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Windward vs. leeward: Inter-site variation in marine resource exploitation on Ebon Atoll, Republic of the Marshall Islands

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Abstract: The variation in windward and leeward marine environments has been linked to distinctions in marine subsistence on large, high volcanic Pacific Islands, but these patterns have not been explored on low coral atolls. We document windward vs. leeward islet site variation in the taxonomic composition of fish bone and mollusc shell assemblages from three archaeological sites at Ebon Atoll, Republic of the Marshall Islands, to elucidate the relationship between local environment, archaeological site type and the taxonomic composition of marine archaeofaunal assemblages. While the representation of taxa at each site was broadly similar in terms of measures of taxonomic heterogeneity (richness, evenness and dominance), chord distance and correspondence analysis reported variation in taxonomic composition at each site. For mollusc shell assemblages, variation in taxonomic abundance indicates the influence of the marine environments adjacent to each site and the relative exposure of these coastlines to heavy surf, wind, waves and extreme weather events. Fish bone assemblages recovered from 6.4 mm screens had less inter-site variation in richness, evenness and rank order, but differences were noted in the rank order of fish taxa recovered from selective 3.2 mm screening of archaeological deposits when compared between sites. In contrast to patterns for molluscs, variation in the taxonomic composition of fish bone assemblages likely relates to site function, rather than the marine environments adjacent to each site. These trends highlight for the first time the complex range of factors that influenced the prehistoric acquisition of marine resources between leeward and windward islets, and document variation in prehistoric marine subsistence within one atoll.

Keywords: atoll archaeology, marine subsistence, Marshall Islands, Micronesia, Pacific fishing, shell midden studies, zooarchaeology, archaeomalacology, ichthyoarchaeology

Introduction

Marine resources were a critical component of prehistoric subsistence systems across the Pacific Islands (Allen 2012; Fitzpatrick et al. 2011; Jones 2009; Leach and Davidson 1988; Ono and Clark 2012; Szabó and Amesbury 2011; Thomas 1999; Weisler et al. 2010). Finfish and molluscan remains are ubiquitous in Marshall Islands archaeological sites (Beardsley and Athens 1994; Dye 1987; Riley 1987; Rosendahl 1987; Shun and Athens 1990; Weisler 1999b, 2001b), and ethnographic and linguistic evidence highlights the varied and complex ways that Marshallese interact with the marine landscape (Abo et al. 1976; Erdland 1914; Kramer and Nevermann 1938; Spoehr et al. 1949; Tobin 2002). The intertidal reef platforms of the Marshall Islands host at least 1000 species of mollusc (Vander Velde and Vander Velde 2008), and over 800 fish taxa occur within 60 m ocean depth (Myers 1999). These expansive reefs—often greater in area than the terrestrial zone of atolls—provided predictable and possibly sustainable yields of marine subsistence resources throughout prehistory (e.g., Ono and Addison 2013; Thomas 2014); indeed, on Utrök Atoll situated at the northern limit of permanently-inhabited atolls in the Marshall Islands, an 1800-year occupation sequence points to human populations, albeit in low numbers, with no indications of marine resource depression (Weisler 2001b: 128).

The degree of wave exposure has been recognised as a key factor influencing a range of important ecological processes which are critical for structuring faunal composition in tropical intertidal environments (Drumm 2005) and has been related to variation in human behaviour in archaeological contexts. However, determining whether taxonomic composition of archaeofaunal assemblages is driven by ecological conditions and/or human agency is undoubtedly a complex endeavour. Patterned variation in site use and diet as it relates to site location (windward vs. leeward) has been documented on large, high volcanic Pacific Islands (e.g., Bayman and Dye 2013; Kirch and Dye 1979: 58; Palmer et al. 2009; Weisler and Kirch 1985). In the Hawaiian archipelago particular agricultural practices are more commonly associated with leeward or windward locations, with rainfed agriculture and sweet potato cultivation associated with dry, leeward landscapes, and irrigated taro cultivation better suited to wetter windward regions (Palmer et al. 2009: 1444, Earle 1977: 224, Weisler and Kirch 1985). The differences in windward and leeward environments have also been recognised as influencing the exploitation of marine fauna.

Ethno-archaeological research into Niuan fishing strategies (Niuatoputapu, Polynesia) recognised the relationship between fishing practices and distinctions in reef structure, tidal activities and faunal communities that were related to windward or leeward location (Kirch and Dye 1979). Similarly, Kirch (1982) noted variation in exploitation of fishes from three Hawaiian archaeological sites that was inferred to be driven by local environment. Also in Hawai'i, fishponds are more common on the

leeward coasts than on the exposed windward zone (Weisler and Kirch 1985). Distinctions in taxonomic composition between two assemblages, Tangarutu (leeward) and Akatanui 3 (windward), from Rapa Island were attributed to their windward/leeward location, and while similar species were identified at each site, their rank-ordering was variable, with pomacentrids more common at the windward site of Akatanui 3 (Vogel and Anderson 2012).

Mollusc assemblages from large, high volcanic Pacific Islands also demonstrate a link between site location and taxonomic composition. Assemblages from windward sites in Hawai'i are dominated by limpets (*Cellana* spp.) and turban shells (*Turbo* spp.), characteristic of rocky shores, but are rare in leeward sites (Kirch 1982, Morrison and Hunt 2007). Similarly, mollusc assemblages from Vanuatu (Bedford 2007), Fiji (Szabó 2009) and Rapa (Szabó and Anderson 2012) reflect local environmental conditions across the windward/leeward divide and have been interpreted as the result of non-selective foraging strategies operating in varying environments. On atolls, the configuration of marine environments and the distribution and relative abundance of fauna is determined by geological history, exposure to wind, waves and currents as well as myriad stochastic, local ecological, biological and abiotic factors and relates to the windward and leeward exposure of each islet (Wiens 1962). However, atoll settlement patterns and subsistence practices reflected in the variation between windward and leeward environments have not been investigated.

