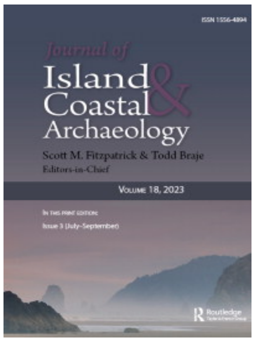

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New archaeological discoveries in north-central Timor-Leste indicate sociocultural adaptations to landscape change during the Holocene

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ABSTRACT
During the Holocene, Wallacea saw dramatic sociocultural changes during the Pre-ceramic, Neolithic, Metal-age, and Colonial periods, as well as climatic and associated environmental changes that affected the landscapes and ecologies of islands. These environmental and cultural processes appear to have influenced human socioeconomic adaptations throughout the archipelago. Here, we present new anthropological and archaeological data demonstrating the effects of these processes. Excavations at the cave site of Hatu Saur on the north coast of Timor-Leste have revealed a deep archaeological sequence that dates from ca. 10,500 years until the present. The site contains extensive assemblages of faunal remains, as well as stone artifacts, revealing settlement patterns that were influenced by sea level change and estuarine infilling after 7 ka. The sequence encompasses the beginning of the Neolithic in Timor-Leste, some 3500 years ago, and the period from ca. 700 years ago when outside influences, including Chinese and Makassar traders and Dutch and Portuguese colonization, greatly affected the indigenous culture and economy on the island of Timor, reflected in the material culture remains from Hatu Saur. The archaeological findings complement related anthropological research in the region that highlights unique local mythologies of settlement origins and their contested histories.

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Introduction

The archaeological record indicates that globally, the Holocene witnessed dramatic economic and social changes in precolonial indigenous communities with the development

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of elaborate material cultures, new technologies, food production, and more complex sociopolitical systems (e.g., Bellwood 2023; Langley et al. 2023; O'Connor 2015). Research in Timor-Leste and elsewhere in the tropical islands of the Asia-Pacific has indicated that these global forces for change in human culture and economy were also expanding in this region during the Holocene. Pre-ceramic maritime culture with obsidian networking, sailing technology, shell disk bead ornaments, and advanced coastal foraging practices had already been established in Wallacea (Glover 1986; Kealy et al. 2020; Langley and O'Connor 2015, 2016; Langley et al. 2016; Langley et al. 2023; O'Connor et al. 2022; Oliveira 2008; Reepmeyer et al. 2011; Reepmeyer et al. 2016; Shipton et al. 2020) by the time Austronesian-speaking Neolithic cultures also spread across open seas from Taiwan and Mainland Southeast Asia into Island Southeast Asia (ISEA) with pottery and domesticates (Bellwood 2023; O'Connor 2015). This paradigm shift underwent complex interactions with local indigenous peoples and cultures (Bellwood 2023; Lape et al. 2017; O'Connor and Veth 2005; Veth et al. 2005) and was followed further by later dispersals of metal-age culture after 2500 cal BP before subsequent colonial powers became dominant (Bellwood 2023; Hawkins et al. 2020; Ono et al. 2021). These sociocultural and economic changes, as indicated by anthropological studies (O'Connor et al. 2012), likely resulted in a complex series of sociopolitical interactions seen in the contemporary period of Timor-Leste today.

Until recently, little was known of the socioeconomic past of precolonial societies in north-central Timor-Leste. Previous archaeological studies have largely focused on the Baucau plateau and the eastern end of the island (see Glover 1986; O'Connor 2007; O'Connor et al. Clarkson 2011; O'Connor et al. 2010; Oliveira 2008; Shipton et al. 2019; Veth et al. 2005). Current data for Wallacea indicate that resource intensification and diversification occurred over time as indigenous populations adapted to significant climatic and environmental changes (Hawkins et al. 2017; Kealy et al. 2020; Roberts et al. 2020; Shipton et al. 2019). Sea levels had risen sharply during the Holocene and stabilized with reef expansion facilitating coastal resource foraging, although the north coast of Timor is steep and so not much reef expansion occurred there. Warmer and wetter conditions likely increased the use of riverine environments by inhabitants in Wallacea and the establishment of horticulture during the Middle Holocene (Brockwell et al. 2016; Kaharudin et al. 2019; Kealy et al. 2020; Shipton et al. 2020; Veth et al. 2005). However, more data are required to test cultural adaptations to these shifts in climate and environment at the regional and temporal level.

In 2011, excavation was undertaken at the rockshelter Hatu Saur near the village of Laleia in north-central Timor-Leste. This revealed deep archaeological deposits with a sequence that records cultural activity at the site from ca. 10,900 years until ca. 200 years BP, although occupation was not continuous. The site contains extensive assemblages of faunal remains and stone artifacts. It encompasses the inception of the Neolithic in Timor-Leste dated to some 3500 years ago, which brought pottery and domestic animals to the island (O'Connor 2006, 2015; Oliveira 2008; Piper 2017). It also covers the contact period from ca. 1000 years ago during which outside influences, from Chinese and later Makassar traders to Portuguese and Dutch colonization, profoundly affected the indigenous culture and economy (O'Connor et al. 2012). Historical research and the remains of indigenous fortifications on hill tops overlooking the Laleia River and the sea on the north coast suggest that the often reported sixteenth century Portuguese trading port of Adê (Adem) was located nearby (Fenner et al. 2020; McWilliam 2007). This paper presents the results of archaeological and anthropological research in the Laleia river catchment to understand human settlement patterns and adaptations to regional sociocultural and climatic changes in the vicinity of this once strategic economic coastal center of Timor-Leste. To this end, we utilize zooarchaeological (vertebrate and invertebrate) and artifact (lithic, shell) analyses at Hatu Saur, complemented by oral histories that highlight local mythologies of settlement origins and their contested histories and paint a vibrant picture of sociopolitical complexity in historic and contemporary Timor-Leste.

