

# 6

## Investigating Variability in the Intensity of Occupation and Resource Use

The previously highlighted analyses of the spatial and temporal patterning in the archaeological record across the Point Blane Peninsula have demonstrated a close relationship between the structure of the economy and those environmental changes noted more broadly across northern Australia and the Indo-Pacific region. Variation in the exploitation of specific resources and habitats indicates that resources were targeted in a highly localised pattern across time and space. Following from this, the question of whether the archaeological record reflects differing site functions and changes in the intensity of both site and resource use requires attention. As such, the following analyses assess whether the available archaeological evidence is best characterised as reflecting cultural selection and discard practices, or as a representation of the environmental and ecological parameters in place during the late Holocene. To achieve this, site densities, site morphology and intensity of resource exploitation, as well as the overall chronological patterns of occupation for the study area, must be addressed in order to assess possible changes in the foraging economy and differences in site function.

### Temporal and spatial evidence

The available sample of radiocarbon age determinations from sites on the Point Blane Peninsula is relatively large, with 39 dates having been obtained from 20 sites. In order to produce a broadly representative chronology for the study area, the distribution of these sites across the peninsula reflects a range of site types in varying environmental contexts (Faulkner 2008:81–84). These ages are listed in chronological order according to their broad location on the Point Blane Peninsula, with the calibrated ages for Myaoola Bay in Table 6.1 and Grindall Bay in Table 6.2. Taking these ages together, these dates again demonstrate a late Holocene sequence of occupation within the area, ranging from 2953 cal BP to the present, with the majority of the radiocarbon dates clustered between approximately 2500 BP and the present. Although this grouping lends itself to a certain degree of time and space averaging (see Lyman 2003), coarse patterning in the distribution of dates in this way is still evident. In line with suggestions by Bailey (1983, 1999) for the time lag in the appearance of coastal sites in the Weipa area, it is suggested here that the general chronological pattern from the Point Blane Peninsula relates to occupation following sea level rise and a time lag in the establishment of habitats suitable for the proliferation of resources in this particular area. In reviewing all of the radiocarbon dates available, however, while being characterised as relatively long-term, occupation on the Point Blane Peninsula does not appear to have been continuous in all areas.

Several key elements that can create uncertainty in the interpretation of chronological patterns of shorter durations need to be acknowledged in the interpretation of the radiocarbon ages from the Point Blane Peninsula. These aspects include regional and localised differences in the marine reservoir effect and  $\Delta R$  correction values, as well as isotopic fractionation and the determination of  $\delta^{13}\text{C}$  values (e.g. Mangerud 1972; Olsson 1974; Spennemann and Head 1996; Ingram 1998; Ulm 2002, 2006a, 2006b; Deo *et al.* 2004; Douka *et al.* 2010; England *et al.* 2012). 17 of the 39 radiocarbon dates obtained for this study do not have determined  $\delta^{13}\text{C}$  values, with estimates of  $0.0 \pm 0.0$  to  $0.0 \pm 2.0$  used to arrive at conventional radiocarbon ages for these samples. This can be problematic, as a deviation of  $1\text{‰}$  will produce an error of approximately 16 years in determining the radiocarbon age (Mangerud 1972:147–8). While these differences are minor when investigating the broader chronological trends from both Myaoola and Grindall Bays, this does add a slight degree of uncertainty, as estuarine shell taxa are known to exhibit highly variable  $\delta^{13}\text{C}$  values. Further to this, Ulm (2002, 2006b) has demonstrated a lack of consistency in  $\Delta R$  values within and between regions. This is relevant here, as Myaoola Bay is characterised by terrestrial river input into open and shallow water, contrasting with the predominantly estuarine and mangrove fringed Grindall Bay. Therefore, there may well be a degree of variability in  $\Delta R$  values between these areas given the differences apparent in processes of landscape formation and environmental conditions (Faulkner 2008:86). Given these factors, a more extensive and high-resolution dating program in combination with the determination of estuarine specific  $\Delta R$  values for the Point Blane Peninsula would strengthen the interpretation of these radiocarbon sequences. That said, based on the chronological patterns presented here relative to variations in use of the landscape and resources through time, it is still possible to draw tentative conclusions regarding human behaviour and use of the area.

Previous analyses of the available radiocarbon dates from the Point Blane Peninsula (Faulkner 2008, 2009, 2011, in press) identified a number of chronological phases based on statistically significant differences in calibrated age ranges in Myaoola and Grindall Bays. While the recalibration of these dates using the  $\Delta R$  correction value of  $55 \pm 98$  recommended for the Gulf of Carpentaria (Ulm 2006b) removes or closes the gaps between these phases, those previously identified trends are still apparent in the calibrated radiocarbon age distributions within and between these areas. Within Myaoola Bay, the radiocarbon estimates cluster predominantly between 683 cal BP and the present (Figure 6.1), preceded by two dates at 1115 and 1518 cal BP. There is one date at 2953 cal BP that is significantly different, and clearly separate to the dominant clustering of radiocarbon dates for this area. This grouping of dates may be explained as resulting from behavioural and/or taphonomic issues. This pattern may relate to sporadic or low intensity occupation of this margin of the peninsula prior to approximately 1000 BP (e.g. Rowland 1983:73; Hall and Hiscock 1988:11), or alternatively might reflect gaps in the visibility of older sites in the area due to the dynamic nature of beach ridge development along this area of coastline. While it is true that the absence of sites does not indicate the absence of people, and by extension, ephemeral evidence for occupation may not indicate ephemeral occupation (Cribb 1986; Bourke 2000:354), the latter argument is more convincing when this chronological patterning is considered relative to the sites located within the Grindall Bay area. The radiocarbon ages available for sites located in Grindall Bay suggests that occupation in this area spans an approximate 1800 year period, with initial occupation at 2287 cal BP, and use of the area phasing out around 526 cal BP (Figure 6.2). In comparison with the chronological pattern from Myaoola Bay, there is a concentration in site deposition between approximately 2287 and 1009 cal BP, with another grouping of radiocarbon determinations occurring between 584 and 526 cal BP. The peaks and troughs in the Grindall Bay chronological sequence may relate to localised variability in the intensity of occupation and use of resources within this area. While the archaeological record across the Point Blane Peninsula has undoubtedly been affected by post-depositional disturbance and destruction, as noted above, it is still possible to cautiously draw conclusions from these chronological patterns relative to variations in the structure of the economy and the nature of the landscape itself.

In comparing the radiocarbon ages from the two bay areas, there appear to have been two main phases of occupation on the Point Blane Peninsula: an initial phase between approximately 3000 and 1000 BP, and a second phase between approximately 1000 BP and the present. Use of the more exposed coastal areas of Myaoola Bay may have been more sporadic between 2953 and 1115 cal BP, contrasting with a pattern of more intensive use of Grindall Bay during this time. In the second phase, the patterning of ages in Myaoola Bay suggests a period of comparatively more intensive use throughout the last 1000 years. During this second phase, there was one relatively short and intense period of site deposition between approximately 584 and 526 cal BP in Grindall Bay. The trough observable in the summed probability distribution preceding this second phase of occupation and site deposition in Grindall Bay was previously interpreted as reflecting a hiatus in use of the area (Faulkner 2008, 2009, in press), but perhaps relates more to a change in the intensity of resource exploitation and/or site deposition. To some degree, the clustered patterns of age determinations reflects the age of the surfaces onto which these sites were deposited (Holdaway *et al.* 2002:358, 2005:45). For example, the relative dearth of radiocarbon dates prior to approximately 1000 BP in Myaoola Bay conceivably relates to ongoing processes of beach ridge development that have the potential to distort and/or disturb the archaeological record of this area. While it is possible that the relative discontinuities in the chronological pattern for this area may in part reflect preservation and sampling issues, use of Myaoola Bay prior to 1000 BP appears to have been more sporadic and of lower intensity compared with the second occupation phase identified between 1000 BP and the present (as also evidenced by site morphology and deposition).

Table 6.1: Radiocarbon age estimate ranges for sites in Myaoola Bay.

Site Code	Site Type	Square	Excavation Unit	Depth (cm)	Lab Code	Sample	$\delta^{13}\text{C}$ (*estimate)	$^{14}\text{C}$ Age (years BP)	1 $\sigma$ cal Age BP (68.3% probability)	2 $\sigma$ cal Age BP (95.4% probability)	Cal Age BP Median
BMB/084	Midden Complex	Test Pit 1	1	0 - 1	ANU-11911	<i>M. hiantina</i>	$0.0 \pm 2.0^*$	$122.3 \pm 1.0\%$	Modern	Modern	--
BMB/084	Midden Complex	Test Pit 1	4	4 - 7	ANU-11914	<i>M. hiantina</i>	$0.0 \pm 2.0^*$	$360 \pm 60$	Modern	Modern	--
BMB/084	Midden Complex	Test Pit 1	5	7 - 11	ANU-11912	<i>M. hiantina</i>	$0.0 \pm 2.0^*$	$460 \pm 70$	Modern	Modern	--
BMB/084	Midden Complex	Test Pit 3	5	12 - 15	ANU-12093	<i>M. hiantina</i>	$0.0 \pm 2.0^*$	$470 \pm 60$	Modern	Modern	--
BMB/016	Midden	Test Pit 1	3	6 - 10	ANU-11497	<i>M. hiantina</i>	$0.0 \pm 2.0^*$	$580 \pm 60$	1#–257	1#–374	168
BMB/022	Midden	Test Pit 1	4	9 - 14	ANU-11716	<i>S. bilocularis</i>	$0.2 \pm 0.2$	$630 \pm 70$	1#–306	1#–418	207
BMB/015	Midden	Test Pit 1	5	10 - 13	ANU-11498	<i>M. hiantina</i>	$0.4 \pm 0.1$	$640 \pm 50$	68–315	1#–414	213
BMB/116	Mound	Test Pit 1	1	0 - 1	ANU-12019	<i>A. antiquata</i>	$0.0 \pm 2.0^*$	$650 \pm 60$	77–333	1#–426	225
BMB/084	Midden Complex	Test Pit 1	7	14 - 17	ANU-11913	<i>M. hiantina</i>	$0.0 \pm 2.0^*$	$860 \pm 70$	309–516	149–643	424
BMB/003	Midden	Test Pit 1	1	0 - 5	ANU-11501	<i>M. hiantina</i>	$0.2 \pm 0.1$	$900 \pm 50$	336–549	274–640	461
BMB/067b	Midden	Test Pit 1	1	0 - 2	Wk-17745	<i>A. granosa</i>	$2.2 \pm 0.2$	$1063 \pm 35$	511–661	433–773	592
BMB/116	Mound	Test Pit 1	11	32 - 36	ANU-12020	<i>A. antiquata</i>	$0.0 \pm 2.0^*$	$1120 \pm 60$	531–719	473–869	638
BMB/017	Midden	Test Pit 1	3	5 - 8	ANU-11500	<i>G. tumidum</i>	$0.0 \pm 2.0^*$	$1160 \pm 80$	547–771	485–911	676
BMB/084	Midden Complex	Test Pit 3	10	29 - 34	ANU-12094	<i>M. hiantina</i>	$0.0 \pm 2.0^*$	$1170 \pm 60$	561–770	505–897	683
BMB/067a	Midden	Test Pit 1	1	1 - 5	ANU-11715	<i>A. granosa</i>	$3.0 \pm 0.2$	$1620 \pm 80$	992–1247	856–1367	1115
BMB/067b	Midden	Test Pit 1	9	27 - 31	ANU-11714	<i>A. granosa</i>	$2.0 \pm 0.2$	$2010 \pm 80$	1369–1657	1269–1809	1518
BMB/018	Midden	Test Pit 1	3	11 - 17	ANU-11503	<i>S. bilocularis</i>	$0.0 \pm 0.0$	$3200 \pm 70$	2779–3080	2700–3263	2953

Note: # are suspect due to impingement on the end of the calibration data set.

Source: Calibration data from CALIB 6.1.1, marine04.14c (Huguen *et al.* 2004),  $\Delta R = 55 \pm 98$  (Ulm 2006b).

Table 6.2: Radiocarbon age estimate ranges for sites in Grindall Bay.

