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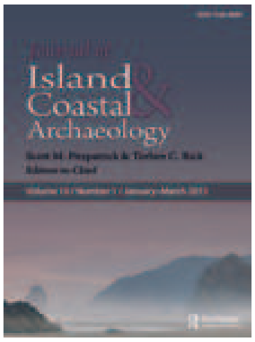

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The Diversity of Late Holocene Shellfish Exploitation in Velondriake, Southwest Madagascar

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ABSTRACT

Shellfish represent an important component of human diet, especially for coastal communities, and shells are integral to a wide range of activities and social interactions. In addition to providing rich information on questions of subsistence, daily and ritual practices, and trade and exchange, shellfish remains serve as sensitive paleoecological indicators of changes in climate and environment. The exploitation of shellfish by ancient communities is a well-studied field in archaeology; however, little has been published to date with regard to shellfish exploitation—either in the past or present—in Madagascar, the fourth largest island in the world. This article presents the first detailed description of archaeological shellfish assemblages from Madagascar. These assemblages were recovered from the excavation of several archaeological sites located in the southwest's Velondriake Marine Protected Area. The archaeological record of Velondriake spans the period from ca. cal AD 600 to cal AD 1900, making it one of the longest occupation sequences currently known in Madagascar. The primary objective of this article is to present the range of shellfish taxa identified in Velondriake archaeological assemblages as a baseline for future work, and to offer preliminary comments on inter-site variability in taxonomic diversity, taphonomy, and Velondriake's ancient communities' reliance on different marine habitats.

Keywords archaeology, foragers, Indian Ocean, Madagascar, shellfish

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INTRODUCTION

The study of shellfish remains is a central field of archaeology. Indeed, the realization that numerous impressive shellfish accumulations worldwide are anthropogenic and have dramatically re-shaped landscapes and altered local ecologies is central to the disciplinary developments of both geology and archaeology (Claassen 1998; Trigger 1996; Waselkov 1987). Shellfish remains have yielded insights into a wide range of anthropological questions, from subsistence and paleoenvironmental reconstruction to gender in archaeology, craft production, ritual and trade (Claassen 1998).

Shellfish constitute an important, though heavily debated, component of human diet, especially for coastal communities around the world (Codding et al. 2014; Erlandson 2001, 2010). Despite earlier thinking that shellfish are exclusively "low-ranked" prey offering limited energetic returns as compared to other wild and cultivated foods (Osborn 1977), the vast anthropological literature on shellfishing—including "Global Patterns in the Exploitation of Shellfish," a recent special issue in the *Journal of Island & Coastal Archaeology*—is replete with examples of the significance of this form of aquatic foraging (Codding et al. 2014). Shellfish provide a reliable source of protein that can be acquired by all members of a community (Erlandson 1988); gathering of many shellfish species is a "low-risk" and "low-tech" activity that can be accomplished while managing other time-consuming tasks, like childrearing (Erlandson 1988; Whitaker and Byrd 2014). Variability in shellfishing practices worldwide presents many opportunities for cross-cultural and diachronic comparisons of shellfish-dependent lifeways (Claassen 1986; Moss 1993).

In addition to providing information about subsistence, shellfish remains in archaeological deposits serve as sensitive paleoecological indicators that can be used to address a range of questions relating to human-environment dynamics, from changes in the intensity of resource exploitation to seasonality (Claassen 1986, 1988; Erlandson, Braje, et al. 2011; Klein and Steele 2013). For example, archaeological shellfish remains recovered from sites around the Chesapeake Bay spanning the last three and a half millennia were recently analyzed alongside Pleistocene and modern shellfish remains to provide a long-term continuous view of shellfish exploitation patterns and the dynamics of estuarine health (Rick et al. 2016). At the same time, the wealth of data that can be extracted from shellfish is tempered by many methodological and interpretive challenges related to this class of remains; the collection and interpretation of shellfish data is subject to vigorous debate, and the complexity of factors influencing the biostratinomy and diagenesis of shellfish remains warrants caution, the use of multiple lines of evidence, and further experimental and ethnographic study of the formation of shellfish-bearing deposits (Claassen 1998, 2000). These challenges have, however, stimulated innovative research that has been instrumental in bridging disciplinary divides and making zooarchaeological data more broadly relevant (Peacock et al. 2012; Wolverton et al. 2016).

Beyond their value as a source of subsistence and paleoecological data, shellfish remains represent an important cultural material that is central to many activities of daily and ritual life—often transformed into tools, objects of adornment and ritual, and currency—and witness to local as well as far-reaching spheres of social, political, and economic interaction (Allibert 2000; Boivin and Fuller 2009; Malinowski 1922; Mitchell 1996; Paulsen 1974). Considering the ubiquity of shell artifacts and the values and symbolism associated with shellfish (Claassen 2008; Trubitt 2003), it is not surprising that shellfishing played an important role in periods of socio-political transition; recent work has shown how the study of archaeological shellfish remains can help elucidate broad social processes, such as the emergence of sociopolitical complexity (Erlandson, Willis, et al. 2011).

Despite the growing body of scholarly work demonstrating the importance of shellfish remains in understanding the foodways, socio-political complexity, craft production, trade and exchange, ritual practices, and paleoenvironments of archaeological communities all over the world, shellfishing has received limited scholarly attention in Madagascar. To the best of the author's knowledge, with the exception of brief mentions of shellfishing among the Vezo (Iida 2005; Koechlin 1975), there are no prior archaeological or ethnographic publications that specifically address the topic of shellfishing on the island. This constitutes an important gap in our understanding of coastal communities and their interaction with marine and coastal ecologies in Madagascar, the fourth largest island in the world, where a majority of the population lives in coastal zones and exploits marine resources (Le Manach et al. 2012).

This article takes a first step in investigating patterns of shellfish exploitation in Madagascar by presenting archaeological shellfish assemblages from the Velondriake Marine Protected Area, Toliara Province, southwest Madagascar (Figure 1). The primary objective of the paper is to characterize the taxonomic diversity of shellfish remains recovered from the excavation of a group of limestone rock shelters and open-air villages located in the vicinity of the modern fishing village of Andavadoaka. Taxonomic identifications allow for discussion of the range of exploited shellfish taxa and for an assessment of archaeological communities' reliance on different marine and coastal habitats. This paper thus provides a baseline upon which future archaeomalacological work can build, particularly through further study of taphonomy and the use of shellfish in the production of tools, beads, and other objects of daily use, ritual practice, and economic interaction. The analysis of archaeological shellfish remains in Velondriake has tremendous potential to inform us about forager lifeways, population dynamics, and the nature and intensity of coastal resource exploitation in the past. Shellfish remains are particularly valuable sources of archaeological data in Velondriake given their high degree of preservation as compared to the fragmentary and weathered state of fish, bird, herpetofauna, and mammal bones from archaeological deposits (Douglass 2016).

Shellfish Research in Africa and Madagascar

Studies of shellfishing in African contexts are especially well developed in southern Africa because of the association between shellfishing and important Middle Stone Age contexts dated between ca. 164 and 55 ka, with evidence for complex human cognition (Henshilwood et al. 2014; Marean 2010). The earliest evidence for shellfishing predates the advent of anatomically modern humans (Steele 2010), and the input of shellfish proteins may have been critical to the development of the human brain (Broadhurst et al. 2002; Erlandson 2010), though this remains an area of scientific debate (Carlson and Kingston 2007; Cunnane 2010; Cunnane et al. 2007). Intensification of shellfish harvesting has been correlated with significant demographic and climatic shifts in the Middle and Late Stone Age, and the use of shells has left evidence of early symbolic behavior and changes in social organization and interaction (Henshilwood et al. 2014; Jerardino 2012; Klein and Steele 2013; Marean 2014; Marean et al. 2007; McBrearty and Brooks 2000).