We explore inter-islet and inter-site variation in the taxonomic composition of fish bone and mollusc shell assemblages from archaeological deposits on three islets on Ebon Atoll, Marshall Islands to elucidate the relationship between human foraging behaviour, site function, site location (windward v. leeward) and local environment. A range of statistical techniques are employed to investigate whether differences in the taxonomic composition of the assemblages is a reflection of ecological variability and site location (windward vs. leeward marine habitats) or site function (village vs. camp site). Future research avenues for exploring spatial variation in atoll settlement patterns and subsistence are then suggested.

Sites and samples

Ebon Atoll is the southernmost atoll in the Marshall Islands. Consisting of 22 islets encircling a 104 km² lagoon, the total land area is approximately 5.4 km² (Figure 1). The reef platform totals over 22 km², roughly a 4:1 ratio of reef to land area. Two field seasons (1995/1996 and 2011/2012) of survey and excavation were conducted on Ebon Atoll as part of a larger project directed by Weisler to investigate regional variation in Marshall Islands archaeology as it relates to the 700+ km north-south rainfall gradient, as well as documenting intra-atoll differences in settlement patterns and subsistence (Weisler 1999a, b, 2000, 2001a, b, 2002; Weisler and Swindler 2002; Weisler et al. 2012). We report

results from the analyses of the fish bone and mollusc shell remains retained in 6.4 mm and 3.2 mm screens at three sites excavated during the 2011/2012 Ebon Atoll field season. A total of 68 m² was excavated across seven archaeological sites on three islets, one situated on the leeward rim (Ebon Islet), one with windward exposure (Moniak Islet) and Enekoion Islet located between the two extremes. The archaeological sites chosen for analysis here include two lagoonside villages (MLEb-1 and MLEb-33) (Weisler 2001b) and a much smaller, shorter-term occupation site (MLEb-31) on Moniak (Weisler 2002). Lagoonside deposits were explicitly selected at all three sites to minimise diachronic effects on these analyses as they all represent a later phase of Marshallese prehistory in which habitation sites occur adjacent to the lagoon, in contrast to earlier phases where deposits are in the interior and associated with horticultural pits (Weisler 2001a: 129).

The following description of mollusc and finfish habitats on oceanic atolls derives from: Carpenter and Niem (1998); Demond (1957); Hiatt and Strasburg (1960); Kohn (1987) and Wiens (1962). The largest islets and widest reef platforms are on the leeward south-eastern, western and north-western rim of Ebon Atoll. MLEb-1 and MLEb-33 lie in this zone, relatively sheltered from waves, winds and currents and feature high-rugosity coral reefs, and fine grained interreefal sand flats and seagrass beds on the lagoonside, and expansive, low relief pavements on the oceanside. Habitat complexity is highest on leeward islets, with a corresponding increase in faunal diversity predicted (Gratwicke and Speight 2005; Kohn and Leviten 1976). While mollusc taxa are generally sessile, and strongly associated with particular benthic habitats, finfish taxa are more difficult to associate with windward or leeward environments. Fish often track across multiple habitats with day/night cycles, tides, and during feeding. However, some taxa are strongly associated with certain substrate types, which vary in predominance between leeward and windward reef habitats as described below.

Leeward oceanside mollusc communities are highly diverse, with colonies of macroalgae and shallow tide pools hosting large numbers of cowries (Cypraeidae) drupes and other murex shells (Muricidae) top shells (Trochidae), cone shells (Conidae) and nerites (Neritidae). These reef platforms are also associated with large schools of parrotfish (scarids), surgeonfish (acanthurids), wrasse (labrids), goatfish (mullids), and small bodied sharks (carcharhinids), and algal turfs provide grazing for rabbitfish (siganids), sea chubs (kyphosids), butterflyfish (chaetodontids), acanthurids, damselfish (pomacentrids) and triggerfish (balistids).

The lagoonside reefs, seagrass beds and sand flats host communities of giant clams (*Tridacna* spp. and *Hippopus* spp.), spider conchs (*Lambis* spp. and *Harpago* spp.) Conidae, mitre shells and auger snails (*Terebra* spp. and members of the family Mitridae). The upper intertidal sand flats provide habitat for the easily accessible sand dwelling bivalves including the violet asaphis (*Asaphis violascens*), venus clams (*Gafrarium* spp.), cockles (*Vasticardium* spp.), ark clams (*Arca* spp.) and

surf clams (*Atactodea striata*). Areas of coral growth on the lagoonside are associated with diverse herbivorous, carnivorous, and omnivorous fish communities including scarids, balistids, chaetodontids, pomacentrids, moray eel (muraenids), squirrelfish and soldierfish (holocentrids), grouper (serranids), snapper (lutjanids), labrids, filefish (monacanthids), and pufferfish (tetraodontids).

MLEb-31 is located on a windward islet, which is smaller and generally more exposed to winds, waves and currents. The intertidal zone is primarily composed of poorly sorted coral rubble washed from the ocean facing subtidal reefs, wave cut erosional channels, and coarse, gravelly sands on the lagoonside. Habitat complexity is generally lower on windward islets, with a decrease in richness and diversity of mollusc and fish communities predicted (Gratwicke and Speight 2005; Kohn and Leviten 1976). Mollusc communities characterised by large and robust Turbo, drupes (*Drupa* spp.), Cypraeidae, Conidae, vase shells (*Vasum* spp.), polished nerites (*Nertia polita*) and frog shells (*Bursa* spp.). Finfish communities on windward islets are varied and complex, but taxa characteristic of exposed surge channels include muraenids, carcharhinids, hawkfish (cirrhitids), serranids, lutjanids, acanthurids, pomacentrids, labrids, scarids, combtooth blenny (blenniids), and balistids.