Site Code	Site Type	Square	Excavation Unit	Depth (cm)	Lab Code	Sample	$\delta^{13}\text{C}$ (*estimate)	$^{14}\text{C}$ Age (years BP)	1 $\sigma$ cal Age	2 $\sigma$ cal Age	Cal Age BP Median
									BP (68.3% probability)	BP (95.4% probability)	
BMB/036	Mound	N/A	N/A	Surface	ANU-12018	<i>A. granosa</i>	$0.0 \pm 2.0^*$	$980 \pm 130$	389–667	239–847	526
BMB/045	Mound	Test Pit 1	1	0–2	ANU-11717	<i>A. granosa</i>	$3.5 \pm 0.2$	$990 \pm 60$	461–637	314–708	539
BMB/045	Mound	Test Pit 1	16	43–46	ANU-11718	<i>A. granosa</i>	$-3.7 \pm 0.2$	$1040 \pm 60$	492–659	375–781	577
BMB/045	Mound	Test Pit 1	31	91–95	ANU-11719	<i>A. granosa</i>	$3.1 \pm 0.2$	$1050 \pm 60$	49–664	387–791	584
BMB/061	Midden	Test Pit 1	1	0–4	ANU-11720	<i>A. granosa</i>	$4.6 \pm 0.2$	$1510 \pm 50$	900–1137	776–1243	1009
BMB/061	Midden	Test Pit 1	4	9–12	Wk-25466	<i>A. granosa</i>	$-3.8 \pm 0.2$	$1684 \pm 35$	1071–1280	951–1373	1178
BMB/071	Mound	Test Pit 1	1	0–3	ANU-11722	<i>A. granosa</i>	$2.9 \pm 0.2$	$1700 \pm 60$	1067–1299	936–1412	1192
BMB/061	Midden	Test Pit 1	7	17–22	ANU-11721	<i>A. granosa</i>	$4.1 \pm 0.2$	$1720 \pm 50$	1095–1320	962–1433	1213
BMB/052	Mound	N/A	N/A	Surface	Wk-17744	<i>A. granosa</i>	$-3.3 \pm 0.2$	$1763 \pm 37$	1152–1367	1039–1496	1258
BMB/071	Mound	Test Pit 1	6	19–24	ANU-11723	<i>A. granosa</i>	$-2.5 \pm 0.2$	$1810 \pm 60$	1176–1419	1053–1551	1310
BMB/071	Mound	Test Pit 1	11	42–46	ANU-11724	<i>A. granosa</i>	$3.1 \pm 0.2$	$1980 \pm 60$	1343–1599	1259–1753	1483
BMB/101	Mound	N/A	N/A	Surface	ANU-11894	<i>A. granosa</i>	$0.0 \pm 2.0^*$	$2010 \pm 80$	1369–1657	1269–1809	1518
BMB/093	Mound	N/A	N/A	Surface	ANU-11893	<i>A. granosa</i>	$0.0 \pm 2.0^*$	$2240 \pm 80$	1617–1924	1485–2101	1779
BMB/082	Mound	N/A	N/A	Surface	ANU-11892	<i>A. granosa</i>	$0.0 \pm 2.0^*$	$2340 \pm 70$	1747–2047	1591–2210	1900
BMB/029	Mound	Test Pit 1	4	8–11	ANU-11499	<i>A. granosa</i>	$-4.0 \pm 0.1$	$2350 \pm 60$	1771–2058	1613–2207	1912
BMB/029	Mound	Test Pit 1	8	23–28	ANU-11502	<i>A. granosa</i>	$0.0 \pm 2.0^*$	$2360 \pm 60$	1788–2074	1646–2242	1925
BMB/029	Mound	Test Pit 1	1	0–3	ANU-11496	<i>A. granosa</i>	$-3.4 \pm 0.1$	$2410 \pm 50$	1850–2120	1728–2279	1985
BMB/029	Mound	Test Pit 1	12	41–45	ANU-11505	<i>A. granosa</i>	$-2.8 \pm 0.1$	$2420 \pm 50$	1858–2129	1742–2287	1997
BMB/029	Mound	Test Pit 1	14	49–53	ANU-11494	<i>A. granosa</i>	$-2.6 \pm 0.1$	$2460 \pm 50$	1892–2171	1795–2314	2045
BMB/033	Mound	N/A	N/A	Surface	ANU-12017	<i>A. granosa</i>	$0.0 \pm 2.0^*$	$2540 \pm 60$	2010–2290	1853–2420	2140
BMB/029	Mound	Test Pit 1	16	58–62	ANU-11504	<i>A. granosa</i>	$-3.1 \pm 0.2$	$2630 \pm 60$	2085–2380	1952–2595	2245
BMB/029	Mound	Test Pit 1	20	75–81	ANU-11495	<i>A. granosa</i>	$0.0 \pm 2.0^*$	$2660 \pm 60$	2122–2435	1995–2648	2287

Source: Calibration data from CALIB 6.1.1, marine04.14c (Hughen *et al.* 2004),  $\Delta R = 55 \pm 98$  (Ulm 2006b).

In contrast, the absence of sites in Grindall Bay dating prior to approximately 2287 cal BP likely relates to processes of landscape and habitat formation in the area via sedimentary infilling and progradation (Woodroffe *et al.* 1985a, 1985b; Clark and Guppy 1988), and the effects these processes had on the availability and proliferation of molluscan resources. Rather than reflecting post-depositional or sampling issues, the clustering of radiocarbon determinations into two main phases in this Grindall Bay (based on the summed probability distribution), particularly in comparison with the patterns identified in Myaoola Bay, may be more firmly related to occupation and resource exploitation. The present day Grindall Bay landscape has formed as a result of Holocene sea level rise and subsequent progradation, however the sites are relatively well protected from extreme environmental conditions, particularly in the form of strong wind and wave action. All of the sites that fall between 2287 and 1009 cal BP are located on the laterite ridge bordering this area that forms a comparatively stable surface. The two sites that provide the radiocarbon dates falling between 584 and 526 cal BP, however, are both located on the surface of the saltflats away from the laterite ridge. Rather than a period of local abandonment (as presented in Faulkner 2008, 2009), the clustering of radiocarbon dates in combination with differences in the location of sites between these two phases indicates a shift in the intensity of landscape and resource utilisation. This pattern has implications for human behaviour linked to the formation of the peninsula following sea level rise, and the subsequent differential patterning of resource distribution and exploitation. As has been noted by Holdaway *et al.* (2002:362), variability in the record of radiocarbon determinations at different times may reflect a situation where long-term human adaptation involved a discontinuous use of space, indicating relatively different or changing patterns of human-environment interactions. If variability in the radiocarbon record

does represent discontinuous occupation, then the late Holocene may well be characterised by differences in the distribution and intensity of foraging behaviour through time and space, and not represent a period of stable, long-term adaptation to the environment (see Fanning and Holdaway 2001; Attenbrow 2004; Holdaway *et al.* 2005; Faulkner 2006, 2008, in press; Ulm 2006a for similar arguments).

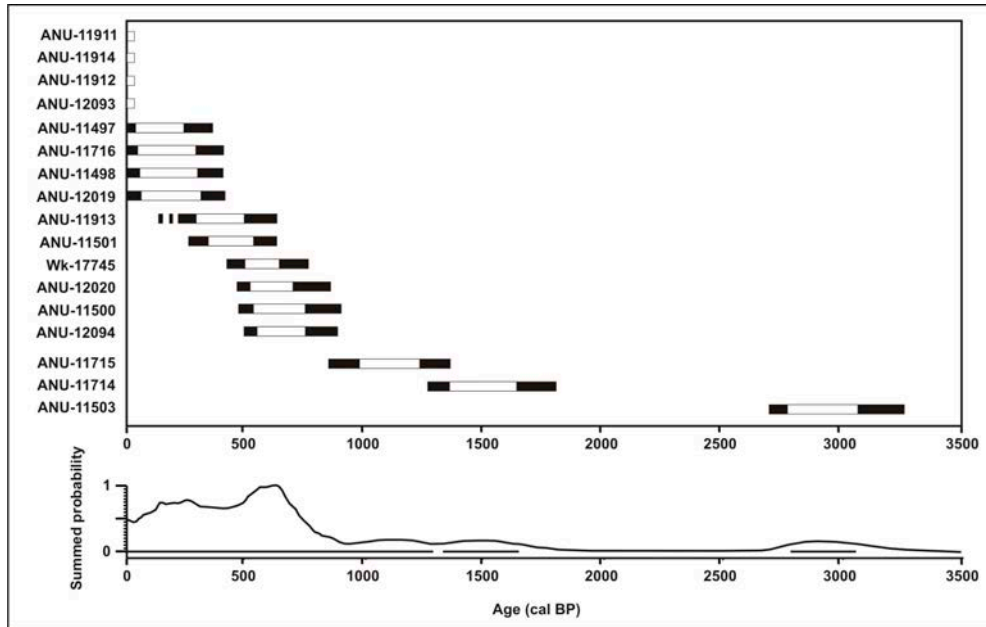


Figure 6.1: Comparison of the 1 and 2σ calibrated radiocarbon ages for sites on Myaoola Bay (above), and the calibrated radiocarbon age summed probability plot (below).

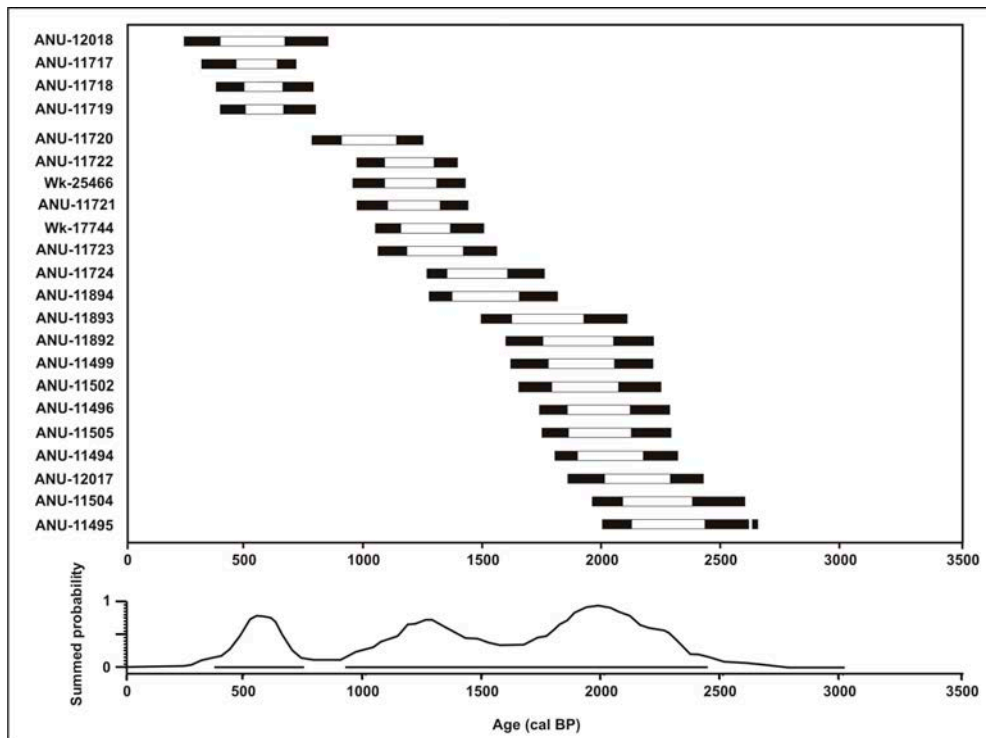


Figure 6.2: Comparison of the 1 and 2σ calibrated radiocarbon ages for sites on Grindall Bay (above), and the calibrated radiocarbon age summed probability plot (below).



### Variation in occupation intensity: Shell middens and mounds

In analysing variations in the spatial and temporal intensity of occupation within a given region, rates of site accumulation based on the number of sites per unit of time have often been used (Attenbrow 2004:1). Added to this, referred to as changes in ‘the intensity of site use’, quantitative differences in the discard of cultural material in individual sites, such as stone artefacts or faunal remains, have also been used as providing evidence for assessing the extent to which the use of specific locations varies over time (Morwood 1981; Attenbrow 2004:1; also Ulm 2006a). While viewing the archaeological record from the Point Blane Peninsula in this way would be useful, there are a number of obstacles in using these methods.

Given the issues noted above relating to the available radiocarbon dates, the level of chronological resolution is limited within each of the sites, and has therefore enabled only a basic understanding of variations in site formation across the study area. Although trends in molluscan exploitation have still been identified within and between each site, analysis in terms of differences in rates of accumulation and the degree of occupation intensity is limited. While there are observable differences between the excavated sites across the Point Blane Peninsula, the number and weight of shell per unit volume are a measure of geometric density, and do not necessarily accurately reflect rates of accumulation per unit time within these deposits (Bailey and Craighead 2003:182). As noted by Stein *et al.* (2003:309–10), the period of time over which site accumulation occurred will also have an effect on the level of detail obtained in determining accumulation rates. This is particularly relevant when examining sites with rapid formation indicated via radiocarbon dating, as is the case with several of the sites analysed here, where potentially variable rates of accumulation relative to shorter-term phases of occupation may not be distinguishable. In addition to this, the number of radiocarbon dating samples employed in calculating accumulation rates affects their accuracy, and ultimately the interpretation of human behaviour based on these data. Those rates based on only two or three samples, which is the number generally available within the sample of the six excavated sites detailed in Chapters 4 and 5 (and often in other north Australian shell mound studies, e.g. Bourke 2000, Morrison 2010), will not provide the level of detail required for an accurate evaluation (Stein *et al.* 2003:310). For this reason, therefore, the density of shell mound and midden sites on the margins of the peninsula per kilometre of coastline, combined with an examination of site area and volume, are used here in place of accumulation and/or discard rates to investigate possible differences in resource use and the intensity of occupation (Faulkner 2006, in press). There are also limitations in the application of this type of analysis, largely due to potential variability in patterns of site establishment, use and reuse through time, and particularly in combination with post-depositional processes that can limit site visibility or alter site morphology, however, this approach is well suited to identifying broad-scale trends in human behaviour. Relative to the chronological patterns identified above, and as occupation of the peninsula has been characterised as being localised and temporally discrete, it is argued here that variations in the density and size of the shell deposits across the Point Blane Peninsula provides a reasonable measure of the distribution and intensity of human behaviour (for similar arguments see Jerardino *et al.* 2008; Jerardino 2010). Bailey (1994:108), for example, has also argued that with a larger resident population, the resulting shell debris on a given stretch of coastline will be larger and more numerous, based on the reasonable assumption that the quantity of shell discarded and site size can be correlated with the intensity of human activity.