Nevertheless, in less remote periods of the archaeological past and in other well-studied regions, investigations of shellfish exploitation are underrepresented in the Africanist literature. Perceptions and categorizations of shellfish as low-ranking, starvation foods relied upon in times of stress and poverty may explain a greater focus on other aquatic resources, such as finfish (Msemwa 1994; Quintana Morales 2012). Research along the East African coast and its offshore islands has recently underlined the importance of the marine environment in the formation of social identity among Late Holocene coastal communities (Fleisher et al. 2015). Building on these interpretations, emerging research into the development of marine adaptations on East African islands sets a strong example for future studies by demonstrating the importance of

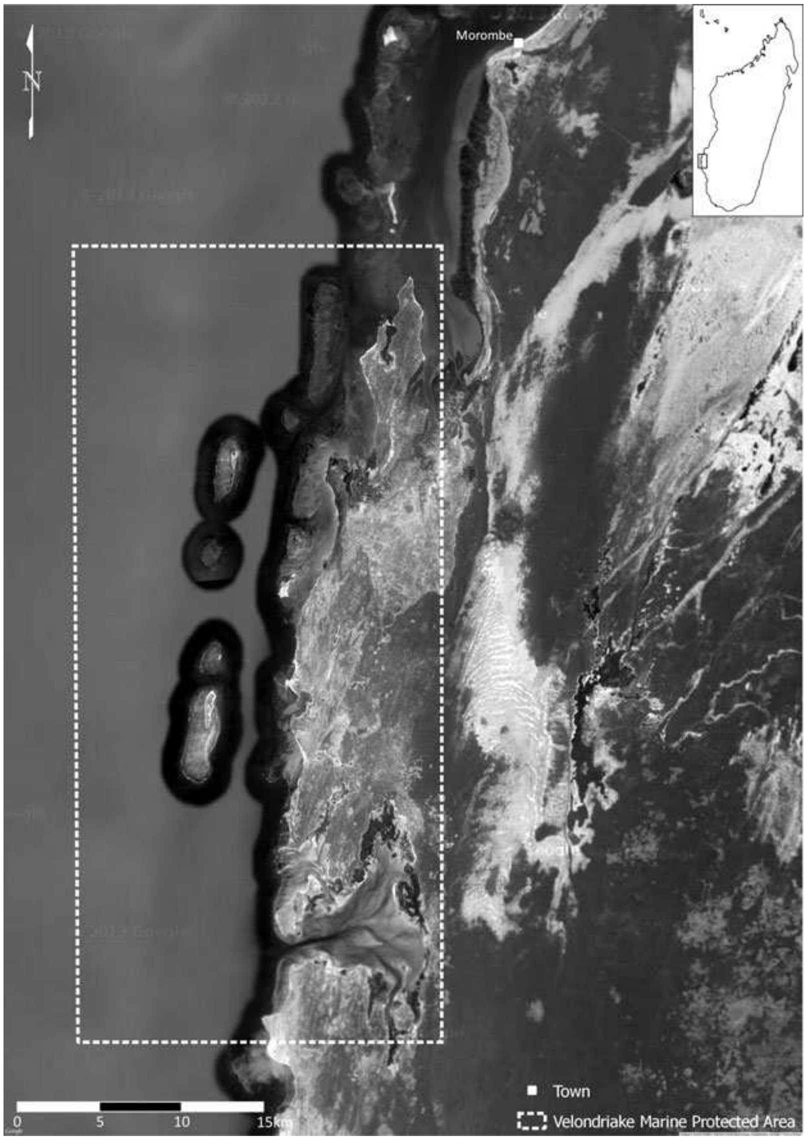

Figure 1. *Map showing the location of the Velondriake Marine Protected Area in southwest Madagascar (rendered by C. Bruwer).*

comprehensive assessment of subsistence data, including shellfish remains (Crowther et al. 2016).

Unsurprisingly, shellfish have been recorded at a diverse array of archaeological sites in Madagascar, from forager rock shelters like Lakaton'i Anja in the far north, to dense urban centers like the stone town of Mahilaka on the northwest coast (Dewar et al. 2013; Radimilahy 1998). At the southern coastal site of Talaky, the visibility of shell middens is what initially drew the original investigators to the site (Battistini et al. 1963). Beyond brief recording of the presence of shellfish remains and some indications of taxonomic representation, however, descriptions of archaeological shellfish assemblages are limited. A survey of archaeological faunal assemblages from southern and southwestern Madagascar in the collections of the Institut de Civilisation Musée d'Art et d'Archéologie (ICMAA) at the University of Antananarivo revealed that roughly one third of the 126 sites studied had shellfish remains (Rakotozafy 2005). The survey results also suggest, however, that the recovery and recording of shellfish remains at the sites in question was not a research priority, since the Minimum Number of Individuals cited for different classes of shellfish at individual sites is always "1" (ibid.).

The most detailed prior descriptions of shellfish assemblages from Madagascar are offered in Parker Pearson's volume on the archaeology of southern Madagascar (Parker Pearson 2010). Shellfish taxa were identified and described by excavation context at several sites, including at Talaky, where new excavations were carried out (ibid.). Abundance of different shell taxa was described qualitatively, and further quantitative analyses would be useful. Descriptions of shellfish assemblages were also offered in two earlier theses, one on the faunal remains of the town of Mahilaka (Rakotozafy 1996), and the other on excavations at the southwestern coastal village of Sarodrano (Barret 1985). Rakotozafy primarily identified mussels (*Pinctada sp.*), oysters (*Ostreidae*), and estuarine snails (*Terebralia sp.*) among the food remains at Mahilaka (1996), but did not provide information on quantification of the assemblage. Barret, writing a decade earlier, recorded a larger diversity of taxa at Sarodrano, including *Fasciolaria trapezium*, *Murex ratusus*, *Anadana natalensis*, and *Pyrazus palustris*, which he ranked in this descending order of importance according to the weight of identified specimens. The recorded weights of *Fasciolaria trapezium* and *Murex ratusus* (32 and 8 kilograms, respectively) far outweighed all other taxa. Interestingly, Barret remarked that no worked shell was recovered from Sarodrano (Barret 1985). He noted only the conspicuous absence of opercula of both *Fasciolaria trapezium* and *Murex ratusus*, which he hypothesized was due to medicinal use of opercula by Vezo fishermen (1985:38). Some shell artifacts were recorded, however, at Talaky and at the necropolis of Vohemar on the north coast, where Vérin and Parker Pearson describe spoons made from turbo and giant clam shell (Battistini et al. 1963; Parker Pearson 2010; Vérin 1975). The apparent lack of worked shell at coastal sites like Mahilaka and Sarodrano is surprising considering the quantities and variety of worked shell from Velondriake. Full description of the worked shell from Velondriake, including beads and net weights, warrants a separate paper and will not be provided here. Re-analysis of other assemblages and comparison with the Velondriake worked shell assemblage, however, may lead to the identification of hitherto unnoticed signs of working.

In recent years, coastal archaeologists have stressed the antiquity of coastal and marine adaptations and the centrality of marine resources to the evolution, growth, and dispersal of human populations around the globe (Erlandson 2010; Erlandson and Braje 2015; Erlandson and Fitzpatrick 2006). As a generally "low-tech" form of resource procurement, shellfishing may have been particularly crucial for communities migrating into formerly uninhabited areas, where new ecological knowledge and procurement strategies had to be developed, especially for the acquisition of more mobile prey, such as finfish, birds, and mammals. The study of shellfishing should therefore lend valuable insights into human colonization of new regions and the development of marine adaptations. In the case of Madagascar, where much remains unknown about the initial phase of the island's settlement and where ephemeral forager sites predominate the early archaeological record, shellfish-bearing deposits—recorded at the earliest known archaeological locality in Madagascar, the rock shelter of Lakaton'i Anja in the far north (Dewar et al. 2013)—may offer a rich source of data on early lifeways, seasonality, spheres of interaction, and paleoenvironment.