The following analyses are based on all fish bone and mollusc shells retained in the 6.4 mm screens from lagoonside deposits on Ebon Atoll; Test Pit (TP) 17–20 at site MLEb-1, TP 2–6 at site MLEb-31 and TP 2 and 8 at site MLEb-33 (Figure 1). A single unit from each site—MLEb-1 (TP 17), MLEb-31 (TP 2) and MLEb-33 (TP 8)—was sieved with 3.2 mm screens during the 2011/12 fieldwork. All excavated sediments were wet-sieved. Hereafter, the single-unit sub-samples of fish bones recovered from nested 3.2 mm and 6.4 mm screens are described as the 3.2 mm samples.

MLEb-1

MLEb-1 is located at the centre of a ~ 2 km long village system on Ebon Islet (Weisler 2002). Ebon Islet is the largest islet of the atoll, featuring high-rugosity coral reefs and sand flats in the lagoon intertidal and expansive, relatively calm intertidal reef flats on the oceanside (Figure 1a). Cultural material, including molluscan remains, fish bone, charcoal, oven (um) stones and worked shell artefacts were recovered from a 2 × 2 m unit (TP 17, 18, 19 and 20) excavated into a low mound, built by the accumulation of successive coral pavements, located 40 m inland of the current lagoon shore and 20 m northwest of the Primary School. Cultural deposits extend to a depth of 1.75 m. Cultural material retained in the 6.4 mm screens yielded 3464 fragments of mollusc shell (MNI [Minimum Number of Individuals] = 1258), and 4188 fish bones (MNI = 509), with 94.1% and 39.3% of fragments, respectively, identified to family, genus or species. The 3.2 mm fish bone samples (TP

17) yielded a NISP (Number of Identified Specimens) of 2655 (MNI = 378), with 14.4% of fragments identified to family, genus or species.

MLEb-33

Situated on Enekoion Islet, MLEb-33 is a sparse to dense midden deposit surrounding a large aroid pit situated from 100 m to 25 m from the lagoon shore. A 1 × 2 m trench was excavated on the lagoonward side of the aroid pit where cultural deposits extended to 40 cm below surface. The oceanside reef flat is generally wider than at Ebon or Moniak, but is mainly composed of coral rubble, boulders and eroded beachrock slabs, more similar to the exposed reef flat of Moniak than Ebon Islet. The lagoonside environment features expansive seagrass meadows (*Thalassia* spp., Figure 1b) and sand flats, and some coral growth in the intertidal, similar to the lagoon environments at Ebon Islet. Cultural material retained in the 6.4 mm screens yielded 617 fragments of mollusc shell (MNI = 230), and 144 fish bones (total MNI = 67), with 96.8% and 60.5% of fragments, respectively, identified to family, genus or species. The 3.2 mm fish bone samples (TP 8) yielded a NISP of 98 (MNI = 34), with 20.1% of fragments identified to family, genus or species.

MLEb-31

The small midden site MLEb-31 is located ~ 75 m from the lagoon shore on the windward islet of Moniak (Weisler 2002). Cultural deposits extend to a maximum depth of 70 cm. The oceanside intertidal is characterised by coral boulder ramparts and cobbles deposited by extreme weather events (Figure 1c), in contrast to the relatively protected oceanside of Ebon and Enekoion Islets. The lagoonside sands of Moniak are coarse and the shore declines steeply to the lagoon floor. Cultural material retained in the 6.4 mm screens yielded 1740 fragments of mollusc shell (MNI = 650), and 1084 fish bones (MNI = 326), with 95% and 53.5% of fragments, respectively, identified to family, genus or species. The 3.2 mm fish bone samples (TP 6) yielded a NISP of 648 (MNI = 192), with 20.4% of fragments identified to family, genus or species.

Methods

Identification and quantification protocols

Fish remains were identified by Lambrides (Appendix B and C) and mollusc remains by Harris; all identifications were completed to the lowest taxonomic level using Indo-Pacific comparative reference collections housed at The University of Queensland archaeology laboratory (see Lambrides and Weisler 2015a: 5; Weisler 2001b: appendix 3, for a description of the fish reference collection). Reference manuals were also used for molluscan identification, including: Abbott and Dance (1990); Poppe (2008); Röckel et al. (1995) and Burgess (1985). Due to the richness of Indo-Pacific marine

fauna, all fish bone (see Lambrides and Weisler 2015b) and mollusc shell fragments were attempted for identification, but lower order taxonomic identifications (e.g., genus and species) were assigned with caution to avoid over-identification (Driver 1992; Wolverton 2013). Taxonomic abundance of archaeological fish bone and mollusc shell were quantified by NISP and MNI. For fish remains, MNI values were calculated following standard zooarchaeological protocols for vertebrate fauna (Grayson 1984; Lyman 2008; Reitz and Wing 2008) and for molluscs following Harris et al. (2015). The quantification methods used here allow comparison of fish and mollusc taxonomic abundance as MNI values were consistently determined using the most frequently occurring Non Repetitive Element (NRE).

Statistical analyses

Both mollusc shell and fish bone samples were aggregated at the site level. The NRE frequency for each taxon was summed by cultural layer for calculating MNI. Relative taxonomic abundance is used here to examine differences in the taxonomic composition of fish bone and mollusc shell assemblages from the three sites to explore the interaction between windward vs. leeward islets, local environment and the extraction of marine fauna. A range of statistical tests were utilised including taxonomic richness and diversity as measured by NTAXA, the Shannon-Weiner index of diversity (H'), Shannon's evenness (E), Simpson's dominance ($1-D$), and Fisher's α . Similarity and difference in faunal composition was analysed using chord distance analysis, and correspondence analysis (CA). These statistics have proven utility for examining similarities and differences in taxonomic composition for archaeological assemblages, including faunal (Faith 2013) and archaeobotanical samples (Wright et al. 2015). All statistical analyses reported below were carried out using MNI values for comparability with other Pacific Island assemblages, but it should be noted that statistical analyses of NISP values were tested and revealed similar trends (Grayson 1984; Lyman 2008). All statistical analyses were completed using PAST Paleontological Statistics Package, version 3.06 (Hammer et al. 2001).