Thirty-four sites were recorded along approximately 22km of coastline in Myaoola Bay, with 1.54 sites/km. In contrast, 85 sites were recorded along the approximately 13km surveyed in Grindall Bay, with 6.54 sites/km (Table 6.3). There are therefore approximately four times more sites per kilometre of coastline (or former coastline) surveyed in Grindall Bay than recorded in Myaoola Bay, indicating the possibility of a higher level of occupation intensity and resource exploitation in

the former location. The number of sites per cluster is also compared here between these two areas (Table 6.3). This is a useful measure, as resources are generally not distributed in a homogeneous way in coastal areas, with variability in the abundance of resources evident relative to the length of available shoreline (Waselkov 1987:133; Rowland 1994b:155). There are implications for human behaviour and population density relative to these kinds of environmental or ecological patterns, and by extension may be used as further evidence in investigating the intensity of occupation (e.g. Lourandos and Ross 1994; Bourke 2000:107). Regarding this issue, Bailey (1975a:VII:42–4, 1983:567) has argued that the clustering of shell mounds at Weipa has resulted from people operating within a non-linear landscape placing themselves in the optimal position to exploit both marine and terrestrial resources. Therefore, the clustering of sites is another feature of the site distribution pattern, a phenomenon that has implications for human population density, and by extension, may be used as evidence for more intensive occupation (e.g. Lourandos and Ross 1994; Bourke 2000:107; Morrison 2010:318–324; Faulkner in press). The clustering of sites in both Myaoola and Grindall Bays is highlighted in Figure 6.3. The divisions between the site clusters are defined primarily by the distribution or positioning of sites relative to surrounding environmental or geographic features. Sites concentrated around headlands are separated from those dispersed along open beaches in a linear fashion, or where significant natural features like watercourses separate sites. Six site clusters have been determined for both Myaoola and Grindall Bays, and the density of sites per cluster corresponds reasonably well with the number of sites per kilometre of coastline surveyed. There is an average of 5.67 sites per cluster in Myaoola Bay, two and a half times less than that found in Grindall Bay, where there is an average of 14.17 sites per cluster. As the number of sites per cluster potentially reflects the density of occupation relative to the focal points of resource exploitation within each area, there would appear to have been a greater intensity of occupation and use of resources in Grindall Bay.

Table 6.3: Site density estimates for Myaoola and Grindall Bays, Point Blane Peninsula.

	Myaoola Bay	Grindall Bay
Approx. Length of Coastline Surveyed (km)	22	13
Number of Sites Recorded	34	85
Number of Sites per Kilometre Surveyed	1.54	6.54
Number of Site Clusters	6	6
Average Number of Sites per Cluster	5.67	14.17

Table 6.4: Descriptive statistics for site areas in Myaoola and Grindall Bays.

	Myaoola Bay	Grindall Bay
Descriptive Statistics – Site Area (m <sup>2</sup> )		
Mean	1085.02	490.46
Median	79.39	238.35
Standard Deviation	3282.40	1179.77
Minimum	0.50	22.44
Maximum	16000	10620
Descriptive Statistics – Site Volume (m <sup>3</sup> )		
Mean	111.76	461.26
Median	7.94	113.72
Standard Deviation	328.04	1023.02
Minimum	0.05	2.24
Maximum	1600	7327.80
<b>Number of Sites</b>	<b>34</b>	<b>85</b>

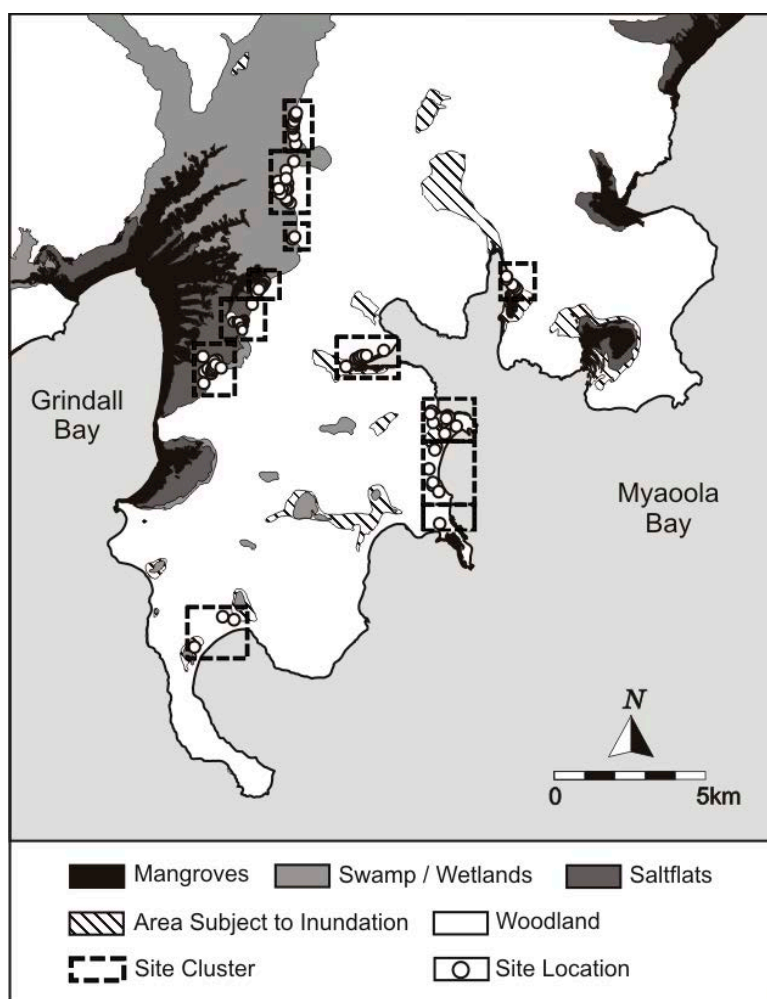


Figure 6.3: The distribution of site clusters (shell deposits only) on the margins of the Point Blane peninsula.

Source: Based on Banyala 1:50 000 Topographic Map.

This interpretation is further supported by comparing mean site area and volume between the two margins of the peninsula (Table 6.4). Comparing site morphology between these two areas, the Myaoola Bay shell deposits generally conform to a pattern of low, horizontally spread middens, with larger mounded shell deposits dominating the margins of Grindall Bay. Mann-Whitney  $U$  tests indicate that there are significant differences in both site area ( $U = 998.5$ ,  $z = -2.867$ ,  $p = 0.004$ ,  $r = 0.26$ ) and site volume ( $U = 646.5$ ,  $z = -4.903$ ,  $p = 0.000$ ,  $r = 0.45$ ) between Myaoola and Grindall Bays. While site area is generally larger within Myaoola Bay, reflecting the greater horizontal spread of the sites in this area, in assessing variation in the potential intensity of resource use and site formation, the fact that a far greater volume of material was deposited within the sites in Grindall Bay is of more importance. Individually, the chronological patterns for the two sides of the Point Blane Peninsula, and variations in site density and site morphology are only suggestive of differences in occupation intensity. When viewed in combination, however, the interpretations presented here are strengthened. Based on the density of sites and volume of material deposited within the Grindall Bay sites, combined with the available radiocarbon ages, there appears to have been a greater intensity of occupation and exploitation of resources relative to the Myaoola Bay area (Faulkner in press). If this is indeed the case, then there should also be



an observable effect on the primarily exploited resource within the Grindall Bay sites. That is, with a higher level of human predation, the size and structure of the *Anadara granosa* population in the area may have been affected.

### ***Anadara granosa*: Biology and ecology**

As noted by Catterall and Poiner (1987:119) many previous attempts at investigating the effects of exploitation through midden analysis have been hampered by a lack of information on the biology and ecology of the exploited species (although see Jerardino *et al.* 1992; Bourke 2000, 2002; Campbell 2008; Faulkner 2009, in press; Giovas *et al.* 2010). Fortunately, these parameters can be addressed for *Anadara granosa*, the dominant species within the mounded shell deposits in this area and across much of northern Australia. Presently, marine bivalve molluscs of the family Arcidae (subfamily Anadarinae) are an important source of protein for coastal populations in many tropical, subtropical and warm temperate areas (Broom 1985:1). The molluscan bivalve genus *Anadara* is distributed worldwide, and in the Indo-Pacific region is economically important in the Philippines, Thailand, Malaysia and Borneo (Pathansali and Soong 1958:26). Along the north Australian coastline at present *A. granosa* has disappeared entirely from natural coastal habitats, is confined to specific regions, or exists in very low densities (e.g. Morrison 2003, 2010). Reasons provided for the disappearance of *Pinctada nigra* within the Transkei region of South Africa may equally apply to the relative absence of *A. granosa* across northern Australia: a combination of relatively high exploitation pressure, together with the low occurrence or disappearance of suitable habitat (de Boer *et al.* 2000:295).

*A. granosa* are essentially soft substrate dwellers, occurring naturally in large estuarine mudflats bordered on the landward margin by mangrove forests. This species thrives under comparatively calm conditions especially in shallow inlets or bays, with a sub-stratum of fine, soft, flocculent mud (Pathansali and Soong 1958:27). Although *Anadara* are found in sandy-mud areas, they have not been observed to settle or establish colonies in these areas comparable in size and number to those in fine, soft brackish mud, particularly off mangrove forests (Pathansali 1966:90; Broom 1985:4). In terms of the establishment and proliferation of shell beds, the three most important factors are the nature of the substrate, salinity levels, and the slope of bed. Most species of *Anadara* are intertidal or marginally subtidal in their distribution. They usually settle on muddy shores between mean high water of neap tides (MHWN) and mean low water of neap tides (MLWN). Neap tide refers to either of the two tides that occur at the first or last quarter of the moon when the tide-generating forces of the sun and moon oppose each, producing the smallest rise and fall in tidal level. *A. granosa* usually do not extend into the area above MHWN, which is usually dominated by mangrove swamp forests. Peak densities are usually encountered around mid-tide level, although in some regions they are dense subtidally, and this degree of variation likely relates to different salinity regimes (Broom 1985:4). This species is able to function relatively efficiently at salinities above 23 parts per thousand, although young individuals can continue normal feeding activity at a lower salinity than older specimens, down to 18 parts per thousand. This species has the ability to cope with short-term salinity fluctuations, but are characteristically stenohaline (Bayne 1973:804; Broom 1985:6; Peterson and Wells 1998). Therefore, the known distribution of *A. granosa* coincides with a salinity range of around 26 to 31 parts per thousand, with short-term fluctuations (Broom 1985:6). The optimal habitats are therefore protected from strong wave action, and situated outside the mouth of estuaries and tidal creeks, with a salinity range between 18 to 30 parts per thousand (Pathansali 1966:91).

Temperatures to which this species are exposed vary according to their geographical range. For example, the average water temperature throughout the year experienced by *A. granosa* in Malaysia is generally around 29° to 32° C, though sub-populations on higher shore areas may

be subjected to a temperature range of 25° to 40° C, coinciding with minimal water movement (Broom 1985:7). Other ecological criteria for *A. granosa* shell bed establishment and proliferation include a moderate seaward slope between 5-15°. If the gradient is too small, the culture will be exposed for too long between tides, and where the gradient is too great, growth can be inhibited. The shell bed should also not be near a strong current, but currents should be strong enough to transport natural food (Broom 1985:47; Tiencongusmee and Pontjoprawiro 1988: section 3). From spatfall observations, it has been demonstrated that *A. granosa* displays a definite seasonality in its breeding cycle, though some spawning probably takes place throughout the year (Broom 1985:24). Seasonal salinity fluctuations are thought to play a major part in the seasonality of this species. There are two possible spawning cues, almost certainly linked in some way to the seasonal salinity depression, and periods of high rainfall may depress temperatures on the intertidal mudflat (Pathansali and Soong 1958:26; Pathansali 1966:85, 90; Broom 1985:24).

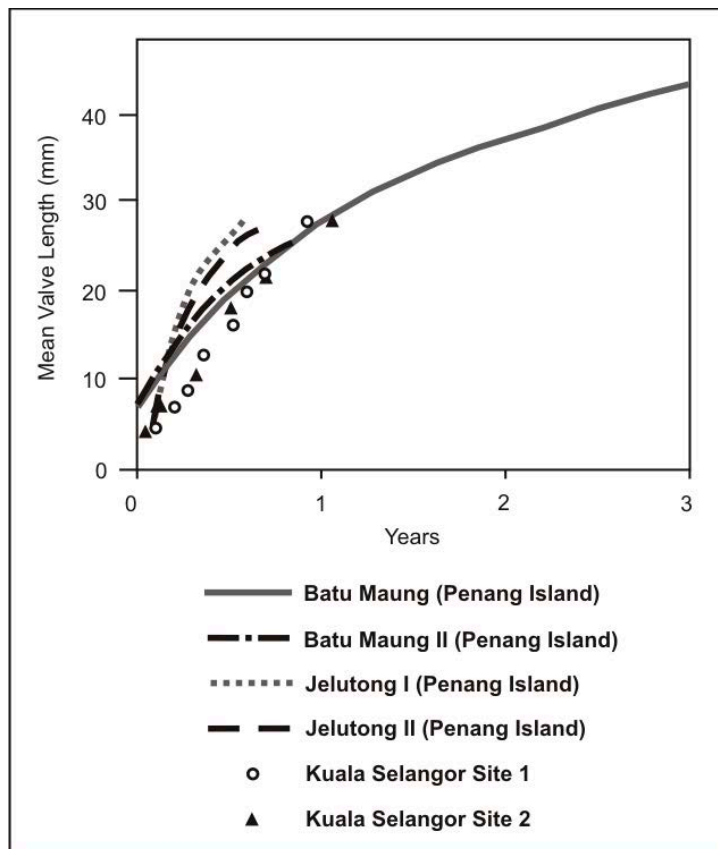


Figure 6.4: Growth rates for *Anadara granosa* from commercial culture beds in Malaysia.