SITE DESCRIPTION

Location

The shellfish remains discussed in this paper were recovered from the excavation of a group of coastal archaeological sites in the vicinity of the modern fishing village of Andavadoaka (22° 04'S, 43° 14'E), in the central part of the Velondriake Marine Protected Area coastline (Figure 2). With the exception of the Andamoty-Be site (ANDA), which lies 8 km to the north, all of the archaeological sites discussed here are situated around a bay located 1 km directly south of the village of Andavadoaka (Figure 3 and Figure 4). These sites include the rock shelters Lakatom-Bato Tony (TONY), NSS 2 and 4 (Figure 5), and the open-air villages Antsaragnasoa (ANTS), Antsaragnagnangy (ANGY), and Antsokobory (BORY) (Figure 6). Excavations of these sites were carried out by the Morombe Archaeological Project (MAP) between 2012 and 2014 and are reported in detail elsewhere (Douglass 2016).

Velondriake is a locally managed marine protected area (LMMA)—the first of its kind in Madagascar—in Morombe District's Rural Commune of Befandefa (Harris 2007). Velondriake is bounded by Madagascar's wide western continental shelf, featuring the longest continuous reef system in the western Indian Ocean, and by the highly endemic floral and faunal communities of the island's desert spiny forest (Le Manach et al. 2012). The Velondriake LMMA encompasses a network of 25 modern fishing communities that collaboratively manage local marine resources, in partnership with Blue Ventures, a marine conservation organization. Though shellfish have not received the same attention as other fisheries, a decade of research and conservation efforts have yielded a wealth of data on the exploitation of marine resources by Velondriake's modern communities and recent changes in habitat condition (Cripps 2009; Cripps et al. 2015; Hantanirina and Benbow 2013; Harris et al. 2010; Nadon et al. 2007; Roy et al. 2009). The availability of modern and archaeological datasets on coastal resource use and environmental change in Velondriake presents a unique opportunity in Madagascar for the study of coastal historical ecology (Douglass 2016).

Dating

There is clear evidence for the arrival of human communities in Velondriake beginning in the middle of the first millennium AD at the open-air site of ANGY (Table 1). Based on preliminary findings from a small rock shelter, however, human occupation of Velondriake may extend further back in antiquity and span the last three millennia (Douglass 2016). The earliest recorded radiocarbon date for an archaeological context in Velondriake comes from the rock shelter NSS 2 and, if confirmed with further dating, would place initial occupation of the area between ca. 800 and 500 cal BC, following conservative calibration parameters (Table 1). Given the well-documented "old shell" problem (Rick et al. 2005), the date for NSS 2 was obtained from a perforated *Nerita textile* shell that showed minimal abrasion and was likely gathered as a living organism and buried shortly thereafter. Further details regarding the sample selection and pre-treatment are provided elsewhere (Douglass 2016:151–153). This early date must be confirmed, however, before such a long sequence can be asserted for Velondriake, and due to the uncertain chronology, the shellfish remains from NSS 2 and the other NSS shelters are not discussed in detail in this paper. The NSS 2 date presents the possibility of a relatively early, though perhaps short-lived, human presence in Velondriake and fits within an emerging picture of early foraging activity in Madagascar (Dewar et al. 2013). Radiocarbon dates from the TONY rock shelter suggest short-term, perhaps seasonal, occupation of the shelter by foraging communities beginning as early as cal AD 884–981 through to the modern day. It is possible that the rock shelters of Velondriake served as seasonal forager camps throughout much of the archaeological sequence.

Evidence of a strong maritime orientation is first seen at ANGY, an open-air fishing village. The village features the earliest open-air settlement currently documented in

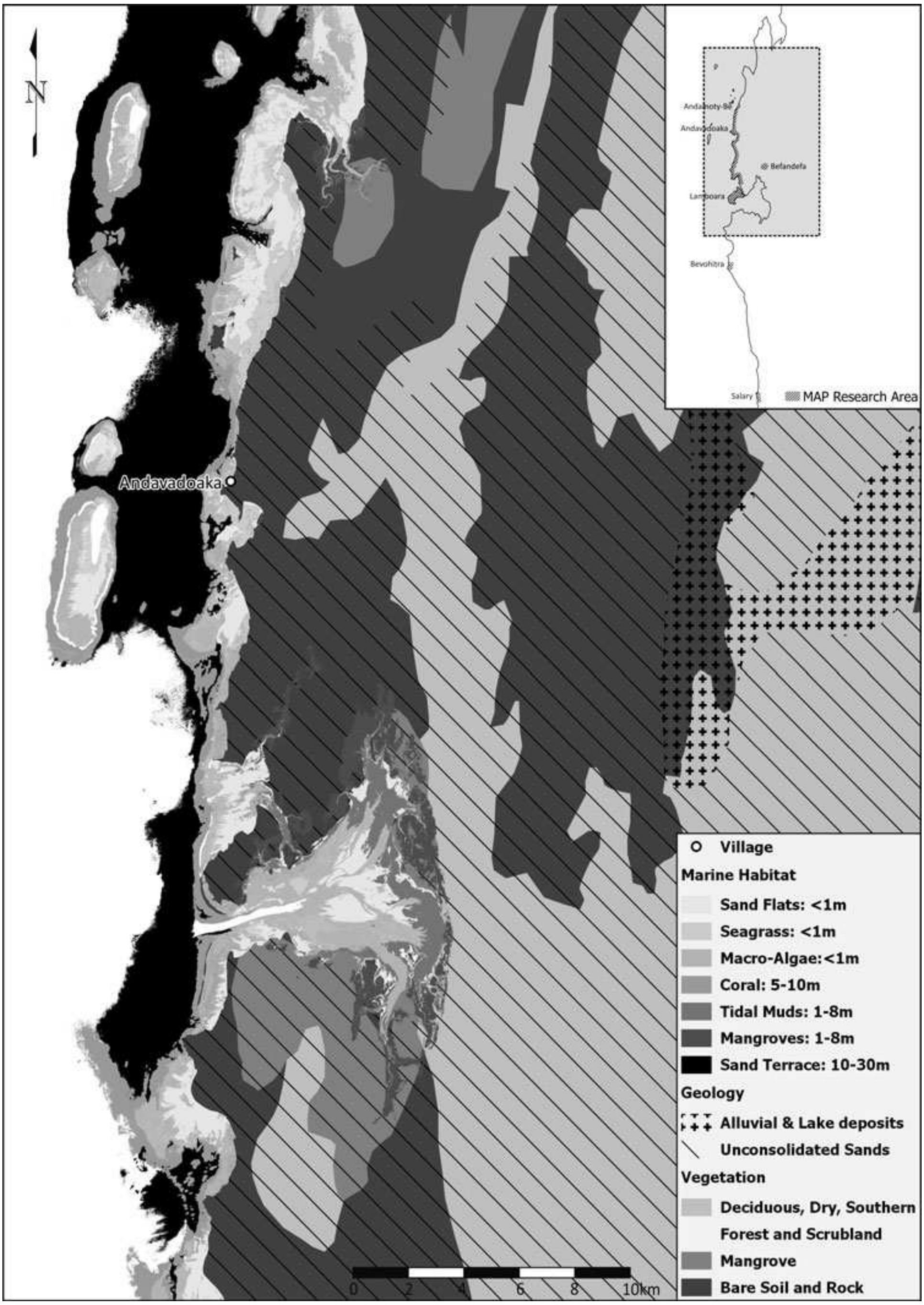

Figure 2. *Map of Velondriake ecology and geology (rendered by C. Bruwer based on data from Roy et al. 2009 and DuPuy and Moat 1996).*