Species richness (the number of species in an analytical unit) was assessed using NTAXA. Evenness, being the relative abundance of species in the assemblage, was measured using the Shannon-Weiner index of diversity (H') and Shannon's evenness (E). H' values range between 0 and a theoretical maximum of 5, but values between 1.5 and 3.5 are most common. Higher H' values indicate greater species diversity and richness. E values range between 0 and 1, with 0 indicating assemblages dominated by a single taxon, and values closer to 1 indicating rich, even assemblages (Lyman 2008: 195; Reitz and Wing 2008: 111). The dominance of few species in the assemblage was assessed using Simpson's index of diversity ($1-D$). $1-D$ values range from 0 to 1, with lower values indicating assemblages dominated by a single taxon (Magurran 2004: 116). Fisher's α , a measure of diversity,

was also utilised as Shannon's indices and NTAXA can be influenced by sample size (Faith 2013). Fisher's α values are considered to be relatively independent of sample size (Hayek and Buzas 2010: 295–296). Fisher's α tracks the occurrence of taxa represented by single individuals as a measure of overall diversity (Karlson et al. 2004). Significant difference between diversity indices calculated for each sample were also carried out using random permutation tests of relative abundance data.

Chord distance and exploratory CA analyses were conducted using non-aggregated (i.e., not collapsed by NTAXA) relative abundance data. NTAXA quantifies richness by collapsing taxa at the highest common taxonomic level for each assemblage. NTAXA values are generally correlated with sample size and can be influenced by identification protocols, but do ensure richness values are not inflated by species that are more easily identified to lower taxonomic levels. Chord distance analysis is a scaled measure of Euclidean distance for examining the dissimilarity between samples in relative abundance of species, such as sites or cultural units (Faith et al. 1987; Legendre and Gallagher 2001). Chord distance values range from 0, indicating samples with no difference in relative abundance, up to $\sqrt{2}$ indicating no species in common between samples. Chord distance values are useful measures of dissimilarity for the assemblages examined here, as species represented by single individuals are not highly weighted.

This suite of statistical tests allows an exploration of the role of site location (windward vs. leeward marine habitats) and site function (village vs. camp site) on the taxonomic composition of the assemblages. Taxonomic measures of heterogeneity and chord distance are complementary analyses which can be used to assess human collection strategies (i.e., non-selective or selective behaviours) that are linked to local faunal community structure (i.e., number of species, dominance of particular taxa, etc.) and site function. Correspondence analysis is used to further explore the relationship between particular taxa, ecological variables, and site function, and provides useful data for comparison with the results of the other statistical analyses used here.

Results

Figure 2 presents the relative abundance of mollusc and fish taxa identified from the 6.4 mm and 3.2 mm screened assemblages at sites MLEb- 1, MLEb-31 and MLEb-33. To highlight broad trends in taxonomic composition at each site, quantification data are aggregated at the family level. Characteristic of Indo-Pacific marine archaeofaunas, many species are represented (e.g., Morrison and Addison 2009; Ono and Intoh 2011; Riley 1987; Szabó 2009; Weisler 2001b). The molluscan assemblage is dominated by gastropods ($x = 84.2\%$ MNI/81.7% NISP), with bivalves contributing minimally to MNI and NISP. Both 6.4 mm and 3.2 mm fish bone assemblages are dominated by

piscivores and omnivores/benthic carnivores, which account for 75.2% and 84.4% of total MNI, respectively.

Taxonomic measures of heterogeneity for all samples report high richness and evenness and low dominance overall (Table 1). Random permutation tests for significant difference between index values at each site reported significant values only for 1-*D* values for molluscs between MLEb-1 and MLEb-31 ($p = 0.0002$) and E values for 3.2 mm fish bone samples from MLEb-1 and MLEb-31 ($p = 0.0264$). 1-*D* values are sensitive to differences in the relative abundance of the top ranked taxa, explaining the significant result for mollusc samples. E values are sensitive to alterations in the relative abundance of all taxa, once again explaining the significant difference reported for 3.2 mm fish samples from MLEb-1 and MLEb-31.

Chord distance was used to measure the dissimilarity between the relative abundance of taxa in each assemblage. The greatest faunal dissimilarity as measured by chord distance was reported for molluscan assemblages from site pairs MLEb-1/MLEb-31 and MLEb-1/MLEb-33. Minimal dissimilarity was reported for the mollusc assemblage from MLEb-31/MLEb-33, 6.4 mm fish bone assemblages from all site pairs and 3.2 mm fish bone assemblage from site pair MLEb-1/MLEb-31. Moderate dissimilarity was noted for 3.2 mm fishbone assemblages from site pairs MLEb-1/MLEb-33 and MLEb-31/MLEb-33. Chord distance analysis indicates that molluscan assemblages tend to be more taxonomically dissimilar than fish bone assemblages across all site pairs, except for MLEb-31/MLEb-33. Both taxonomic measures of heterogeneity and chord distance analysis indicate that all assemblages were relatively similar in terms of richness, evenness, and relative abundance of taxa, with the most pronounced differences generally between mollusc assemblages from MLEb-1 and MLEb-31.