Source: After Faulkner 2009; data from Broom 1982a:73 and Pathansali 1966:98.

Growth rates are known to be affected by environmental conditions and population density (Tiencongusmee and Pontjoprawiro 1988: section 4.5-4.6). It was found in two natural populations that growth rates could vary enormously between subpopulations subject to different environmental conditions (Broom 1985:16). At higher shore levels, compensatory feeding or metabolic activity would be likely to help maintain growth in the face of increasing exposure, although there is also probably a level above which growth rates decline rapidly with increasing exposure unless preceded by death of the organism due to the increasing effects of other factors, such as thermal stress (Broom 1985:17). On natural beds where density was less than 11 per square metre, *A. granosa* grows from a range of 4-10mm diameter to 18-32 mm in 8 months, whilst on commercial beds where the density was 500-1000/square metre, 10-12 months elapsed before

harvest size of 24–30 mm was attained (Pathansali and Soong 1958:28; Broom 1985:14). It is expected that *A. granosa* would attain sexual maturity at about 25 mm in shell length in northern Australia, when they are approximately 6 months old (Pathansali and Soong 1958:27; Pathansali 1966:85; Broom 1983b:215, 1985:23). In general, *A. granosa* is characterised by rapid growth rates, early maturity and a short lifespan. High fecundity and rapid growth rates of *A. granosa* results in biomass dominance, often comprising from 33% up to 97% of the standing biomass in sand/mudflat habitats (Broom 1982b:138; 1983a:395; 1985:10–11). Data from commercially cultured populations in Malaysia (Figure 6.4) demonstrates rapid growth: approximately 50% of the population reaches a size of 25.4 mm within 6 months (Pathansali 1966:89), and between 30–32 mm in 8 to 12 months (Pathansali and Soong 1958:28; Broom 1985:14). Extrapolating from the data presented in Figure 6.4 suggests a short lifespan of approximately 5–6 years as there is a progressive decrease in growth rate as size increases (Broom 1982a:74). Mortality rates are relatively high, particularly in the younger smaller age/size classes (Broom 1982b:142), with overall mortality in some commercial plots over one year amounting to 80% (Pathansali and Soong 1958). Mortality rates of 20–50% have been recorded in other populations, much of which can be attributed to natural predation or environmental fluctuations (e.g. salinity) (Broom 1983a:395; Broom 1985:19). In terms of maximum size, Broom (1985:15) has suggested that individuals larger than 53.5 mm would rarely occur in natural populations, and Pathansali (1966) has proposed a theoretical maximum size of 63 mm. Valve lengths of 58–69 mm have been recorded from live-collected specimens housed in the Queensland Museum collection (Faulkner 2010:1944), and Lamprell and Healy (1998:54) recorded a maximum shell length of 76 mm.

Morrison (2003, 2010), Clune and Harrison (2009) and Harrison (2009) have recently emphasised that *A. granosa* is an extremely “fragile” species, sensitive to minor environmental alterations and mass mortality rates. While some of the *A. granosa* biological and ecological literature is reviewed by these authors (particularly by Morrison 2003:2, 2010:299), this argument appears to hinge more on an understanding of contemporary habitat structure and recent observations of prevalence in modern coastal environments. As such, it has been suggested that it is unlikely that *A. granosa* would have been seasonally available in large quantities, as it is prone to dramatic population reductions due to environmental shifts. *A. granosa* will, however, successfully cope with short-term environmental fluctuations that would adversely affect other species, although populations are not as resilient to sustained environmental changes beyond tolerable limits (e.g. tidal cover, temperature, salinity levels) (Davenport and Wong 1986; Nakamura and Shinotsuka 2007). As a species, *A. granosa* have been seen to be characteristically successful in exploiting a niche typified by fluctuating physical variables (tidal cover, salinity, temperature) as well as difficult trophic conditions (high suspended solids loads) for suspension feeders. As a broad generalisation, this species is likely to dominate intertidal and marginally subtidal muddy substrates in areas where there is an estuarine influence (Broom 1985:10, 32). While the natural conclusion would be that this species would not experience devastating mortalities via natural levels of predation (Broom 1985:10, 33), intensive exploitation combined with size selection may have an effect. For example, it was observed that within commercial culture plots, problems in maintaining viable populations occurred largely because of the rapid growth of *Anadara granosa*, where the removal of larger individuals occurred before the onset of the major breeding season (Pathansali 1966:88, 92).

## Investigating the intensity of resource exploitation

### *Methods for testing the level of exploitation*

There are increasing numbers of archaeological studies conducted worldwide investigating the potential effects of human exploitation on various marine and freshwater molluscan taxa, essentially aimed at measuring potential resource depletion (e.g. Swadling 1976, 1977; Botkin 1980; Spennemann 1987; Yesner 1988; Jerardino 1997; Lightfoot and Cerrato 1998; Bourke 2000, 2002; Peacock 2000; Mannino and Thomas 2001, 2002; Bailey and Craighead 2003; Masse *et al.* 2006; Braje *et al.* 2007; Milner *et al.* 2007; Antczak *et al.* 2008; Baez and Jackson 2008; Bailey *et al.* 2008; Bailey and Milner 2008; Erlandson *et al.* 2008; Jerardino *et al.* 2008; Morrison and Cochrane 2008; Nielsen 2008; Parkington 2008; Peacock and Mistak 2008; Rick *et al.* 2008; Whitaker 2008; Faulkner 2009; Yamazaki and Oda 2009; Giovas *et al.* 2010; Thangavelu *et al.* 2011). In many of these studies, a reduction in average shell size and changes in the relative abundance of higher-ranked resources in the archaeological record are viewed as indicating increased pressure via human or environmental factors (e.g. Botkin 1980:135; Koike 1986; Spennemann 1989; Mannino and Thomas 2001; de Boer and Prins 2002; although see Giovas *et al.* 2010 for size increase through time). In terms of human induced resource depression, interpretations are often linked to economic intensification stemming from increased population size and/or density, as well as changes in residential mobility (e.g. Beaton 1991; Lupo, 2007:160–1). The effectiveness of these studies are often borne out by considering that, with continued or intensive human exploitation of a given resource, the population structure of the resource is often altered (Hockey and Bosman 1986; de Boer *et al.* 2000:287; de Boer *et al.* 2002:250), an effect that can often be discerned in the archaeological record. The general archaeological criteria proposed by a number of researchers (e.g. Claassen 1998:45; Mason *et al.* 1998:317; Mason *et al.* 2000:757, 759; Mannino and Thomas 2002:458) to examine the potential of intensive human exploitation or over-exploitation are as follows:

1. The relative abundance of preferred species will decrease through a midden deposit;
2. Mean shell length will decrease from the bottom of the deposit to the top. A general decrease in the age-size structure of the population would have to be shown, reflected by a decrease in the average size of individuals collected and/or an increase in the number of juveniles;
3. The mean or modal size of the archaeologically derived populations of a species, when examined against figures for an unexploited population of the same species, will be significantly smaller;
4. Less easily procured species will increase in number through a midden deposit;
5. Less easily processed species will increase in number.

Based on this, criteria for investigating the effects of intensive exploitation should include a reduction in the mean age of individuals through a sequence of deposits (Claassen 1986:130), possibly in conjunction with changes in mean shell size, and the ratio of adults to juveniles. High levels of human predation will potentially not only reduce the range and number of resources available for exploitation, but the size of the individuals comprising the exploited population may also decrease (Botkin 1980:125). It can therefore be hypothesised that different levels of exploitation intensity will have a direct effect on the composition of the population. If the intensity of exploitation changes, the size and age structure of the population will be altered, and therefore, increased intensity will correspond with a decrease in the size and age structure. This type of pattern may indicate that more of the prey population was being removed than

could be replaced by natural increase or yearly growth rates of surviving individuals (Botkin 1980:126, 135; Faulkner 2009). While Whitaker (2008:1121) states that continued harvesting would not result in decreased productivity within the shell beds as sexually immature individuals are too small to be economically feasible and the removal of larger individuals relieves competitive pressure, if the size at maturity exceeds the rejection size then there is a risk that all or most reproductively active individuals will be removed from the population, potentially reducing the recruitment rate (Catterall and Poiner 1987:120). The predator-prey balance, which may be stable at lower exploitation levels, will become inherently unstable as the intensity of exploitation increases. In some respects, species-specific spawning and growth rates can counter these processes. For example, it has been suggested that species characterised as having high fecundity, such as *A. granosa*, may be able to withstand high predatory pressure (Catterall and Poiner 1987:120; Hockey *et al.* 1988:361; de Boer *et al.* 2000:288; Faulkner 2009, in press). The impact of exploitation, however, will also depend on the vulnerability of the given species over time regardless of fecundity. A decrease in the mean size of certain species can negatively affect fertility, due to the relatively greater contribution of larger individuals to the reproductive output of the species. Therefore, consistent removal of the larger, more mature individuals may result in a decrease in the population size (Waselkov 1987:134; de Boer *et al.* 2000:288; de Boer *et al.* 2002: 250; Faulkner 2009, in press), leaving it susceptible to the effects of intensive exploitation.

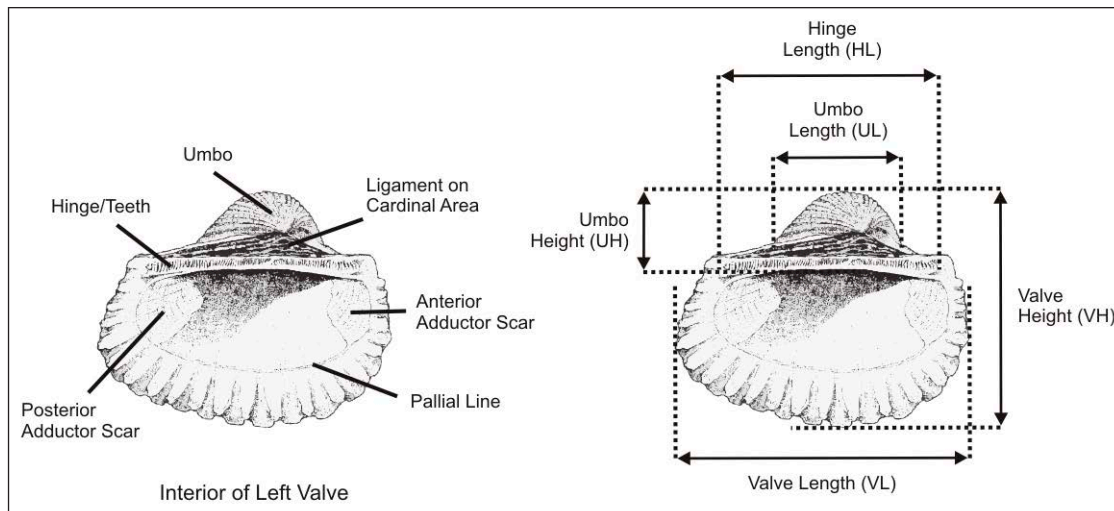


Figure 6.5: *Anadara granosa* valve terminology and measured attributes for predicting maximum valve length from morphometric equations.

Source: After Faulkner 2010:1944, valve redrawn from Poutiers 1998:147.

In bivalves, changes in shell size have frequently been investigated by measuring the greatest valve length, also referred to as the maximum anterior-posterior measurement of complete shells (e.g. Spennemann 1987:85, 89; Claassen 1998:108; Bailey and Craighead 2003:187). The use of only complete shells for metrical analyses has the potential to introduce bias into the sample via differential patterns of fragmentation relative to size (Jerardino and Navarro 2008; Thangavelu *et al.* 2011). In order to investigate changes in size throughout the *A. granosa* dominated deposits, therefore, complete and fragmented valves were measured and reconstructive morphometric equations (as outlined in Faulkner 2010) applied to the fragmentary valves for the establishment of full lengths (Figure 6.5).