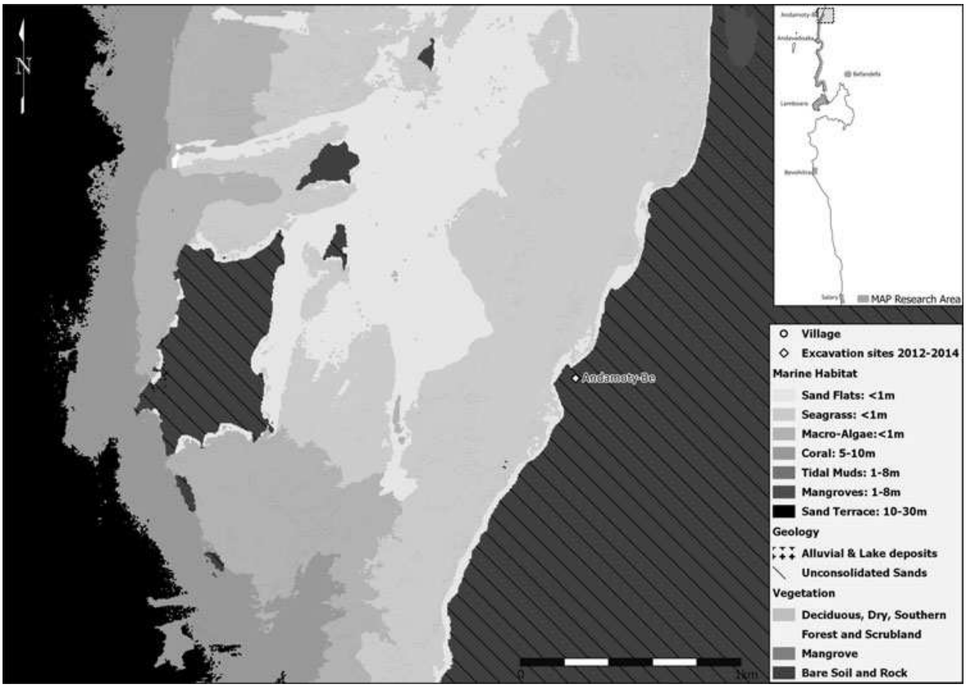

Figure 3. *Habitat map of Andamoty-Be showing the location of ANDA excavations (rendered by C. Bruwer based on data from Roy et al. 2009 and DuPuy and Moat 1996).*

Velondriake, beginning between cal AD 526 and 774, with the densest occupation phase dating around AD 1051–1224. The early date at ANGY was obtained from a perforated *Turbo coronatus* shell, which was selected, dated, and calibrated following the same criteria as the *Nerita textile* shell dated at NSS2. ANGY is the only open-air site with multiple occupation layers investigated in Velondriake thus far. The contemporary villages of ANDA and ANTS, separated by 8 km of coastline, revealed single-occupations dating to the eighteenth–twentieth centuries based on the presence of British stoneware imports and European glass beads.

Environment

Velondriake is located in southwest Madagascar, the most arid region of the island, with annual rainfall averaging less than 50 cm per year (Dewar and Richard 2007). The geology of Velondriake is characterized by unconsolidated sands with alluvial and lake deposits to the east and large mangrove swamps to the north and south (DuPuy and Moat 2003). Large stretches of the coastline feature karst cliffs and outcrops, which pepper the landscape with rock shelters and sink holes. The vegetation is predominantly xerophytic spiny thicket and low-lying shrub, with large areas of bare soil and rock (Figure 7).

The biotic communities of the southwest feature the highest levels of endemicity in Madagascar (DuPuy and Moat 2003; Gautier and Goodman 2003). Despite high overall levels of endemicity, biodiversity is highest with regard to flora and marine life, while mammal and avifaunal diversity are moderate and poor, respectively (Garbutt 2007; Langrand 1990). Biodiversity in southwest Madagascar has declined significantly in the last two thousand years. Most famously, this region has suffered the extinction of

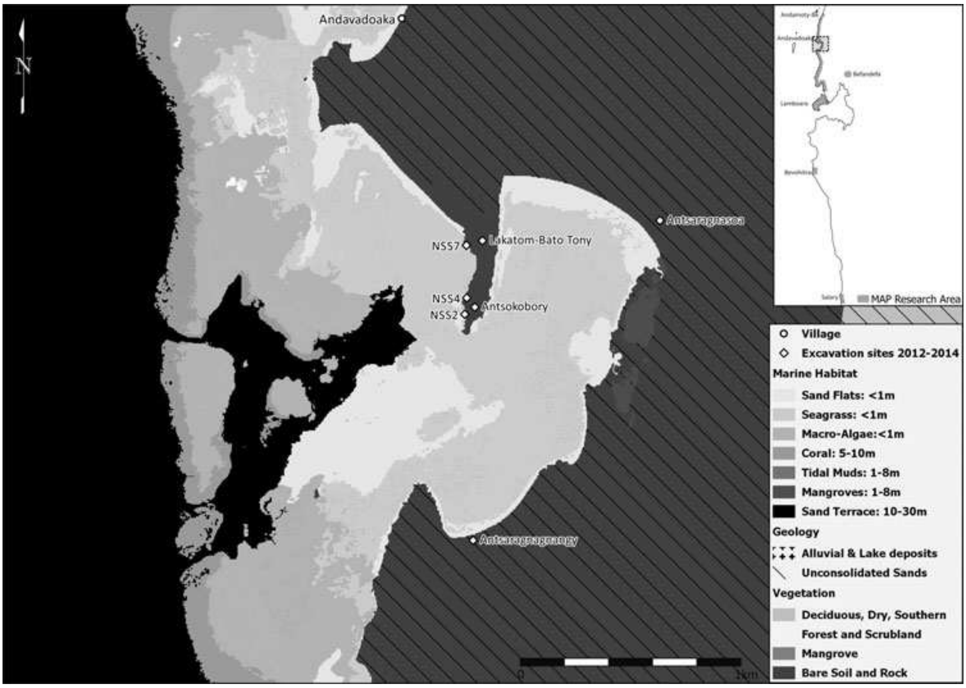

Figure 4. *Habitat map of the Bay of Antsaragnasoa showing the location of ANTS, ANGY, BORY, NSS, and TONY excavations (rendered by C. Bruwer based on data from Roy et al. 2009 and DuPuy and Moat 1996).*

several megafauna taxa, including the large flightless birds of the Aepyornithidae family whose eggshell remains are abundant in the archaeological record of Velondriake (Goodman and Jungers 2013) (Figure 8).

The marine environment from the shoreline of Velondriake to its barrier reef can be divided into four bathymetric zones (Roy et al. 2009) (Figure 2). The shallow reef flats, with water depths of less than 1 m are dominated by sand flats made up of unconsolidated carbonate sand sheets. These sand flats are most common in the shallows of fringing reefs, in the interior of embayments and in the flats of Velondriake's offshore islands. In addition to sand flats, macroalgae and seagrass communities characterize shallow reef flats. Macro-algae cover is most commonly made up of species of Sargassum, while seagrass meadows are predominantly colonized by *Thalassodendron ciliatum* with sub-dominance of *Thalassia testudinum*. Inshore embayments, most impressive in the southern part of Velondriake, generally feature water depths between 1 and 8 m. As one heads inshore, these embayments are characterized by successive overlapping zones of sand flats, tidal muds, and mangrove stands. Mangrove forests thrive in embayments where they draw on the high organic content of tidal muds and are protected from the force of high waves. The five species of mangrove present in Velondriake are *Avicennia marina*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Rhizophora mucronata*, and *Sonneratia alba*. In water depths of between 5 and 10 m, stony coral communities with sporadic patches of macro-algae dominate reef slopes. These living corals today sit atop expansive beds of dead and fossil corals, indicating widespread cover by massive corals in the past. Stony corals in Velondriake include *Acropora, Echinopora, Favia, Favites, Fungia, Pavona, Porites*, and

Figure 5. *TONY rock shelter prior to brush clearing and excavation (photo: K. Douglass).*

many others. The final bathymetric zone is the continental shelf, where water depths range between 10 and 30 m. This sand shelf fills the area between the landward fringing reefs and the offshore reef systems, with a substrate of unconsolidated carbonate sand.