CA of taxonomic abundance (6.4 mm data) was used to investigate whether differences in the taxonomic composition of the assemblages as initially determined by the results of the diversity measures, and chord distance, was better explained by local ecological variability (windward vs. leeward marine habitats) or site function (village vs. camp site). Figure 3a–c plots CA axis 1 and 2 for all samples, which account for 77.8% and 22.2% of the variance in taxonomic abundance, respectively. Axis 1 discriminates between windward and leeward islets, with MLEb-1, on the most leeward islet, reporting the lowest axis 1 score and MLEb-31, on the most windward islet, reporting the highest axis 1 score. MLEb-33, which is moderately exposed to windward waves, currents and wind, reports an intermediate axis 1 score. The negative axis 1 score that characterises MLEb-1 is associated with 43 mollusc taxa and six fish taxa (*Carcharhinus* spp., *Decapterus* spp., *Elagatis bipinnulata*, Ostraciidae, *Sphyræna* spp., and *Thunnus* spp.) that occur only at that site, and account for 11% and 4.3% of total site MNI, respectively. MLEb-31 is characterised by positive axis 1 scores,

and is associated with 34 mollusc taxa and a single fish taxon (*Zebrasoma* sp.) that occur only at that site, and account for 7.7% and 0.3% of total site MNI, respectively. MLEb-33 is characterised by negative axis 2 scores, and is associated with five molluscan taxa (*Conus leopardus*, *Conus lividus*, *Corculum cardissa*, *Harpa* spp., *Periglypta* spp.) that occur only at that site (2.5% of total site MNI), but no distinct fish species. Axis 1 scores are negatively loaded by reef flat pavement dwelling gastropod taxa, the most common habitat exploited for mollusc gathering at MLEb-1 (Harris and Weisler, in review). Conversely, axis 2 scores are negatively loaded by sand-dwelling gastropod and bivalve taxa. Interestingly, the extant lagoon environment adjacent to MLEb-33 is predominately turtle grass (*Thalassia* spp.) beds and sand flats. Habitat proclivities are more difficult to assess for the non-sessile fish but, generally, the representation of feeding behaviours (piscivores, omnivores/benthic carnivores and herbivores) for non-distinct taxa were broadly similar at each site. In contrast, the CA of 3.2 mm fish bone taxonomic abundance data (Figure 3d) report similar levels of variance for both axis 1 and axis 2, 58.2% and 41.8%, respectively. This suggests that there is less taxonomic similarity between sites than represented by the 6.4 mm data, which is also reflected by the chord distance scores (Table 2). Similar to the 6.4 mm fish bone CA, distinct taxa from all sites only accounted for a small percentage of the assemblage, specifically 5.6% of total MNI. CA results reflect the substantially different rank ordering of taxa at each site as represented by the 3.2 mm data.

Discussion

Spatial variation in marine subsistence as it relates to windward and leeward settlement patterns on a single atoll has not previously been assessed in Pacific Island archaeology. A range of statistical analyses were implemented using mollusc shell and fish bone relative taxonomic abundance data reported from three habitation deposits on Ebon Atoll. All sites were located adjacent to the extant lagoon shore, with one a temporary habitation site (MLEb-31), and the other two large villages (MLEb-1 and MLEb-33).

The taxonomic composition of archaeological mollusc and fish bone assemblages from each site evidenced a similar suite of families with assemblages characterised by highly rich and even measures of taxonomic diversity, and no strongly dominant taxa, despite probable differences in habitat complexity at each site. All mollusc assemblages are dominated by gastropods, with bivalves contributing minimally to MNI. The dominance of gastropods is characteristic of macrobenthic mollusc communities recorded for other atolls in the Marshall Islands (Kay and Johnson 1987), potentially indicating a generalised molluscan foraging strategy at all sites (Harris and Weisler, in review, Szabó 2009, Kirch 1982). Richness was generally greatest at MLEb-1, which is unsurprising as this is both the largest sample, and from the most complex habitat (Gratwicke and Speight 2005).

Mollusc assemblages at each site have relatively high ranks for nerites, muricids (*Drupa* spp. and *Thais* spp.), *Conus* spp., Cerithidae, Cypraeidae, *Turbo* spp. and *A. violascens*. Fish bone assemblages recovered from the 6.4 mm screens are generally dominated by piscivorous species (e.g., serranids, lutjanids and carangids) followed in rank order by omnivorous/benthic carnivorous species (e.g., holocentrids, lethrinids and balistids) and herbivorous species (e.g., acanthurids and scarids). Fish bone assemblages recovered from the 3.2 mm screens reported increased dominance of omnivores/benthic carnivores (e.g., holocentrids, exocoetids and mullids) which may be related to average fish bone size for these taxa, bone density and taphonomy. For fish bone assemblages from the 6.4 mm screens, scarids and serranids are rank 1 and 2, respectively, at MLEb-1 and MLEb-31, and rank 2 and 3 at MLEb-33. However, the 3.2 mm samples, while similar in taxonomic composition, showed greater variation in the rank ordering of these taxa when compared to the 6.4 mm samples, similar trends were noted from Rapa Islands archaeological sites, where 2 mm screens were utilised (Vogel and Anderson 2012).

Mollusc assemblages reported generally greater inter-site variation in taxonomic abundance than fish bone assemblages. The statistical analyses utilised here indicate variation in relative taxonomic abundance of mollusc assemblages is due to differences in the local environment at each site. At MLEb-1, the majority of the molluscan assemblage could have been gathered from the oceanside reef flat and coral reefs (Harris and Weisler, in review). Conversely, CA shows that those molluscan taxa that prefer sandy lagoon substrates are most strongly associated with MLEb-33, a marine environment today which is characterised by large lagoonal sand flats and turtle grass beds. Furthermore, assemblages at MLEb-31 consist principally of those taxa which either inhabit the boulder ramparts, typical of windward islets (i.e., *N. polita*), or those taxa which are suitably adapted to constant exposure to wind, waves and currents on the reef edge (i.e., *Mauritia mauritiana*, *Vasum turbinellus*, and *Thais armigera*). The variability in the relative abundance of *Nerita plicata*, *N. polita* and the ranellids (*Monoplex intermedius*, *M. nicobaricus* and *Gutturium muricinum*) likely explains the significant difference in measures of dominance between molluscan assemblages from MLEb-1 and MLEb-31. This result also potentially indicates the influence of local environment, as Ranellidae are most common in areas of coral growth (Govan 1995), which are characteristic of Ebon Islet (MLEb-1), but are rare at Moniak (MLEb-31). The correlation between local environment and the molluscan taxa in the assemblage, in addition to the even, rich and diverse taxonomic composition indicates that a non-selective foraging strategy, mediated by local environment, operated at each site. These patterns are broadly similar to mollusc assemblages from other oceanic islands where richness and evenness are high, and taxonomic composition varies predominately with changes in site location and local environment (e.g., Szabó 2009). Fish bone assemblages, however, generally have lower values of dissimilarity between sites and are harder to link to marine environments adjacent to each site as fish