The analysis of size frequency distributions and size variability of mollusc species, regardless of whether they are natural and/or cultural in origin, requires the expected size distribution or demographic curve to be established (Claassen 1998:111). While recruitment rates and levels of juvenile survivorship (Claassen 1998:108) can influence mean and/or modal size of a population, mean shell size can also vary depending on whether a population has been subjected to human exploitation. Using data published by Pathansali (1966) on Malaysian *A. granosa* commercial populations, where larger individuals had been removed via continuous harvesting, Broom (1985:15) established mean asymptotic valve lengths of between 29.6 and 35.9mm. Broom (1985:15) also presents data from two other Malaysian study sites not subjected to continued exploitation (Pathansali 1966; Broom 1982a, 1983) where mean asymptotic shell lengths of 44.4 to 49.6mm were recorded. Mollusc species like *A. granosa* that are referred to as being r-selecting (Bailey 1999; Veitch 1999a) occur in variable and/or unpredictable environments, are small bodied, generally have a single phase of reproduction with rapid growth rates, and typically a short lifespan with high mortality often occurring in the younger age/size classes (Pianka 1970:593; Claassen 1998:29). In unexploited communities with normal recruitment of young, size frequency distributions should be more negatively skewed towards the larger size classes, with low proportion of small individuals due to very rapid growth, and higher mortality rates early in the life-cycle creating a grading pattern into a higher number of larger individuals (Deevey 1947:285–286; Claassen 1998:108; Peacock 2000:189; Randklev *et al.* 2009:205–206). In populations where recruitment is seasonal, lifespan is short and there is little individual variability in growth rates, a bimodal or polymodal size distribution should be expected, with each peak or distinct mode representing a spawning event (Claassen 1998:109; Gosling 2003:169–170; Campbell 2008:113). This pattern of bimodality indicates that any organism with generation times greater than a year must be adapted to cope with a range of conditions (Pianka 1970:596). With rapid growth in the early stages and a constant rate of recruitment, however, the distinctiveness of these modal peaks may lessen to a degree, and each year class or cohort will effectively merge into the older/larger size classes (Gosling 2003:169–170). Within archaeological assemblages, a polymodal frequency distribution may relate to seasonal recruitment, but could also reflect averaged phases in site deposition given the time-averaged nature of the archaeological record.

Establishing these parameters is difficult due to a lack of comparative size frequency data from modern natural *A. granosa* shell beds; however, they are supported to a certain degree by the data presented in Figure 6.6. Size frequency data from five commercial culture plot samples in Malaysia (adapted from Ng 1986) demonstrates these general patterns while still highlighting the degree of variability in growth and size frequencies between different populations of the same species. For this study, measurements were based on monthly random samples of approximately 500 individual molluscs taken from each of the culture plots, and valve length measurements were obtained with vernier callipers to the nearest 0.1mm. Plots B and C were measured over 12 months, representing a single period of recruitment in each population; as such these show a distinctly unimodal pattern. These plots have a comparatively normal distribution (with only a slight positive skew), without a clear or distinct peak near the mean, and the size frequency distributions are more clustered with minimal tails into the smaller and/or larger size classes. This is not unexpected, as Claassen (1998:108) has suggested that when an age cohort (individuals who were recruited during the same period) is plotted as a size frequency histogram, it will generally appear as a normal or slightly positively skewed distribution. As a contrast, Plots A, D and E were measured over 17 months, and these distributions display the bimodal pattern associated with successive recruitment phases. The variability in the peak of each distribution probably relates to variations in growth rates within and between recruitment phases, as well as environmental conditions specific to each plot location. The commercial culture plot data also suggests that there would be a grading into the larger age classes through time with a relatively negative skew.

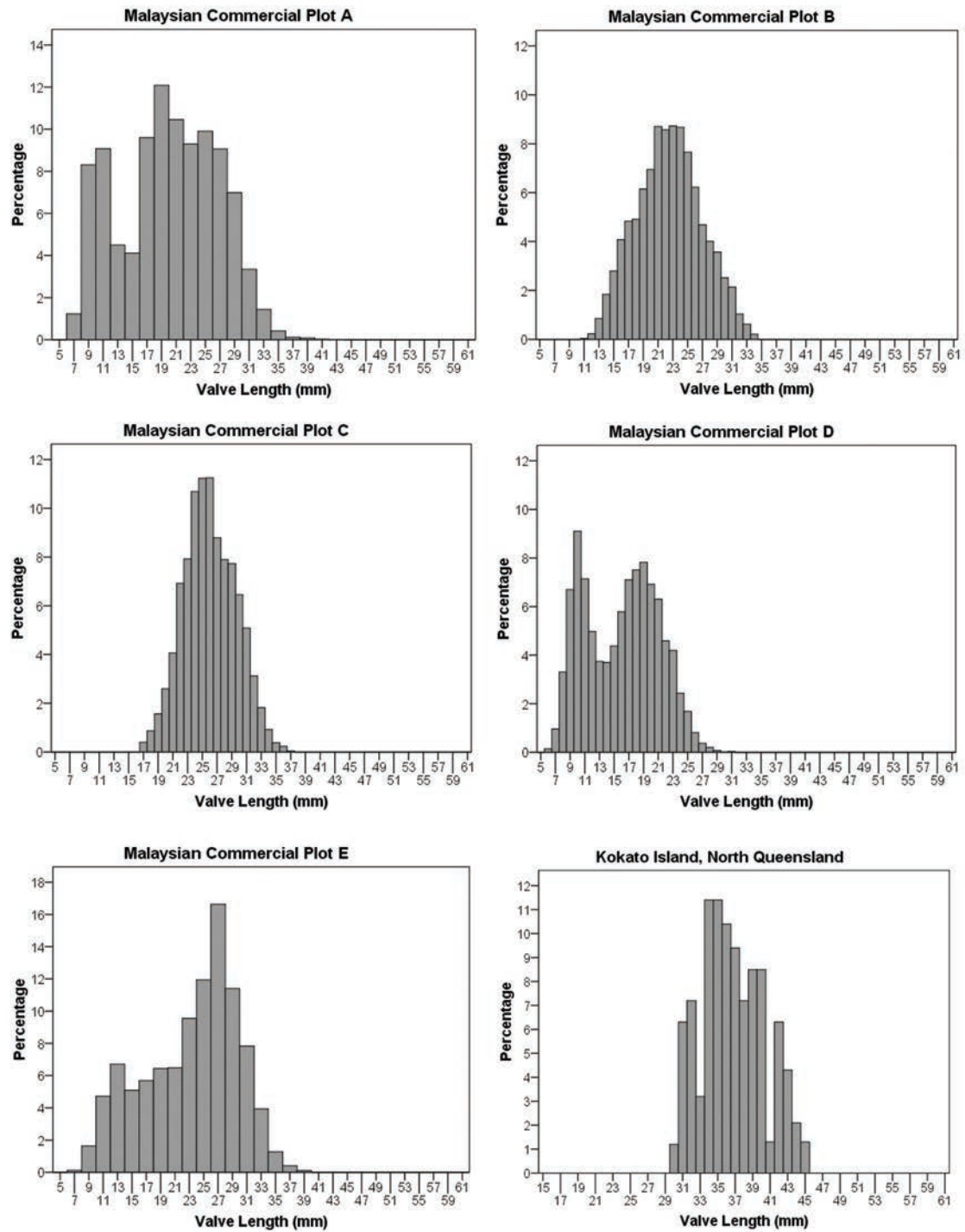


Figure 6.6: Size frequency distributions drawn from Malaysian commercial plots A, B, C, D and E; live collected sample from natural shell bed near Kokato Island, north Queensland. Note variation in percentage scales and size classes, with data from plots A and E only available in 2mm size classes.

Source: Malaysian commercial data from Ng 1986; Kokato Island data redrawn from Bailey 1993:10.

As a further comparison, a size frequency plot is presented of data obtained from the measurement of 97 *A. granosa* valves (obtained from 50 individuals) collected in 1972 from a location near Kokato Island, within the Embley River feeding into Albatross Bay in the Weipa area (Bailey 1977:138, 1993:7, 9–10). This sample was originally collected to examine the condition of the shell and patterns of valve breakage relative to recently observed methods of processing (Bailey 1977:137–138). The Kokato Island sample also displays a negative skew, and the shape of the size frequency distribution is similar to those of Plots B and C, but it is missing the minor peak in the smaller size classes that might be expected of an established population with constant rates of recruitment. There are a number of possible reasons for this difference, such as small sample size, bias in size selection, method of collection, or a lack of natural recruitment in this population (see for example discussion by Morrison 2003 specific to the Weipa area). It does, however, display modal values highlighted by Broom (1985) and Pathansali (1966) as being consistent with a natural population, and as such, is a useful comparison with archaeological data.

Finally, it is important to acknowledge that there are several inter-related factors that can create similar patterns. It has been noted that environmental change, habitat-specific parameters, human exploitation, and temporal variation in the size of accessible shell species can all contribute to variability or a mean decrease in shell size (Hockey and Bosman 1986:12; Hockey *et al.* 1988:353–4, Lasiak 1991a, 1991b; Jerardino 1997; Claassen 1998; de Boer *et al.* 2000:294; Campbell 2008; Faulkner 2009, in press; Randklev *et al.* 2009). Factors such as mean annual sea surface temperatures, increases or decreases in salinity levels, increased exposure of the shell beds, and the density of the shell bed itself are all known to affect the productivity and growth rates of molluscan species, and have been noted above in the previous section for *A. granosa*. Communities can also be characterised by short-term fluctuations in taxonomic composition and number of individuals (Claassen 1998:49; Bourke 2000:190). As an example, Lasiak's (1991a, 1991b) modern ecological studies on the South African coast have indicated that interannual environmental and ecological fluctuations, such as mortality and recruitment rates, could account for differences observed between exploited and non-exploited populations. While these are important considerations, the nature of the archaeological record must also be kept in mind. Mannino and Thomas (2001:1110), have suggested that the time-averaged nature of archaeological deposits means that these kind of short-term events are effectively masked by longer-term trends in exploitation and occupation (see also Braje *et al.* 2007; Erlandson *et al.* 2008; Faulkner 2009).

### *Size frequency distributions and valve size variability*

Based on the discussion presented above, comparisons of size frequency distributions in molluscan assemblages need to be interpreted with caution. Regardless of whether a shell deposit originates from natural or cultural processes, the shape of the size frequency distribution can reflect:

1. The nature or structure of the source population as well as the depositional environment;
2. The nature of the transport agent (i.e. water movement, predatory harvesting - including humans); and
3. Any post-depositional processes in operation (Claassen 1998:113–114; Ford 1989:164).

There are, however, a number of patterns in size frequency distributions that could be expected in cultural shell deposits. It has been suggested that size distributions that conform to a normal curve should be a rare occurrence in middens or mounds, and where they do occur, may reflect size sorting via taphonomic processes rather than cultural processes of size-selection (Claassen 1998:113–114). While there will be a degree of size-selection in operation during human harvesting of mollusc species (e.g. Meehan 1982; Bailey 1993; Bourke 2000, 2002; Faulkner

2006, 2009), the sizes of the molluscs collected will, to a certain degree, reflect those that are available for exploitation from within the population (see discussion by Meehan 1982:133,135). Given the biological and ecological characteristics of *A. granosa*, a size frequency distribution conforming to a normal curve would not be expected. Additionally, while year-round harvesting can potentially produce both positively and negatively skewed distributions (Lasiak 1993); long-term and/or consistent harvesting would be expected to produce a positively skewed size distribution (Bailey 1993:10; Claassen 1998:113–114). With more intensive harvesting, these patterns would be expected in combination with lower mean and/or modal size.

Size frequency data and descriptive statistics are presented here from five of the sites excavated on the Point Blane Peninsula (Figure 6.7 and Table 6.5). As previously noted, three of the five sites (BMB/029, BMB/071 and BMB/045) are characteristic of the *A. granosa* dominated shell mounds prevalent across much of the tropical north Australian coast, being mounded deposits of dense, tightly packed shell. Although not incorporated into the previous analyses of Chapters 4 and 5, the *A. granosa* size data from the Grindall Bay midden BMB/061 (located in the Dilmijpi cluster with BMB/071) are included here to extend the chronological sequence for the exploitation of this species in the area (see Faulkner 2009, in press). This site is positioned approximately 200m to the east of BMB/071, bordering a lower lying swamp and *Eucalypt* woodland. Measuring 13.0 by 10.9m, excavation of this site reached a depth of approximately 22cm, with no observable stratigraphic changes within the densely packed shell deposit. The age estimates available for this site (Table 6.2) indicates rapid accumulation, with occupation of approximately 204 years between 1213 and 1009 cal BP. In line with the chronological patterns from three Grindall Bay shell mounds, the 'test sample significance' function of the CALIB v6.1.1 program indicates that the 2 $\sigma$  calibrated ages for the three radiocarbon samples from BMB/061 are statistically indistinguishable at the 95% confidence level ( $t = 2.10$ ,  $d.f. = 2$ ). As a potential contrast, the Myaoola Bay site BMB/067b is also presented here, as it is a dispersed, horizontally spread midden containing large amounts of shell within dark humic sediments, and may represent different patterns of occupation and resource exploitation.

Table 6.5: Descriptive statistics for Grindall Bay mounds (BMB/029, BMB/071, BMB/045) and midden (BMB/061); and Myaoola Bay shell midden BMB/067b.