METHODS

Test units, ranging in size from 0.5 m × 0.5 m to 3 m × 3 m square, were excavated at all sites following natural stratigraphy. Sediments were screened using 2 mm × 2 mm mesh screens, in order to maximize the recovery of small finds, such as micro-fauna bones, seed beads, and shell fragments. All recovered shellfish remains were sorted and identified in the field using published identification guides and the experience of project team members who have harvested local shellfish their entire lives (Boxshall et al. 2015; Coleman 2003). Shellfish remains were sorted into bags by context and according to family level and, in most cases, species-level identification. Specimens with discernible elements were counted in order to generate the Number of Identified Specimens (NISP), weighed, and bagged pending further measurements and analyses. Small fragments identifiable to taxon but with no discernible elements and generally smaller than 1 cm were weighed and bagged according to context and taxon, but were not counted toward NISP, since taxonomic identification could not be fully confirmed morphologically. All remaining unidentifiable small fragments (usually <1 cm) were weighed and bagged according to their provenience. Taphonomic indicators such as abrasion, perforation due to animal predation, and burning were recorded (Claassen 1998).

Figure 6. *View of ANGY site looking east (photo: K. Douglass).*

All identified taxa were coded based on a preliminary survey in the village of Andavadoaka of how these taxa are currently gathered, processed, consumed, used, and disposed of, adding insight into archaeological patterns. Taxa were also coded as "preferred," "supplementary," and/or "starvation" foods, and these categories were not mutually exclusive. Overlap generally occurred with non-preferred taxa, where some species were thought of both as supplementary food and as starvation food. These

Table 1. **Calibrated radiocarbon dates for archaeological sites in Velondriake.**

Sample ID	Sample description	Context description	Radiocarbon age	$^{13}C/^{12}C$	Calibrated date (2 sigma 95.4%)
NSS2-1-3-1*	Worked marine shell	Rock shelter, Level 3	3086 ± 32	−0.7	825–504 BC
ANGY1B-10-1*	Worked marine shell	Open air site, Level 10	1954 ± 27	2.9	AD 526–774
ANGY1-4-1**	Charcoal	Open air site, Level 4	915 ± 25	−28.1	AD 1051–1224
TONY 1SE2**	Charcoal	Rock shelter, Level 2	1179 ± 21	−19.9	AD 884–981
TONY 2A917**	Charcoal	Rock shelter, Level 1	196 ± 26	−16.8	AD 1663–Present
ANTS 817**	Charcoal	Open air site, Level 1	279 ± 22	−9.8	AD 1520–1798

*Dates calibrated using Marine13 marine curve (Reimer et al. 2013) with estimated δR of 200 years +/− 50 (Southon et al. 2002; Southon pers. comm.).

**Dates calibrated using SHCal13 atmospheric curve (Hogg 2013).

Figure 7. *View of Velondriake coastline with spiny thicket vegetation and underlying karst (photo: K. Douglass).*

ethnographic data on modern exploitation of shellfish include information on gathering seasons and locations, and were complemented by reference material on species ecology, in order to derive habitat associations (Boxshall et al. 2015). These associations offer an idea of how heavily different habitats (primarily marine habitats) were relied upon by the ancient communities represented at different archaeological sites in Velondriake. Further ethnographic and experimental work would undoubtedly allow for additional insights on decision-making among shellfish gatherers in Andavadoaka (Codding et al. 2014; Thomas 2014).

RESULTS AND DISCUSSION

Shellfish remains included mollusks, crustaceans (Class: Malacostraca), and echinoderms (Class: Echinoidea), but the present discussion focuses on mollusks. Overall, shellfish remains were the most prevalent material collected at open-air sites, and were the second most abundant material at rock shelters, where ratite eggshell predominated the assemblages. Foragers at the rock shelters may have come to this part of the coast seasonally, specifically in pursuit of ratite eggs, presumably during the birds' nesting season (Douglass 2016). In this case, shellfish may have constituted a supplementary food source for inland communities who incorporated marine resources on an occasional basis. In contrast, the faunal assemblages of open-air sites in Velondriake suggest an almost exclusive reliance on marine and estuarine taxa, and a close relationship with the sea throughout the year.

A total of 32065 (NISP) gastropod, bivalve, and chiton shells were recorded from

Figure 8. *Concentration of shell in ANGY unit 1, level 2 (photo: K. Douglass).*

excavation sites (Table 2). By weight, gastropods dominate the overall assemblage, followed by bivalves and chitons (Polyplacophora) (Table 3). The ANGY site yielded by far the largest quantity of shellfish remains across all mollusk classes both by total weight and by density (Figure 8 and 9). The higher density of shells at ANGY is likely due in part to the presence of successive dense occupation layers, while ANDA and ANTS featured a dense primary occupation within the first 30 cm of soil, succeeded by occasional finds suggestive of short-term camps. The difference in shell density between ANDA and ANTS may be due to the placement of excavation units in relation to different activity areas; the excavations may have sampled food processing and consumption areas more heavily at ANTS than at ANDA. Differences in the intensity of shellfish exploitation between ANDA and ANTS could also be linked to the location of these sites vis-à-vis diverse coastal habitats (Figure 3 and Figure 4). Though both sites offer immediate access to seagrass beds and sand flats, ANTS is adjacent to a mangrove stand, where estuarine taxa like *Terebralia palustris* can easily be found. Indeed, this mangrove snail was more prevalent at ANTS (NISP = 231) than at ANDA (NISP = 2) (Table 2). Differences in food preferences between the ANDA and ANTS communities are also a possible explanation.

A total of 30 mollusk families were identified, including eight bivalve families, 21 gastropod families, and one family of the class Polyplacophora (Table 2). Within these families, 46 species were recorded. Taxonomic diversity was highest at ANGY. All 30 families identified across the total assemblage were represented at ANGY and a total of 42 species were recorded .

Abrasion was recorded when abrasive action had removed polished surfaces, rounded shell edges, and/or altered the shell sculpture (Claassen 1998:58). Rates of abrasion were heaviest on terrestrial gastropod shells (Cyclophoridae and *Macrochlamys stumpfii*), which is not surprising as these shells are the thinnest in the assemblage and

Table 2. **NISP of identified mollusk taxa in excavation assemblages in Velondriake.**

Identified species by family and class	ANDA	ANGY	ANTS	BORY	NSS	TONY	Total NISP
Bivalvia	**79**	**2787**	**1041**	**51**		**22**	**3980**
Arcidae	5	201	555	29		13	803
Arca avellana		28					28
Barbatia foliata	4	170	555	29		8	766
Navicularis	1	3				5	9
Cardiidae	3	227					230
Tridacna squamosa	3	227					230
Carditidae		7					7
Cardita variegata		7					7
Glycymerididae	7	55	50	1			113
Glycymeris connollyi	7	55	50	1			113
Lucinidae		29				1	30
Family-level ID		29				1	30
Mytilidae		145	9				154
Mytilus galloprovincialis		145	9				154
Ostreidae	34	1450	7	19			1510
Saccostrea cucullata	34	1450	7	19			1510
Veneridae	30	673	420	2		8	1133
Gafrarium pectinatum alfredense		16				1	17
Tivela compressa	30	657	420	2		7	1116
Gastropoda	**612**	**6201**	**737**	**2569**	**228**	**1996**	**12343**
Ariophantidae		145	119	17	12	192	485
Macrochlamys stumpfii		145	119	17	12	192	485
Buccinidae	15	58	3	12	2	6	96
Antillophos roseatus	13	58	3	7	2	2	85
Family-level ID	2			5		4	11
Bullidae		3					3
Family-level ID		3					3
Bursidae	1	1	1			9	12
Family-level ID	1	1	1			9	12
Cassidae		6	1				7
Cassis cornuta		4					4
Cypraecassis rufa		2					2
Phalium fimbria			1				1

(*Continued on next page*)

Table 2. **NISP of identified mollusk taxa in excavation assemblages in Velondriake. *(Continued).***