track across different habitats while foraging, unlike molluscs that are generally sessile. For example, *Katsuwonus pelamis*, a pelagic-oceanic dwelling species, is dominant at the largest village site, MLEb-1 but rare at the campsite, MLEb-31 indicating that variation in fish bone assemblages may be related to site function rather than the marine environments adjacent to the sites. This trend requires further analysis (e.g., assessment of temporal variation and inclusion of additional sites), but could relate to a number of variables, including settlement patterns and fish capture strategies operating at each site. Variability in inter-site taxonomic composition for 3.2 mm samples was generally greater than 6.4 mm fish bone assemblages. Mesh size has been linked to alterations in species richness and diversity (e.g., Nagaoka 2005; Ono and Clark 2012) and inferences made regarding capture methods, morphometric reconstructions of fish size, ontogenetic growth and associated live fish behaviour can be useful for predicting fishing technology (Bertrando and McKenzie 2011).

Conclusion

Exploratory data analyses were implemented to determine whether there are differences and/or similarities in the taxonomic composition of mollusc shell and fish bone assemblages from three archaeological sites situated on windward and leeward islets at Ebon Atoll, Marshall Islands. Results indicate broad similarity in assemblage composition, reflected in similar richness, evenness and dominance scores at each site, regardless if the sites were small intermittently occupied habitations on windward islets or large villages on leeward islets. Where variation in taxonomic composition occurs, the configuration of marine environments at each site may account for much of the differences in the mollusc assemblages, while fishing technology (capture techniques) and site function (i.e., village sites v. campsites) could account, in part, for the variation in fish bone assemblages at each site. Intra-islet variation in taxonomic abundance, metric analysis of fish bone to assess body size over time and possible effects of human impacts to marine fisheries, studies of associated material culture and temporal analysis of alterations to foraging strategies will provide additional datasets for testing the influence of local marine environments and human settlement patterns on relative taxonomic abundance of mollusc shell and fish bone assemblages from Ebon Atoll.

This study has shown that even within a single atoll, human foraging patterns can differ over small spatial scales. The observed patterns follow documented evidence from other Pacific Islands where molluscan assemblages broadly reflect local environmental conditions. In contrast, fishbone assemblages possibly reflect capture methods and site function. The results presented here highlight the importance of atolls for examining the dialogue between human behaviour and local marine environments when investigating long-term trajectories of human-environment interaction. Assessing variation in the composition of archaeofaunal assemblages from windward and leeward islets can yield useful information for understanding variation in settlement patterns and intra-atoll subsistence

practices—the latter previously not recognised. These intra-atoll analyses are critical for assessing variability in marine subsistence practices and are applicable to other island types across the Pacific.

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Table 1. Measures of taxonomic heterogeneity: NTAXA, Shannon's index of diversity (H') and evenness (E), Simpson's dominance ($1-D$) and Fisher's α , as calculated for mollusc shell and fish bone assemblages retained in the 6.4 mm and 3.2 mm sieves for all sites (MLEb-1, MLEb-31 and MLEb-33).

| Index | 6.4 mm samples | | | | | | 3.2 mm samples | | |
|-------------------|----------------|---------|---------|-----------|---------|---------|----------------|---------|---------|
| | molluscs | | | fish bone | | | fish bone | | |
| | MLEb-1 | MLEb-31 | MLEb-33 | MLEb-1 | MLEb-31 | MLEb-33 | MLEb-1 | MLEb-31 | MLEb-33 |
| NTAXA | 47 | 37 | 26 | 27 | 25 | 18 | 29 | 25 | 18 |
| $1-D$ | 0.887 | 0.859 | 0.869 | 0.921 | 0.926 | 0.909 | 0.936 | 0.940 | 0.919 |
| H' | 2.648 | 2.528 | 2.512 | 2.780 | 2.822 | 2.605 | 2.968 | 2.972 | 2.705 |
| E | 0.687 | 0.700 | 0.711 | 0.844 | 0.877 | 0.901 | 0.881 | 0.923 | 0.936 |
| Fisher's α | 9.631 | 8.508 | 7.534 | 6.803 | 6.306 | 8.071 | 7.316 | 7.670 | 15.51 |

Table 2. Chord distance values for mollusc shell and fish bone assemblages retained in the 6.4 mm and 3.2 mm sieves for each site pair.

| Site pair | 6.4 mm samples | | 3.2 mm samples |
|-----------------|-----------------------|-----------|-----------------------|
| | molluscs | fish bone | fish bone |
| MLEb-1/MLEb-31 | 1.085 | 0.463 | 0.481 |
| MLEb-1/MLEb-33 | 1.045 | 0.538 | 0.732 |
| MLEb-31/MLEb-33 | 0.373 | 0.566 | 0.741 |