	BMB/029	BMB/071	BMB/061	BMB/045	BMB/067 <sup>b</sup>
Mean	35.73	31.93	33.31	33.39	32.02
Median	36.35	31.98	33.23	33.62	32.11
Mode	35.01 <sup>a</sup>	31.17 <sup>a</sup>	31.93 <sup>a</sup>	30.96 <sup>a</sup>	30.31 <sup>a</sup>
Std. Dev.	6.48	6.34	6.11	5.99	5.53
Maximum	58.08	53.62	54.39	51.90	55.56
Minimum	15.54	13.38	17.18	10.72	14.61
Skewness <sup>b</sup>	-0.074	0.128	0.255	0.006	-0.005
Kurtosis <sup>b</sup>	-0.041	-0.453	0.157	-0.272	0.208
No.	2309	4300	1551	4041	1378
No. (%) Juvenile (<25mm)	129 (5.59)	725 (16.86)	151 (9.74)	384 (9.50)	156 (11.32)

a. Multiple modes exist, the smallest value is presented; b. In an ideal normal distribution skewness and kurtosis values are 0

All five sites present mean valve lengths ranging between 32 and 36mm, and modal values between 30 and 35mm. These values fall within the range of average asymptotic shell lengths of 29.6 to 35.9mm for continuously harvested populations derived by Broom (1985:15). Broom (1985:16–7) also notes that these values are based on an artificially seeded population and may not reflect the mean size of a continuously exploited natural population, however, they provide a

baseline comparison for size relative to exploitation. Similar values for *A. granosa* valve length have been reported from shell mound deposits in other regions of northern Australia. For example, the work of Bourke (2000, 2002:40) at Hope Inlet (in the Darwin region) demonstrates mean valve lengths of between 28 and 35mm from three excavated shell mounds (HI80, HI81 and HI83), and Bailey (1993:10) presents modal values in the 25 to 35mm range for the Kwamter Mound in Weipa, north Queensland. Those data suggests continuous harvesting, with the range of size classes present in the sites being indicative of those present within the population, with some potential size-selective focus on the larger individuals available.

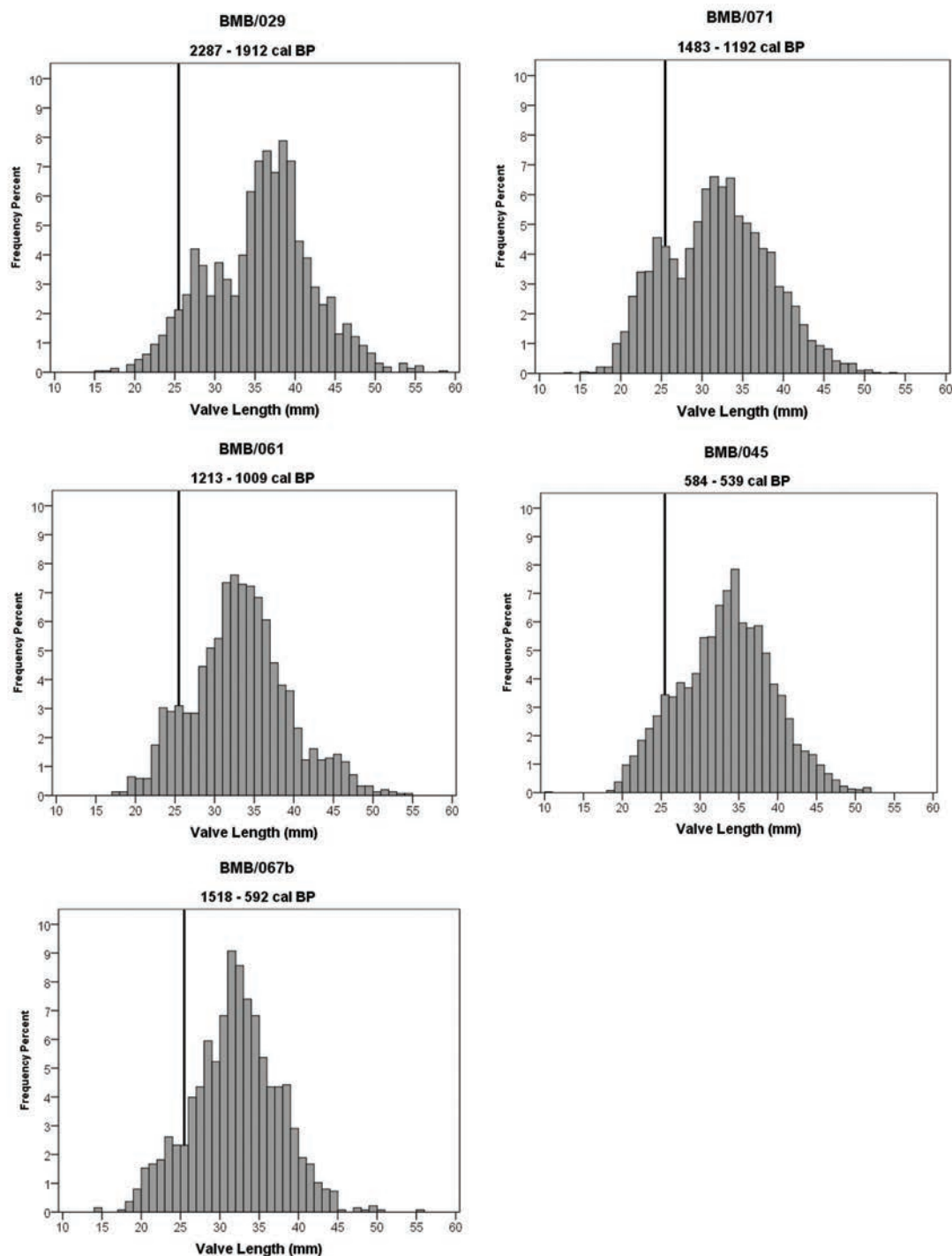


Figure 6.7: *Anadara granosa* size frequency distributions from the Grindall Bay mounds (BMB/029, BMB/071, BMB/045) and midden (BMB/061); and from the Myaoola Bay midden BMB/067b. Black line indicates expected valve size at which sexual maturity is reached (25mm).



A Kruskal-Wallis test confirms that the trends observed in the central tendency for valve length across these five sites are significant ( $\chi^2 = 593.93$ ,  $d.f. = 4$ ,  $p < 0.001$ ), and post-hoc pairwise comparisons employing Mann-Whitney  $U$  tests (Table 6.6) indicate that, with the exceptions of BMB/071 and BMB/067b, and BMB/061 and BMB/045, *A. granosa* valve size for these deposits as a whole are significantly different. All of the distributions are bimodal, all present non-normal distributions (Kolmogorov-Smirnov test results: BMB/029  $D = 0.055$ ,  $d.f. = 2309$ ,  $p = 0.000$ ; BMB/071  $D = 0.39$ ,  $d.f. = 4300$ ,  $p = 0.000$ ; BMB/061  $D = 0.34$ ,  $d.f. = 1551$ ,  $p = 0.000$ ; BMB/045  $D = 0.023$ ,  $d.f. = 4041$ ,  $p = 0.000$ ; BMB/067b  $D = 0.033$ ,  $d.f. = 1378$ ,  $p = 0.001$ ), with the degree of variability in skewness and kurtosis values between sites possibly relating to the intensity of harvesting and duration of site formation.

Table 6.6: Results of Mann-Whitney  $U$ -tests comparing *Anadara granosa* valve size from the Grindall Bay mounds (BMB/029, BMB/071, BMB/045) and midden (BMB/061); and from the Myaoola Bay midden BMB/067b.

Site pair	No.	Mean Rank	Sum of Ranks	$U$	$Z$	$p$
BMB/029	2309	4018.88	9279597.5	3315997.5	-22.289	0.000
BMB/071	4300	2921.66	12563147.5			
BMB/029	2309	2116.73	4887521.0	1360633.0	-12.667	0.000
BMB/061	1551	1653.26	2564209.0			
BMB/029	2309	3621.10	8361125.5	3636438.5	-14.641	0.000
BMB/045	4041	2920.89	11803299.5			
BMB/029	2309	2083.43	4810648.0	1038049.0	-17.679	0.000
BMB/067b	1378	1442.80	1988180.0			
BMB/071	4300	2833.50	12184041.0	2936891.0	-6.975	0.000
BMB/061	1551	3182.45	4935985.0			
BMB/071	4300	3894.05	16747037.5	7499887.5	-10.812	0.000
BMB/045	4041	4465.05	18043273.5			
BMB/071	4300	2829.12	12165220.0	2918070.0	-0.843	0.399
BMB/067b	1378	2871.89	3957461.0			
BMB/061	1551	2752.31	4268830.5	3065254.5	-1.268	0.205
BMB/045	4041	2813.46	11369197.5			
BMB/061	1551	1543.67	2394231.0	946623.0	-5.341	0.000
BMB/067b	1378	1376.45	1896754.0			
BMB/045	4041	2802.95	11326715.0	2408644.0	-7.490	0.000
BMB/067b	1378	2437.43	3358775.0			

Both BMB/071 and BMB/045 display positive skew and negative kurtosis values, without comparatively sharp peaks or long tails to the distribution. These kinds of patterns would be indicative of populations subjected to continuous and relatively intensive harvesting. A similar interpretation can be offered for BMB/061, although this site displays a greater degree of positive skew and positive kurtosis, indicating a higher central peak and a long tail into the larger valve size classes. This site is more similar to the distribution from BMB/045, as also indicated by the lack of a significant difference in *A. granosa* valve size between these deposits as a whole. BMB/029 displays a slight negative skew, but as this site was formed during the earlier phase of mound formation in Grindall Bay, it would be expected that the distribution would lean towards the larger size classes. In contrast, the shell midden BMB/067b, while still displaying a slight bimodal distribution, is negatively skewed with a positive kurtosis value. This site was formed over a longer period with a lower level of exploitation intensity. Thus harvesting within this particular area of the peninsula may have been more seasonally restricted and less intensive,

and while continuous was possibly punctuated through time to a greater degree than would have occurred in the shell mounds. It is also possible that this pattern represents a combination of human harvesting with location specific environmental differences, with BMB/067b located in a more exposed, smaller embayment in Myaoola Bay. The fact that there is not a significant difference between this site and BMB/071 in *A. granosa* size when comparing the overall deposit requires further investigation, as the depositional histories and specific locations are very different. In general, these distributions highlight the expected combination of human size-selectivity and *A. granosa* population structures.

There is also some variability in the proportion of juveniles represented in these deposits through time and space. Within BMB/029, there are proportionally fewer juveniles within this site (5.6%). As *A. granosa* is known to have a high reproductive and growth rates, this percentage is suggestive of a stable, well-established population. While the small number of juveniles could be a result of the exploitation of sexually immature individuals, the representation of so many large individuals in fact suggests that this population may not have previously been exploited, or more likely regularly exploited at a low level. As noted previously, this pattern may relate to the earliest phase of occupation within the overall system and the structure of the environment within this specific locality. The considerable size overlap with the Kokato Island sample also suggests that this mound may document the initial exploitation of *A. granosa* within this area, or a minimal exploitation of *A. granosa*, phasing into possibly longer-term, more intensive utilisation. In contrast, the BMB/071 pattern is consistent with continuous exploitation of *A. granosa* and/or the use of a population already reduced by higher levels of exploitation. There is an apparent reduction in the availability of *A. granosa* within the upper size ranges compared with BMB/029, particularly given the higher percentage of juveniles (16.9%). This indicates that as people are exploiting this resource to a greater degree, a reduction in mollusc size within the natural population means there is a gradual shift towards smaller sizes. For both BMB/061 and BMB/045, while still present, the reduction in the size of the bimodal peaks may mean either that these sites accumulated before further recruitment within the natural population, or that the time-averaged nature of the deposits has smoothed-out this type of patterning. While being more restricted in the overall size range compared with the other Grindall Bay mound sites, both BMB/061 and BMB/045 show a shift away from the type of pattern demonstrated for BMB/071, back towards that shown in BMB/029 relative to mean size and the percentage of juveniles (each at 9.5%).

As these size frequency distributions present a fairly coarse-grained pattern of potential exploitation from time-averaged contexts, the next step is to investigate any potential size variability throughout each of the deposits in more detail. To this end, boxplots of *A. granosa* valve length by excavation unit for each of the five sites are presented in Figure 6.8, and descriptive statistics for *Anadara granosa* length by excavation unit (including the percentage of juveniles) are presented in Table 6.7 for BMB/029, BMB/071, BMB/061, BMB/045 and BMB/067b.

Table 6.7: Descriptive statistics for *Anadara granosa* valve size from the Grindall Bay mounds (BMB/029, BMB/071, BMB/045) and midden (BMB/061); and from the Myaoola Bay midden BMB/067b.