Identified species by family and class	ANDA	ANGY	ANTS	BORY	NSS	TONY	Total NISP
Conidae	5	37	2	73	3	12	132
Conus betulinus	4	18		73	3	11	109
Conus ebraeus		16					16
Conus textile		1					1
Family-level ID	1	2	2			1	6
Cyclophoridae	87	35	24	345	125	1412	2028
Family-level ID	87	35	24	345	125	1412	2028
Cypraeidae	76	184	101	2			363
Cypraea annulus	70	140	98	2			310
Cypraea erosa	2	31	3				36
Cypraea histrio		4					4
Cypraea isabella		2					2
Cypraea moneta	2	5					7
Cypraea tigris	2	2					4
Fasciolariidae	26	1107	19	360	3	81	1596
Family-level ID		2	5			1	8
Fusinus colus		2					2
Fasciolaria trapezium	26	1103	14	360	3	80	1586
Fissurellidae	17	101	40	2		1	161
Family-level ID	17	101	40	2		1	161
Melongenidae		2					2
Volema pyrum		2					2
Muricidae	9	434	17	243	12	13	728
Chicoreus austramosus	5	424	15	243	11	13	711
Drupa ricinus		9	2		1		12
Purpura panama	4	1					5
Nassariidae	7	57	14	21	9	1	109
Bullia annulata	1	19	9	8	1	1	39
Bullia diluta		2					2
Family-level ID	6	36	5	13	8		68
Naticidae	4	175	13	34	4	10	240
Family-level ID	2	26	13	3		2	46
Natica tecta	2	149		31	4	8	194
Neritidae	44	832	19	622	57	93	1667
Nerita albicilla	14	155	5	14	3	29	220
Nerita textile	5	107		31	19	10	172
Nerita undata	25	570	14	577	35	54	1275

(*Continued on next page*)

Table 2. **NISP of identified mollusk taxa in excavation assemblages in Velondriake. *(Continued).***

Identified species by family and class	ANDA	ANGY	ANTS	BORY	NSS	TONY	Total NISP
Olividae		6	1			1	8
Family-level ID		1	1				2
Oliva caroliniana		5				1	6
Phasianellidae		1		1			2
Family-level ID		1		1			2
Potamididae	2	1660	231	306		22	2221
Terebralia palustris	2	1660	231	306		22	2221
Strombidae	1	3				5	9
Lambis lambis						5	5
Strombus decorus	1	3					4
Trochidae	4	5				8	17
Monodonta australis	3	2				8	13
Trochus nigropunctatus	1	3					4
Turbinidae	314	1349	132	531	1	130	2457
Turbo coronatus	314	1349	132	531	1	130	2457
Polyplacophora	**1000**	**6434**	**5380**	**1370**	**10**	**1548**	**15742**
Chitonidae	1000	6434	5380	1370	10	1548	15742
Onithochiton literatus	1000	6434	5380	1370	10	1548	15742
Grand total	1691	15422	7158	3990	238	3566	32065

most prone to degradation from exposure to the elements. The marine gastropod *Turbo coronatus* featured by far the most abrasion of any marine or estuarine species. This is likely due to frequent use of these shells as net weights for fishing in coral communities, since the high density and sphericity of *Turbo coronatus* shells should minimize the effects of post-depositional erosion (Wolverton et al. 2010). On the other hand, bivalve and chiton specimens were almost always recovered as individual valves or valve fragments, suggesting a high degree of fragmentation, as seen in other faunal remains from these sites (Douglass 2016).

Burning was most commonly recorded (40% of total NISP) on chiton remains (*Ornithochiton literatus*). The marine gastropods *Fasciolaria trapezium* (15%) and *Turbo coronatus* (13%), and the mangrove-dwelling snail *Terebralia palustris* (14%) also featured high incidences of burning, suggesting that these species were cooked in their shells over open fires, as they are often prepared today.

Signs of non-human predation were also recorded and were primarily characterized by small conical-shaped boreholes in and through the shell body. Perforations by predatory animals were most common on land snails of the Cyclophoridae family (32% of total NISP), and were also recorded on *Tivela compressa* clams (15%) and on oysters of the species *Saccostrea cucullata* (13%).

Common cultural alterations to shell were drilling and hammering. Hammering was likely used as a method of meat extrac-

Table 3. **Total weight by mollusk class and family of recovered shells in grams for excavated sites in Velondriake.**

	ANDA	ANGY	ANTS	BORY	NSS	TONY	Total weight
Bivalvia	1043	15494	15384	55		12	31988
Arcidae	87	565	14663	19		6	15340
Cardiidae	598	2437					3035
Carditidae		256					256
Glycymerididae	0	104	33	7			144
Lucinidae	19	176				1	196
Mytilidae		66	3			0	69
Ostreidae	272	10849	242	20		0	11383
Veneridae	67	1041	443	9		5	1565
Gastropoda	7834	33758	11326	3914	916	2108	59856
Ariophantidae		20	28	19	2	69	138
Buccinidae	15	93	4	12	4	4	132
Bullidae		9					9
Bursidae	149	10	53			4	216
Cassidae		103	2				105
Conidae	135	128	6	148	32	9	458
Cyclophoridae	82	13	14	365	62	773	1309
Cypraeidae	152	377	80	4			613
Fasciolariidae	4618	12602	2263	1002	480	747	21712
Fissurellidae	2	40	13	1		0	56
Melongenidae		21					21
Muricidae	962	3661	1275	797	76	15	6786
Nassariidae	14	104	14	13	10	1	156
Naticidae	10	405	54	50	19	12	550
Neritidae	176	2034	75	607	230	151	3273
Olividae		11	2			0	13
Phasianellidae		2		1			3
Potamididae	40	10010	6910	484		105	17549
Strombidae	1	14				25	40
Trochidae	27	15				11	53
Turbinidae	1451	4086	533	411	1	182	6664
Polyplacophora	945	4781	292	622	4	520	7164
Chitonidae	945	4781	292	622	4	520	7164
Unidentified	178	6075	869	496		24	7642
Total weight	10000	60108	27871	5087	920	2664	106650

tion and was most commonly recorded on mangrove snails (*Terebralia palustris*—26% of total NISP), the large marine snail *Fasciolaria trapezium* (19%), and the smaller marine snail *Nerita undata* (11%).

Drilling of the shell body is sometimes performed in the modern day for meat extraction, and may have been a technique used in the past as well. Drilling was also used to create what are likely net weights. *Turbo coronatus* shells made up 31% of perforated shells in the overall assemblage, followed in descending order by oyster shells (*Saccostrea cucullata*—20%). These medium-sized shells are still used today as net weights for fishing in inshore waters and on reef flats, whereas large shells like *Fasciolaria trapezium* (9%) are used as weights for heavier gauge nets strong enough to catch large pelagic species. The relatively low occurrence of net weights made of large heavy shells correlates with the primary reliance on reef fishes seen in the fish assemblages from these sites (Douglass 2016; Grealy et al. 2016, in review).

All excavation sites with the exception of ANTS featured shell beads. The analysis of shell beads is ongoing, but two primary types of beads were distinguished: flat spherical beads with complete perforations, and cowrie shell beads with various perforation patterns. The flat spherical beads resemble ostrich eggshell beads, and preliminary assessment indicates that some beads of this type are made of Madagascar ratite eggshell (Douglass 2016). The cowry shell beads were made from a variety of cowries, most commonly *Cypraea annulus*, *Cypraea erosa*, and *Cypraea moneta*. The last of these, the "money cowry", was widely used as currency in the Atlantic, Indian Ocean, and even Pacific trade spheres, beginning as early as the middle of the first millennium BC (Allibert 2000). The cowry beads were exclusively found at ANGY, and are associated with the richest occupation layers dated to cal AD 1051–1224. Further analysis will offer more insight into their use at ANGY and their possible connections to overseas trade.