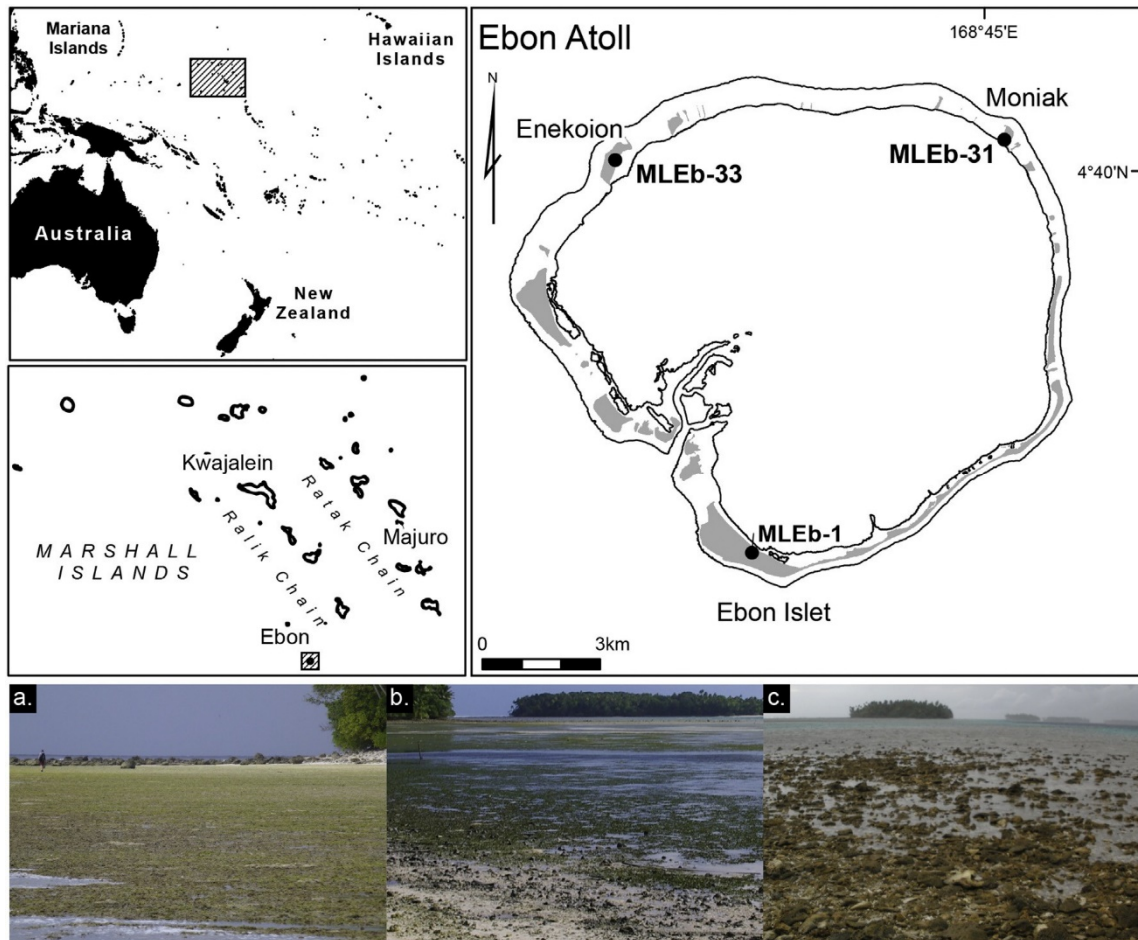


Figure 1. Map of the Republic of the Marshall Islands, with Ebon Atoll and the location of sites MLEb-1, MLEb-31 and MLEb-33, and photos depicting intertidal marine habitats characteristic of each islet (a) Ebon Islet oceanside, view northwest showing expansive reef flat (Photo: A. Lambrides), (b) Enekoion Islet lagoonside, view northeast showing seagrass beds in the intertidal (Photo: M. Harris), (c) Moniak Islet oceanside, view east of coral cobble and boulder intertidal (Photo: M. Weisler).