Site	Excavation Unit	Mean	Median	Std. Dev.	Min	Max	No.	No./(%) Juvenile (<25mm)
BMB/029	1	35.86	36.51	7.11	20.43	58.08	185	11 (5.95)
	3	34.62	35.23	7.77	16.71	55.91	229	28 (12.23)
	5	35.09	34.89	6.94	22.34	50.48	188	11 (5.85)
	7	34.04	34.11	6.60	19.42	55.20	493	39 (7.91)
	9	36.90	37.31	6.02	15.54	54.94	301	18 (5.98)
	11	37.36	37.78	4.53	19.44	51.61	382	4 (1.05)
	13	35.11	35.70	6.12	21.30	53.98	340	15 (4.41)
	15	38.21	38.94	7.18	23.02	55.22	102	2 (1.96)
	17	38.66	38.80	5.42	26.35	51.42	36	0 (0.00)
	19	36.44	36.64	5.04	25.75	47.01	43	0 (0.00)
	21	38.74	39.55	5.58	24.71	44.13	10	1 (10.00)
BMB/071	1	29.68	30.09	5.58	17.19	46.26	181	40 (22.10)
	3	30.38	30.31	6.27	15.64	51.76	442	103 (23.30)
	5	31.78	31.82	6.52	13.38	53.62	1408	275 (19.53)
	7	30.96	31.31	5.37	19.17	48.66	952	110 (11.55)
	9	31.66	31.47	5.97	17.30	49.24	1073	158 (14.73)
	11	33.86	34.06	6.40	16.51	50.75	244	39 (15.98)
BMB/061	1	31.18	31.03	6.41	19.06	51.74	35	8 (22.86)
	2	33.07	32.77	6.20	18.12	52.57	244	26 (10.66)
	3	33.95	33.93	6.64	18.50	53.48	356	33 (9.27)
	4	33.40	33.22	5.90	17.18	54.39	600	51 (8.50)
	5	33.20	33.20	5.10	21.13	49.39	164	12 (7.32)
	6	32.51	32.91	5.96	21.57	47.89	75	9 (12.00)
	7	32.48	32.51	6.52	20.27	52.54	77	12 (15.58)
BMB/045	1	31.65	32.16	5.40	18.02	44.88	122	15 (12.30)
	3	33.40	33.56	4.36	20.66	45.39	283	13 (4.59)
	5	33.58	33.37	4.45	18.45	50.15	335	9 (2.69)
	7	31.34	31.28	5.42	20.86	47.55	355	46 (12.96)
	9	32.27	32.05	5.39	21.09	47.26	404	30 (7.43)
	11	33.08	33.31	5.52	20.47	48.00	272	21 (7.72)
	13	32.99	33.65	5.64	20.36	45.42	232	26 (11.21)
	15	34.27	35.38	5.60	19.75	48.53	200	12 (6.00)
	17	32.18	32.38	6.61	19.51	47.67	234	38 (16.24)
	19	30.98	31.28	7.58	18.60	51.23	306	95 (31.05)
	21	34.50	34.28	4.65	23.93	51.76	210	5 (2.38)
	23	33.69	33.61	4.43	10.72	48.30	176	5 (2.84)
	25	35.40	34.65	5.64	20.02	50.73	179	7 (3.91)
	27	35.84	36.89	6.81	19.58	51.90	410	35 (8.54)
	29	34.15	34.06	7.76	19.16	51.58	150	24 (16.00)
BMB/067b	31	36.66	36.82	6.06	22.82	47.61	173	3 (1.73)
	1	33.54	32.77	5.32	23.14	49.12	50	2 (4.00)
	2	32.44	33.04	5.20	20.07	47.35	117	10 (8.55)
	3	31.68	32.05	5.48	20.07	44.80	193	27 (13.99)
	4	31.67	31.64	5.54	14.61	44.83	267	27 (10.11)
	5	32.15	32.38	5.12	18.80	44.45	174	17 (9.77)
	6	32.02	31.82	5.59	18.53	49.57	310	37 (11.94)
	7	31.99	32.28	6.01	18.76	55.56	170	21 (12.35)
	8	32.24	32.03	5.72	17.90	50.65	97	11 (11.34)

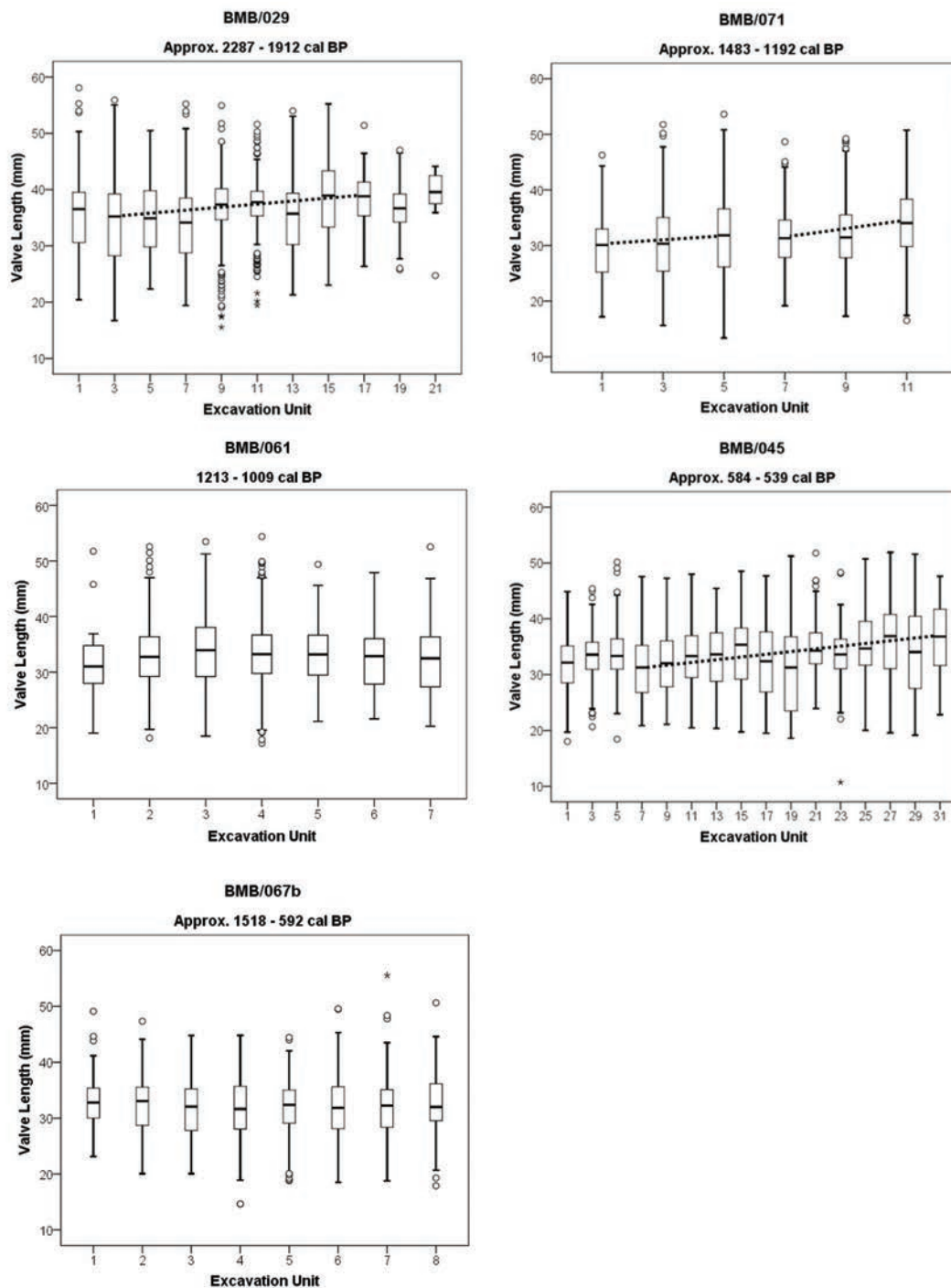


Figure 6.8: Boxplots of *Anadara granosa* valve size from the Grindall Bay mounds (BMB/029, BMB/071, BMB/045) and midden (BMB/061); and from the Myaoola Bay midden BMB/067b (dashed line indicates significant difference at 0.05 level).

While the samples from each excavation unit do not conform to a normal distribution, similar to the size frequency distribution for the sites as a whole, ANOVA tests have been conducted for each site. ANOVA is not as sensitive to violations of the assumption of normality given good sample size (Pallant 2007:110, 204), and has been proven to be an effective statistical test in other archaeological mollusc studies (Jerardino and Navarro 2008; Jerardino *et al.* 2008; Faulkner 2010; Jerardino 2010), particularly in investigating similar questions of potential resource depression. For the three shell mound sites, ANOVA tests indicate that there is a high degree of variability in

mean valve size (BMB/029:  $F = 10.863$ ,  $d.f. = 10$ ,  $p = 0.000$ ; BMB/071:  $F = 27.996$ ,  $d.f. = 5$ ,  $p = 0.000$ ; BMB/045:  $F = 20.108$ ,  $d.f. = 15$ ,  $p = 0.000$ ). Post-hoc comparisons using the Dunnett's C test indicates significant differences at the 0.05 level in mean valve size within each of these three sites, indicating an overall trend for size decrease throughout a significant portion of these deposits (Figure 6.8). In contrast, within both BMB/061 (ANOVA:  $F = 1.903$ ,  $d.f. = 6$ ,  $p = 0.077$ ) and BMB/067b (ANOVA:  $F = 0.931$ ,  $d.f. = 7$ ,  $p = 0.481$ ) the degree of variability is not significant, nor is there a significant trend of size decrease through time. Therefore, the previously identified similarity in size frequency distribution between these sites and shell mounds BMB/071 and BMB/045 respectively are not supported with a finer-grained analysis of valve size variability throughout the deposits.

There are also general trends within BMB/029 and BMB/071 for increasing numbers of juveniles, which again may reflect higher intensity exploitation as available sizes decrease within the shellbed. In comparison, the percentage of juveniles in BMB/061 does not demonstrate a clear trend, decreasing from the base of the deposit to stabilisation, with an increase in excavation unit 1. While BMB/045 demonstrates a high degree of variability in the percentage of juveniles, this site represents shorter-term deposition, and this pattern may represent time-averaged variability in population structure. A more significant contrast is found within BMB/067b, where the proportions of juveniles are relatively stable throughout the excavation units, proportionally decreasing in the upper portion of the deposit. This would suggest more ephemeral exploitation of the resource over the approximate 900 years of site formation, whereby natural recruitment rates can keep pace with the level of exploitation intensity. While there are a few studies available for comparison, detailed metrical analyses have been undertaken on mounded shell deposits in north Queensland and in the Darwin region of the Northern Territory. For the Kwamter mound site in Weipa, north Queensland, Bailey (1993:10) interprets the size frequency pattern as showing no evidence of sustained size decrease typical of over-exploitation, and therefore concludes that the archaeological samples are reflective of a mollusc population subjected to continuous, but not overly excessive, levels of human predation (see Faulkner 2009). A similar interpretation has been proposed by Bourke (2000:318–20) for patterns of *A. granosa* exploitation within the Darwin Harbour mounds. Individually, the Blue Mud Bay sites could be interpreted in a similar way (particularly for BMB/061 and BMB/067b), even given the significant decrease in *A. granosa* size throughout each of the three Grindall Bay mounds. When the five sites are compared, however, the patterns of exploitation appear to be quite different, with the three Grindall Bay shell mounds demonstrating a significant decline in valve size, compared with the comparatively stable pattern exhibited within both BMB/061 and BMB/067b. Given that *A. granosa* is able to cope with short-term fluctuating environmental variables and to be biomass dominant in mudflat environments (due predominantly to its breeding and growth rates), the data presented here are more significant when viewed in terms of the overall pattern within Grindall Bay (Faulkner 2009, in press).

### *Chronological trends in Anadara granosa exploitation within Grindall Bay*

The general archaeological criteria used for assessing the degree of molluscan exploitation suggests that the relative abundance of preferred species should decrease throughout a midden or mound deposit, coupled with an increase in the number of less easily procured and/or processed species. As discussed in Chapter 5, relative abundance patterns for *A. granosa*, as the preferred species within the three Grindall Bay shell mound sites analysed here, demonstrates that this species represents between approximately 68 and 88% of the molluscan assemblages. Based on the criteria outlined above, if human predation had adversely affected this species, it should decline in relative abundance within and between these deposits. In fact, even in excluding BMB/061 from this discussion, relative abundance estimates for *A. granosa* increase significantly throughout



the deposit in BMB/029, and remain at a relatively high, stable level in BMB/071 and BMB/045. Added to this, less easily procured and/or processed species do not appear to have been generally utilised within these sites, let alone increase in number (Faulkner 2009). The analysis of valve size by excavation unit does indicate, however, that mean shell length has decreased significantly throughout the deposits of the three mound sites, and the decrease in mean size is generally accompanied by a general decrease in the age-size structure of the populations. *A. granosa* valve size and proportion of juveniles from the midden BMB/061 presents an anomalous pattern in comparison with the mounds. As such, it is important to determine how these four sites relate to each other within the longer-term sequence of occupation and *A. granosa* exploitation within this area. To investigate this issue, mean valve length within each excavation unit from the four Grindall Bay sites is plotted by approximate age (Figure 6.9). Previous analyses of several of these sites have been based on broad analytical units according to chronological phases identified by statistically significant differences in calibrated age ranges (e.g. Faulkner 2006, 2009:840). Recalibration of the radiocarbon dates has effectively removed these differences, however, and the principal means of investigating longer-term trends in Grindall Bay is achieved here by focusing on the excavation unit as the main unit of analysis. To construct a chronological sequence from the Grindall Bay mounds and midden, each un-dated excavation unit has been assigned an approximate age based on age depth curves. While the inherent assumption of this approach is that the excavation units were deposited at regular intervals relative to the dated portions of the deposit, given the general rapid nature of formation in these sites this approach enables the exploration of potentially finer-grained variability in valve size across the Grindall Bay sequence as a whole.