Based on the preliminary survey of modern food preferences in Velondriake, the most abundant taxa among the starvation foods in the archaeological assemblages were chitons, which are described by Velondriake locals as offering a small amount of meat considering the effort required to pry the animals off rocks and separate the meat from the exoskeleton. In Velondriake today, chitons are thought of as starvation food, but also as snack food for children when they are out playing. Site-by-site comparison of taxa according to their food status indicates that the highest proportions of preferred food taxa were collected at ANGY and BORY (Figure 10). Meanwhile, ANTS and TONY stand out as having a much larger proportion of supplementary and starvation food taxa versus preferred species in their assemblages. At ANTS the reliance on supplementary and starvation foods is matched by a degree of poverty in the material culture assemblage, where quantities and variety of local ceramics and trade items, such as ceramic imports and beads, are very limited in comparison to the material culture of ANDA and of the contemporary phase at ANGY (Douglass 2016). Further analysis of the data may allow for discussion of a possible increase in the reliance on non-preferred taxa in the latter part of the Velondriake sequence. The relatively high proportion of non-preferred to preferred taxa at ANDA and ANTS, both of which are eighteenth-century settlements, when compared to the eleventh–thirteenth-century ANGY phase, could be indicative of changes in the availability of preferred taxa due to heavy exploitation. Multiple lines of evidence must be considered, however, since research on intensive shellfish exploitation in other parts of the world, like on California's Channel Islands, has demonstrated that shellfish populations can be remarkably resilient under the pressure of intensive harvesting (Braje et al. 2012). Heavier reliance on non-preferred shellfish taxa in the later part of the Velondriake sequence must also be considered in light of the decline and extinction of high-value terrestrial fauna, such as the elephant birds (*Aepyornithidae*). In this regard, changes in marine and terrestrial resource exploitation patterns in Velondriake may be compared with archaeological case studies from

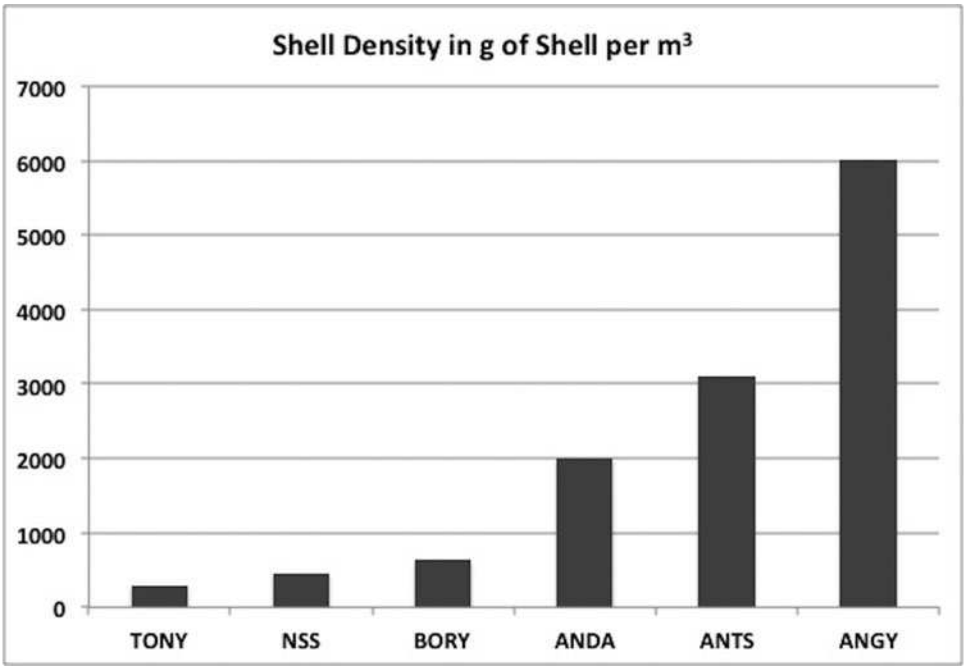

Figure 9. *Density of recovered shells in grams per m^3 of excavated soil.*

New Zealand, where the disappearance of high-value taxa like the moa led to increasingly specialized shellfishing (Jacomb et al. 2010).

Finally, using reference materials and local people's accounts of shellfish-gathering practices in Velondriake, habitat associations were derived for each species for comparison with modern habitat distribution (Roy et al. 2009) (Figure 2, Figure 3, and Figure 4). The habitat categories are not mutually exclusive as some species are found in several of the habitat classes. The overall assemblage indicates a relatively strong reliance on sand flats, and a moderate reliance on coral, seagrass patches, algal ramparts,[1] mangrove and tidal muds (Figure 11). Land shells formed a relatively small proportion of the overall assemblage and were most heavily represented at the rock shelter sites (TONY, NSS). Site-to-site comparison follows the same general trend of heaviest reliance on sand flats. The shellfish data on habitat reliance echo patterns in the finfish remains, which indicate a primary reliance on shallow reef communities, with very little evidence for the pursuit of pelagic species (Douglass 2016; Grealy et al. 2016, in review).

In the eleventh–thirteenth-century ANGY layers there seems to be a stronger reliance on taxa primarily gathered in seagrass habitats than can be seen in the eighteenth–twentieth-century contexts at the ANDA and ANTS sites (Figure 12). This could be indicative of a change in the distribution and health of seagrass communities in Velondriake over time. Seagrass meadows are highly productive and important habitats for many marine species, including fish and shellfish. They also play a critical role in mitigating the disastrous effects of sedimentation on coral communities caused by climatic and anthropogenic factors (Maina et al. 2012; Maina et al. 2013). Virtually no data exist, however, on changes

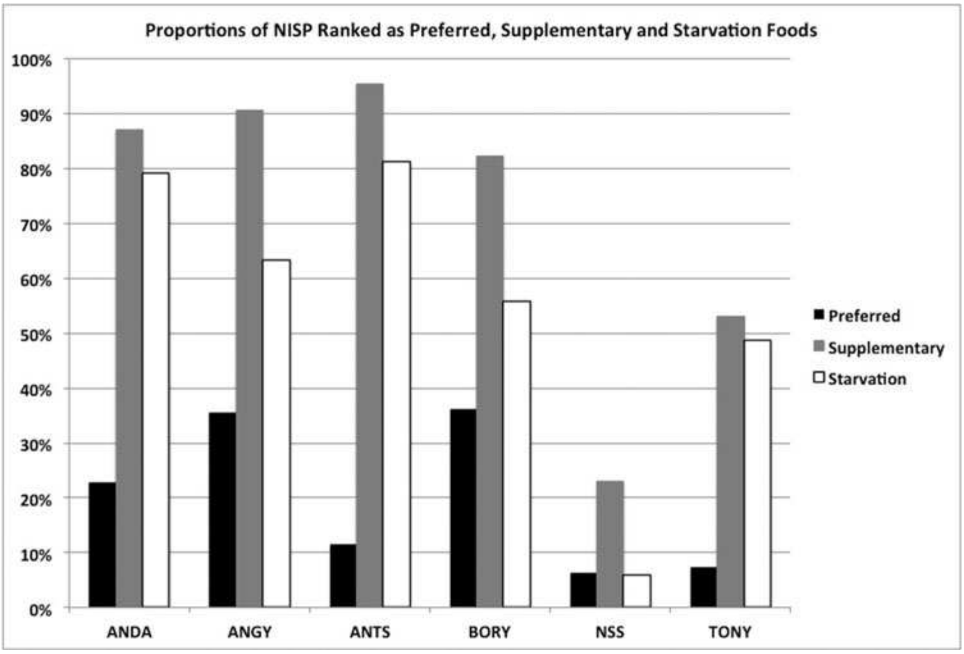

Figure 10. *Relative proportions of shellfish taxa coded as preferred, supplementary and starvation foods using ethnographic survey. Note: Proportions add to >100% because categories are not mutually exclusive. Taxa that are not considered edible are excluded.*

in the health and distribution of seagrass communities in Madagascar in the past; coral reefs and mangroves have traditionally been the research foci of coastal ecologists in Madagascar, despite the importance of seagrasses in maintaining the overall health of intertidal ecosystems (Hantanirina and Benbow 2013). In this case, the zooarchaeological data from Velondriake may be instrumental in understanding changes in the health and distribution of coastal habitats in the region in the past (Wolverton et al. 2016).

CONCLUSIONS

This article has presented an overview of the shellfish remains from recently excavated archaeological sites in the Velondriake Marine Protected Area, and has argued that the investigation of shellfish exploitation in the past and present should be a future research priority in Madagascar, if we are to more fully understand the interaction between human communities and the island's coastal zones. Further analysis of the Velondriake assemblages will undoubtedly offer many more insights into coastal lifeways, craft and tool production, and spheres of social interaction. Particularly important will be comparisons across excavation levels at individual sites, measurement of morphological features to assess changes in size of individual taxa through time, further recording and analysis of taphonomic processes, and the study of shell tool and craft industries.

