range of species available for human exploitation. In contrast, the mound sites in Grindall Bay exhibit much less variability in both the most highly ranked species and the sub-dominant species components. *Anadara granosa* is the most highly ranked species in all three sites, followed by *Mactra abbreviata* and *Marcia hiantina*, all three of which inhabit sand and mud flat areas. The only other species present, *Placuna placenta*, is found within the mangroves, and in terms of ranking, is found only within BMB/029 near the top of the system. In comparing the two areas, it appears that there was a more widespread use of species in Myaoola Bay as opposed to Grindall Bay (Faulkner 2011:146). The species composition from the Grindall Bay sites indicates a possibly more intensive focus on the sand and mud flats, as well as particular species. These interpretations of the overall molluscan composition and ranking of the dominant species are supported when comparing the percentage of the total MNI for each ranking category (Table 5.30).

Table 5.29: Dominant species ranking per site.

	Site Code	Rank 1 Species	Rank 2 Species	Rank 3 Species	Rank 4 Species
Myaoola Bay	BMB/018	*Septifer bilocularis*	*Pinctada sp.*	*Gafrarium sp.*	---
	BMB/067	*Anadara granosa*	*Marcia hiantina*	*Septifer bilocularis*	*Gafrarium* sp.
	BMB/084	*Marcia hiantina*	*Isognomon isognomon*	Mytilidae f.	*Gafrarium* sp.
Grindall Bay	BMB/029	*Anadara granosa*	*Marcia hiantina*	*Placuna placenta*	---
	BMB/071	*Anadara granosa*	*Mactra abbreviata*	---	---
	BMB/045	*Anadara granosa*	*Mactra abbreviata*	---	---

Table 5.30: MNI and percentage MNI by species ranking per site and locality.

	Site Code	Rank 1 Species		Rank 2 Species		Rank 3 Species		Rank 4 Species		Total
		MNI	%	MNI	%	MNI	%	MNI	%	MNI
Myaoola Bay	BMB/018	384	48.73	274	34.77	61	7.74	---	---	788
	BMB/067	518	31.94	342	21.09	276	17.02	137	8.45	1622
	BMB/084	292	29.00	280	27.81	145	14.40	57	5.66	1007
Grindall Bay	BMB/029	1288	68.08	255	13.48	185	9.78	---	---	1892
	BMB/071	2286	87.49	191	7.31	---	---	---	---	2613
	BMB/045	2253	74.21	523	17.23	---	---	---	---	3035

For the Myaoola Bay midden sites, while there is a decline in the relative abundance of species from rank one through to four, this general decline is gradual, particularly for sites BMB/067 and BMB/084. While the pattern for BMB/018 shows a slightly steeper decline in MNI percentages from ranks one to three, with no fourth species occurring at greater than five percent by MNI, this still follows the general trend for the Myaoola Bay area. For these midden sites, there was a relatively more evenly spread use of the available species within the area, with no one species being exploited at a level greater than 50% for the site as a whole. A comparison with the three Grindall Bay mound sites shows a distinctly different pattern of resource exploitation. These three sites are clearly dominated by *Anadara granosa*, occurring between 68 and 88% of the total molluscan assemblages recovered from these deposits. While the second ranked species in the Myaoola Bay sites vary between approximately 21 and 35% of the assemblages, within Grindall Bay sites they comprise a comparatively low 7 to 17%. While other species were exploited in the latter area, as reflected within the composition of the assemblages recovered from the Grindall Bay mound deposits, there was an overwhelming focus on one particular taxon (Faulkner 2011:146). This contrasting pattern of exploitation across the Point Blane Peninsula possibly reflects the relative stability of habitats and, by extension resource availability, throughout the period of landscape development within Grindall Bay, compared with the dynamic and changing nature of the coastline on the more exposed, eastern margin of the peninsula.

Conclusion

The composition of the molluscan assemblages from all of these sites represents the long-term, average structure of mollusc communities in each locality distributed around the Point Blane Peninsula during the period of site formation (Claassen 1998:134). In addition, the analysis of habitat exploitation and species variability detailed here provides further support for the conclusions drawn from a number of previous northern Australia coastal studies (Mowat 1995:153; Hiscock 1999:96; Bourke 2000:146). Species richness is highly variable within and between coastal sites distributed across northern Australia, but as noted by Mowat (1995:148), while there is no single explanation for this variation, there are a number of strongly contributing factors that require consideration. It is suggested here that changes in environmental conditions over time would have affected the species of shellfish available for exploitation. Further to this

point, it is apparent that the differing proportions of species within these sites indicate that environmental changes operating within this region were gradual in nature. Changes in the proportion of species from the different habitat areas identified in this analysis relates to spatial and temporal variation in the availability of molluscan taxa within and between the Myaoola and Grindall Bay areas (Bailey 1994:9; Bourke 2000:143). Following from this point, molluscan procurement strategies within this area are generally characterised by a focus on any profusely available resource, with the subsequent addition of secondary, less abundant resources (Bourke 2000:312). Therefore, any changes in the species exploited can be seen to be a direct reflection of environmental changes. In line with the interpretations presented by Mowat (1995:163) for shell deposits in Western Arnhem Land, foraging behaviour on the coastal margins of the Point Blane Peninsula was highly flexible, with people actively altering their foraging strategies to incorporate increasingly abundant or newly available species (Faulkner 2011:147).

It has been argued by Hiscock and Mowat (1993) that understanding the degree of diversity in shell deposits provides an opportunity for the re-evaluation of models developed to explain the past use of coastal landscapes. While variability in species richness, habitat use and the exploitation of certain species has been tied here to the environment, there is also a cultural or behavioural component that needs to be considered (Faulkner 2011:147–8). It has further been suggested that the relative proportion of mollusc species may be related to differing site functions and the intensity of site use, and as such a reflection of cultural selection and discard practices, rather than being solely representative of the environment from which these resources were procured (Jerardino 1998; Bourke 2000:301; Morrison 2000, 2003). As a result, variations in the intensity of site deposition and resource exploitation, as well as the overall chronological patterns of occupation across the study area, need to be taken into account to assess any changes in the foraging economy and potential differences in site function.