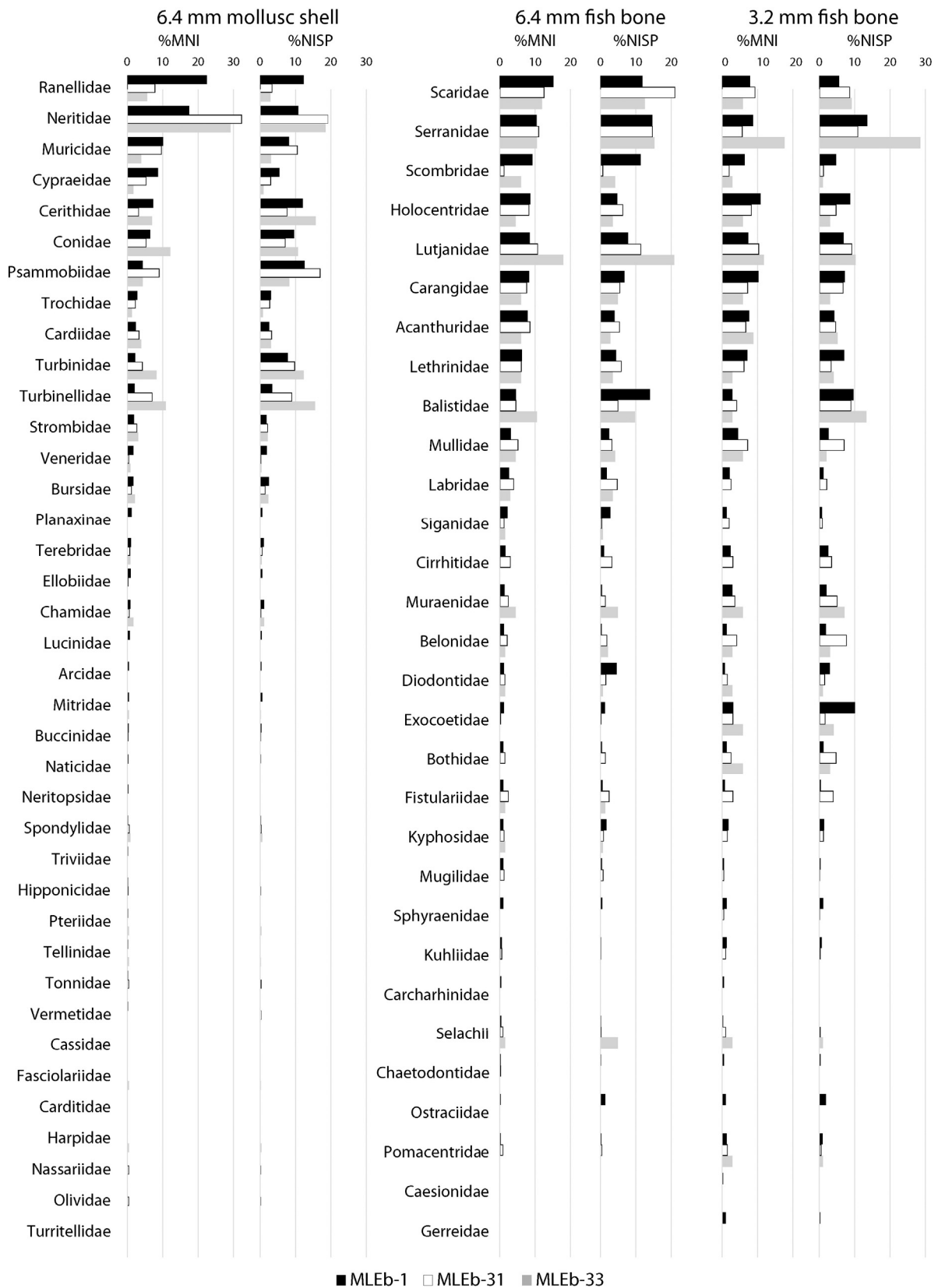


Figure 2. The percent contribution to total MNI and NISP by taxon, site and screen for mollusc shell 6.4 mm samples and fish bone 6.4 mm and 3.2 mm samples. Family level identifications, but note Selachii (modern sharks), which is a superorder/clade.

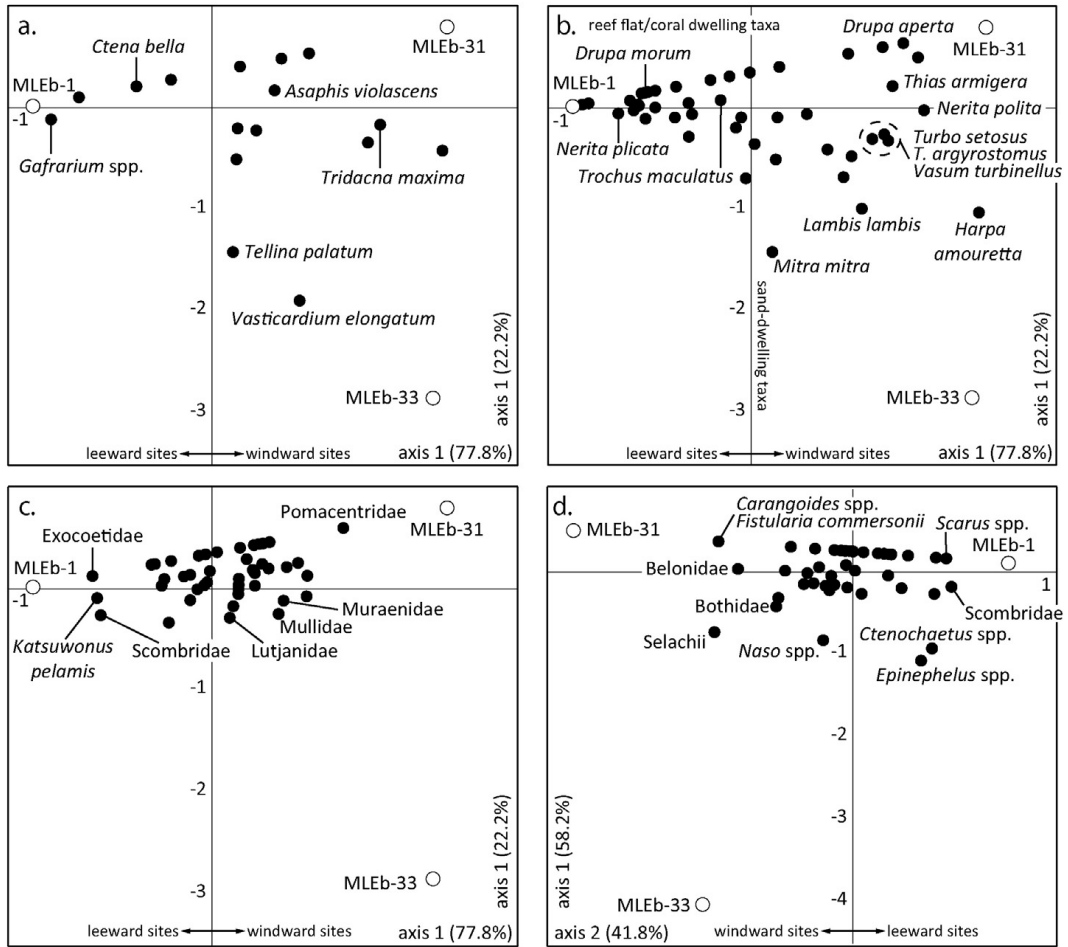


Figure 3. Correspondence analysis of taxonomic abundance. (a) 6.4 mm bivalve shell, (b) 6.4 mm gastropod shell and (c) 6.4 mm fish bone samples are displayed on separate plots for clarity, (d) 3.2 mm fish bone samples. Key taxa are annotated and distinct taxa are not displayed due to minimal contribution to total MNI at each site.