More broadly, future work must tackle the topic of past and modern-day shellfishing in Madagascar in a multitude of ways, including comparative ethnographic and experimental studies of shellfishing, documenting the production and exchange of shell artifacts, and analyzing previously excavated ar-

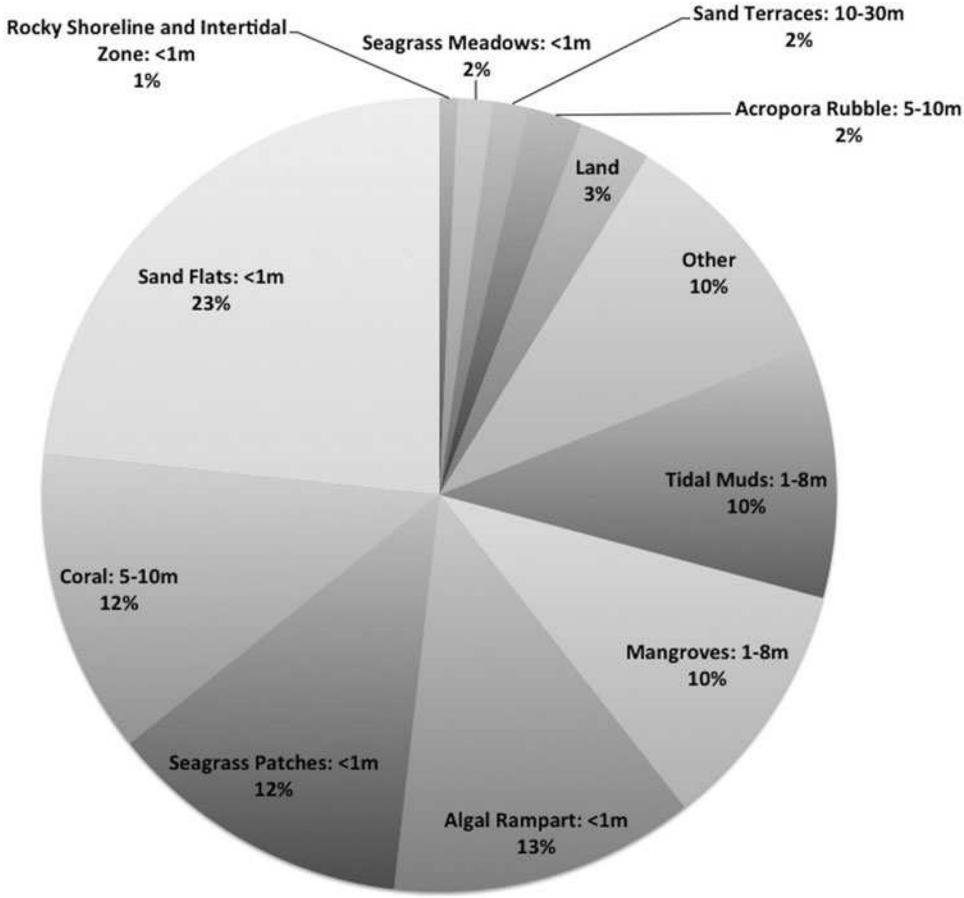

Figure 11. *Habitat associations of combined Velondriake shellfish assemblages.*

chaeological shellfish assemblages. The analysis of previously excavated shellfish collections is particularly crucial and likely to yield new insights into coastal lifeways at several important archaeological sites as we refine taxonomic identifications, identify and describe the working of shell and use of shell tools, use shell chemistry as a proxy measure of paleoenvironmental change and compare shellfish paleoclimate indices with existing paleoclimate archives for Madagascar and the western Indian Ocean (Douglass and Zinke 2015).

Shellfish studies and the field of environmental archaeology more broadly could contribute valuable data and perspectives that could inform current debates over resource exploitation, sustainability, and conservation in Madagascar. Though no quantitative data exist on the current state of shellfisheries in Madagascar, fishermen in the village of Ampasilava in Velondriake have commented on the decline of several highly valued taxa, including shells of the Muricidae and Fasciolariidae families and spiny lobsters of the Palinuridae family (Iida 2005). Archaeological data suggest that these taxa were important to past communities as well, both as food items and for trade. Given the dire forecasts from conservation scientists all over Madagascar regarding resource overexploitation and the decline of native floral

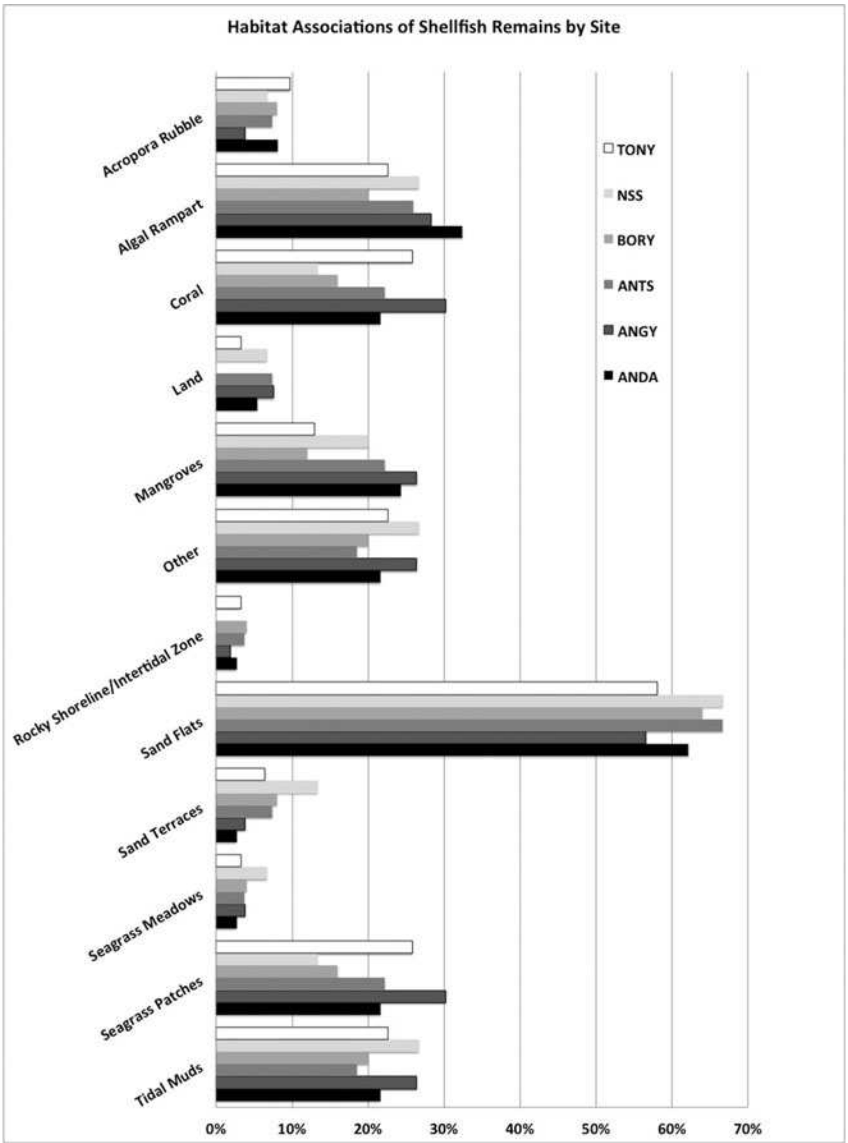

Figure 12. *Habitat associations of shellfish remains by site. Note: Proportions add to >100% because categories are not mutually exclusive.*

and faunal populations (Harris et al. 2010; Le Manach et al. 2012; Rakotomanana et al. 2013; Seddon et al. 2008), the contribution of archaeological data on the past distribution and health of natural communities, and past exploitation patterns, is critical (Wolverton et al. 2016).

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END NOTE

1. An elevated margin forming the seaward periphery of reef flats.

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