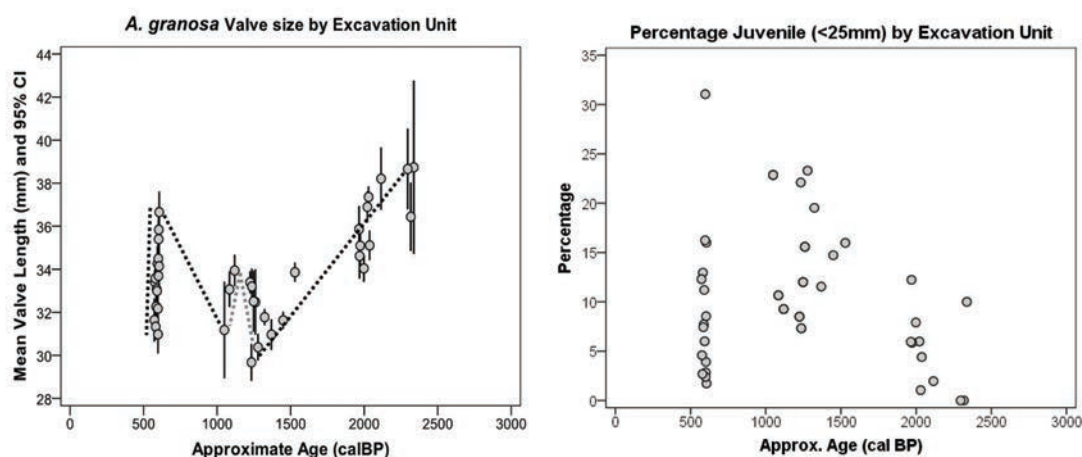


Figure 6.9: *Anadara granosa* mean valve size / 95% confidence interval (dashed black line indicates significant difference at 0.05 level, with dashed grey line indicating possible recovery and subsequent decline); and % of juveniles (<25mm) by excavation unit / age cal BP.

As with the analyses conducted for the individual shell mounds, across the whole sequence there is a high degree of variability in mean *A. granosa* valve size (ANOVA:  $F = 27.396$ ,  $d.f. = 10656$ ,  $p = 0.000$ ), however several trends in the intensity of exploitation can be identified. These patterns in mean *A. granosa* valve size are also relatively reflected in the percentages of juveniles plotted by approximate age (Figure 6.9), indicating a relationship across the whole Grindall Bay sequence between valve size variability and the structure of the exploited population. As *A. granosa* is a rapidly reproducing and fast growing species, a low intensity of human exploitation would be likely to result in the size of collected molluscs remaining relatively stable throughout a sequence of occupation. Comparative stability in the size of this species is seen between 2287 and 2140 cal BP, and arguably between 1310 and 1009 cal BP. If collection practices were intensified while

the species' reproduction and growth rates remained relatively constant, however, then it would be expected that the average size of the remaining shellfish within the population would decrease significantly over time (Waselkov 1987:134). Between 2140 and 1310 cal BP, as well as 584 and 526 cal BP, there are significant reductions in the size of *A. granosa*, which may indicate increasing human exploitation during these periods. Within the overall sequence, there is one phase of significant size increase. This occurs between 1009 and 584 cal BP, which appears to reflect a decrease in the intensity of exploitation during this particular period, and potentially a decrease in the level of occupation and site formation within this part of the study area, allowing the shell beds to recover and stabilise. As noted above, variation in mean valve size between 1310 and 1009 cal BP are not statistically significant, and one interpretation may be of relative stability during this period; however, this could also reflect a period of rebound or recovery and subsequent decline (Rick *et al.* 2008). This pattern may relate to variability or lowering of the intensity of harvesting during this period, changes in environmental processes such as sedimentation, or a combination of the two. The finer scale pattern presented in ordering the excavation units chronologically demonstrates that there was also a significant decrease between 584 and 526 cal BP. After this period it appears that shell mounds ceased to be formed within Blue Mud Bay, and *Anadara granosa* is largely absent from the archaeological record of the area. This would suggest that BMB/045 represents rapid and intensive exploitation of *A. granosa* before its ultimate decline and/or disappearance from this area.

While it is more likely that hunter-gatherers would have collected shellfish based on their size rather than age, size is not independent of age in these populations. Consequently, larger and older shells would be expected to dominate the midden samples as hunter-gatherers would preferentially select the larger, higher meat-yielding individuals (Mannino and Thomas 2002:459–60). However, smaller size classes have to be collected if the size ranges represented within a population are significantly reduced (Tonner 2005:1403; Faulkner 2009:831). As indicated by the percentage of juveniles by excavation unit and approximate age (although the degree of variability is higher in this case), there is a relationship between decreasing valve size and an increase in younger/smaller individuals within these sites. This strengthens the previous interpretation relative to mean size, that an increase in the younger age classes within the sequence prior to, and following, the period spanning 1009 to 584 cal BP reflects intensive exploitation and resource depression. It also suggests that the decrease in occupation and resource exploitation intensity within the area enabled the natural population of *A. granosa* to recover from the effects of predation. The patterns of site formation and rapid deposition with this analysis of *A. granosa* size and age structure within these deposits, combined with the structure of the environment and patterns of progradation, suggests that this resource was subject to long-term intensive exploitation rising to a final peak before the species' ultimate decline and/or disappearance.

While not included in this final analytical stage given its different site morphology and location, the Myaoola Bay midden site of BMB/067b is nevertheless important within the context of *A. granosa* exploitation in Blue Mud Bay. This site demonstrates differences in valve size throughout the sequence of occupation that reflect both lower intensity collecting relative to the three mound sites in particular, as well as location-specific environmental structure. With stability in shell size throughout the approximately 930 years of deposition within this site, human exploitation of the shellbeds in this area was less focussed and less intense over the long-term (and *A. granosa* was only marginally the dominant species). This pattern may also relate to the site location, in a more exposed section of the coast potentially subjected to higher wave action and turbidity levels. This area is also more constrained in size, which would have limited the expansion of shell beds in a location with comparatively limited mudflat development through time. As such, the conditions

for *A. granosa* shell bed establishment and proliferation were less optimal in comparison with the more sheltered, extensive areas of Grindall Bay, and as such, the pattern of mollusc exploitation was different.

In line with the interpretations of Bailey (1993:10) and Bourke (2000:318–20), the individual patterns identified for each of the shell deposits in Grindall Bay could be viewed as indicating that exploitation of *A. granosa* was long-term if not continuous, but not overly intensive. Viewing these sites as part of a longer-term trend changes this interpretation, suggesting that the patterns of exploitation were intensive, albeit with some discontinuity based on the available chronologies for the area. Therefore, intensified human predation pressure will not only result in a decrease in average shell size, but also in a lower average age among collected specimens (Faulkner 2009). Additionally, patterns of size variability can be produced by shifts in environmental and climatic conditions. Productivity and growth rates of molluscan species are known to be affected by variations in mean annual sea surface temperatures, salinity levels and increased shell bed exposure, and these factors have all been noted specifically for *A. granosa* (Broom, 1985:4–7; Pathansali, 1966:90–91). While there are a number of significant palaeoenvironmental changes that occurred throughout the mid-to-late Holocene, however, this level of variability appears to fall within the environmental and climatic ranges tolerated by *A. granosa*. While there were changes in sea surface temperature during the mid-to-late Holocene of 1.5°C to 2.0°C relative to present conditions (Gagan *et al.* 2004:131–2), based on presently available data, this does not appear to have been on a scale that would have had an adverse affect on *A. granosa* populations. Salinity levels appear to have peaked between approximately 500 and 200 BP, but this occurs at the end of the period of shell mound formation in Blue Mud Bay. While variation in salinity levels within Grindall Bay, either representing depressed salinity via freshwater influx or heightened levels due to restricted circulation within the area, might explain some of the variability seen in the *A. granosa* size through time, this would not explain the broader patterns noted here. When viewing the longer-term pattern of mean *A. granosa* valve size, the larger scale peaks and troughs in this sequence also do not appear to correlate with any of the currently known climatic changes for the broader region. It must also be acknowledged, however, that ongoing processes of progradation, combined with increasing aridity during the mid-to-late Holocene, may have played a part in creating these patterns to a certain degree. For example, continuing processes of sedimentation would have gradually changed the gradient or slope of the coastal plain, eventually reducing freshwater input and tidal inundation in these areas (Woodroffe *et al.* 1986), a process that would have led to the gradual isolation of the shell beds (Macintosh 1982:13). Combined with variations in the intensity of human exploitation, as well as possible changes in salinity levels noted above within the localised area, this may explain the degree of variability observed in mean valve size within Grindall Bay. That said, the available data does not explain the longer trends in size decrease, nor the period of *A. granosa* size recovery prior to cessation in mound formation around 500 years ago. Due to the range of possible environmental causes for size change in molluscs, particularly those that may adversely affect *A. granosa* populations operating at scales that may not be currently observable, the longer-term trends identified in the archaeological sample suggests the patterns presented here can be cautiously attributed to human predation (e.g. Mannino and Thomas 2002; Braje *et al.* 2007; Erlandson *et al.* 2008; Faulkner 2009, in press). This interpretation is strengthened when this detailed examination of *A. granosa* size variability is viewed in combination with the broader archaeological evidence for site chronology, distribution and morphology.

The archaeological criteria outlined above for investigating potential anthropogenically induced resource depression must be assessed on a species-specific basis, as each species will respond differently to exploitation. Over-exploitation, or more accurately in this case, long-term intensive

exploitation, may represent a range of possibilities for a molluscan population. There may be a reduction in the average size and age of the exploited species, below those that would be found in natural populations not exposed to human predation. There may also be a reduction in the age structure of the population that might reduce breeding capacity and recruitment, and hence population levels of molluscs on the shore (Mannino and Thomas 2001:1112–3, 2002:464). The data also suggests that the exploitation of *A. granosa* within the area was both long-term and intensive. While not conforming to the generally expected patterns for over-exploitation of a resource, the biological and ecological characteristics of *A. granosa* mean that, as a species, it effectively resists the effects of human predation (see for example Catterall and Poiner 1987:120; Hockey *et al.* 1988:361; de Boer *et al.* 2000:288). When viewed as a long-term pattern, however, it is apparent that human predation did have an effect on the structure of the population (Faulkner 2009:831, in press), particularly when viewed in combination with longer-term environmental processes.

## Conclusion

The interpretations of the archaeological evidence presented here strongly indicate that there were several phases of economic reorganisation throughout the discernible 3000 years of occupation for the Point Blane Peninsula. The radiocarbon determinations indicate that there was an initial phase of occupation between 3000 and 1000 BP, with a second phase occurring between approximately 1000 BP and the present. Within this broad phasing, variability in the occupation and exploitation of resources within both Myaoola and Grindall Bays are evident. Between 3000 and 1000 BP there was sporadic or low level use of Myaoola Bay, contrasting with more focussed and intensive use of Grindall Bay. During the second phase, the radiocarbon evidence suggests that there was a change to a comparatively more intensive use of Myaoola Bay throughout the last 1000 BP. During this second phase of occupation, there was a relatively short, intense period of site deposition between approximately 584 and 526 cal BP in Grindall Bay. Discontinuities in radiocarbon dates in Grindall Bay preceding 584 cal BP suggests that there was a shift in the use of this particular area, an interpretation that is supported by the analysis of *A. granosa* size variation through time. These chronological differences are complemented by evidence of variations in the intensity of occupation and resource exploitation as assessed by variations in site size and content.

Based on differences in the density and morphology of sites, there was a greater intensity of occupation and resource exploitation correlated with mound building in Grindall Bay compared with the midden sites in Myaoola Bay. This evidence is further supported by the analysis of *A. granosa* exploitation from the four mound and midden sites. A consistent reduction in the size and age structure of *A. granosa* through time is viewed here as a reflection of intensive, long-term exploitation. Further to this point, the cessation of mound formation in the area appears to coincide with a period of economic reorganisation leading into the kind of patterns noted by Mitchell (1994a) for the pre-Macassan contact period. The interpretation of shell mound construction on the Point Blane Peninsula suggests that molluscan exploitation, particularly between 2287 and 1009 cal BP, was much more intense and focussed, and as such is distinct from those exploitation patterns observed during the historic period. The primary difference between shell middens and shell mounds is in fact one of degree, rather than kind, with morphological differences stemming from variations in the intensity of discard at particular locations through time. In a broad sense, these sites reflect more constant, intensive harvesting of *A. granosa* (see also Clune 2002; Faulkner 2006; Morrison 2010). Rather than being viewed in isolation as an anomaly, mounds are considered here as forming one aspect of the overall spectrum of the economic structure of the area, which also included smaller sites and surface scatters (Cribb

1996:169; Bailey 1999:105). As such, the mounds on the Point Blane Peninsula suggest neither low level harvesting, such as seasonal exploitation by small foraging groups (Bailey 1975a; Bourke 2000), nor occasional high intensity harvesting by larger groups for ceremonial purposes (e.g. Bourke 2000, 2005; Morrison 2003; Clune and Harrison 2009).

There are also a number of broader implications based on the patterns described here for shifts in economic activity through time, particularly related to the interpretation of the shell mounds outlined above. Given the extent of variability in the late Holocene archaeological record of the Point Blane Peninsula identified here, it follows that phases of reorganisation in the foraging economy may well have been accompanied by alterations in the importance of molluscs in the economy, population size and levels of mobility on the coast.