Study area

Timor-Leste is located on the eastern side of Timor Island in the Lesser Sunda Islands at the southeastern periphery of eastern Indonesia and northwestern Australia (Figure 1). This steeply uplifted coral limestone island, with Australian continental plate core, is located eight degrees south of the Equator, and the north and south coasts of Timor are divided by mountain ranges rising to 3000 m. Archaeological excavation was undertaken at Hatu Saur in 2011 on the north-central coast, east of the capital Dili. The cave is located 20 km east of the main district town of Manatuto, 4 km south of the coast, and 1 km west of the village of Laleia, which lies on the Laleia River (Figure 2). The village, with its remnant Portuguese fortification and fine eighteenth century Catholic Church, strategically straddles an elevated ridge overlooking the irrigated rice fields of the Laleia River floodplains (Figure 3). The settlement is locally renowned as the birthplace of Xanana Gusmão, hero of the resistance movement during the

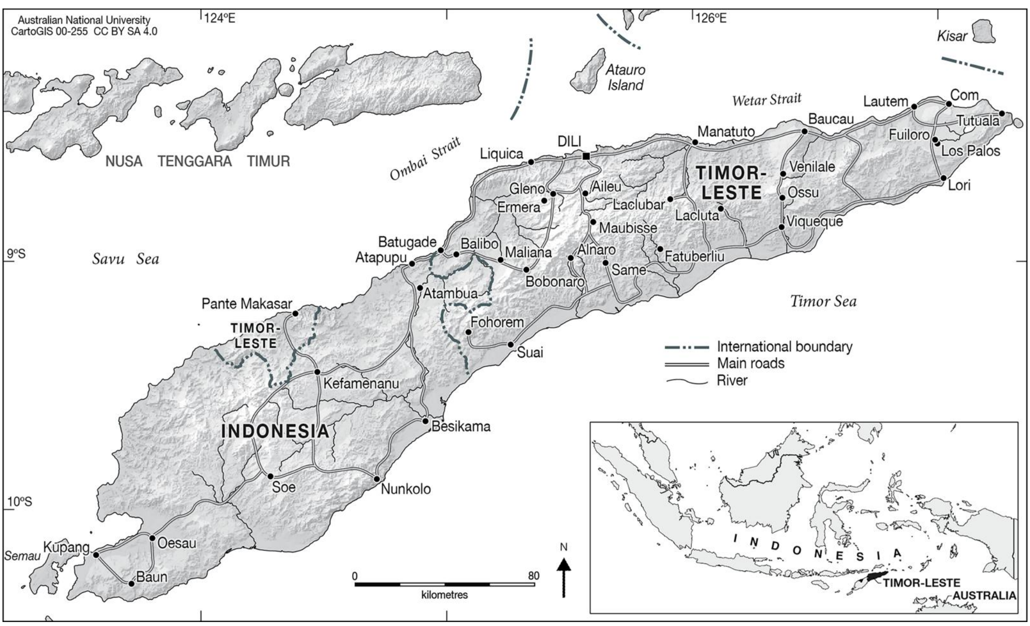

Figure 1. The island of Timor showing the country of Timor-Leste. Inset indicates the location of Timor-Leste in the wider Indonesian Archipelago.

Figure 2. Satellite image from GoogleEarth of the northern Manatuto region showing the location of Laleia and Hatu Saur.

Indonesian occupation from 1975 to 1999, and first President and current Prime Minister of Timor-Leste.

Regional archaeology

The earliest modern human settlement of Wallacea and the longest record for occupation in this central part of Timor-Leste derives from Laili, a large cave located within a limestone formation 1 km from Hatu Saur in the central part of the village of Laleia (Figure 3A) and dated to between ca. 11,200 and 44,200 cal BP (Hawkins et al. 2017). The upper Holocene deposits of Laili cave are thought to have been removed by human agency (O'Connor et al. 2017) and, thus, the results from the excavation at Hatu Saur offer a critical and complementary component to understanding the full human settlement history of the Laleia region.

Previous investigations, west of the current study area, revealed open sites with stone artifacts, shell, and local pottery, rockshelters with stone and shell assemblages and rock art, and fortified hilltop settlements. All are dated within the last 6000 years and most within the last 2000 years (Chao 2008; Forestier and Guillaud 2013; Lape and Chao 2008).

Surveys in the Laleia region have revealed a similar range of sites, including remnants of old villages with stone wall and house foundations and concentrations of marine and

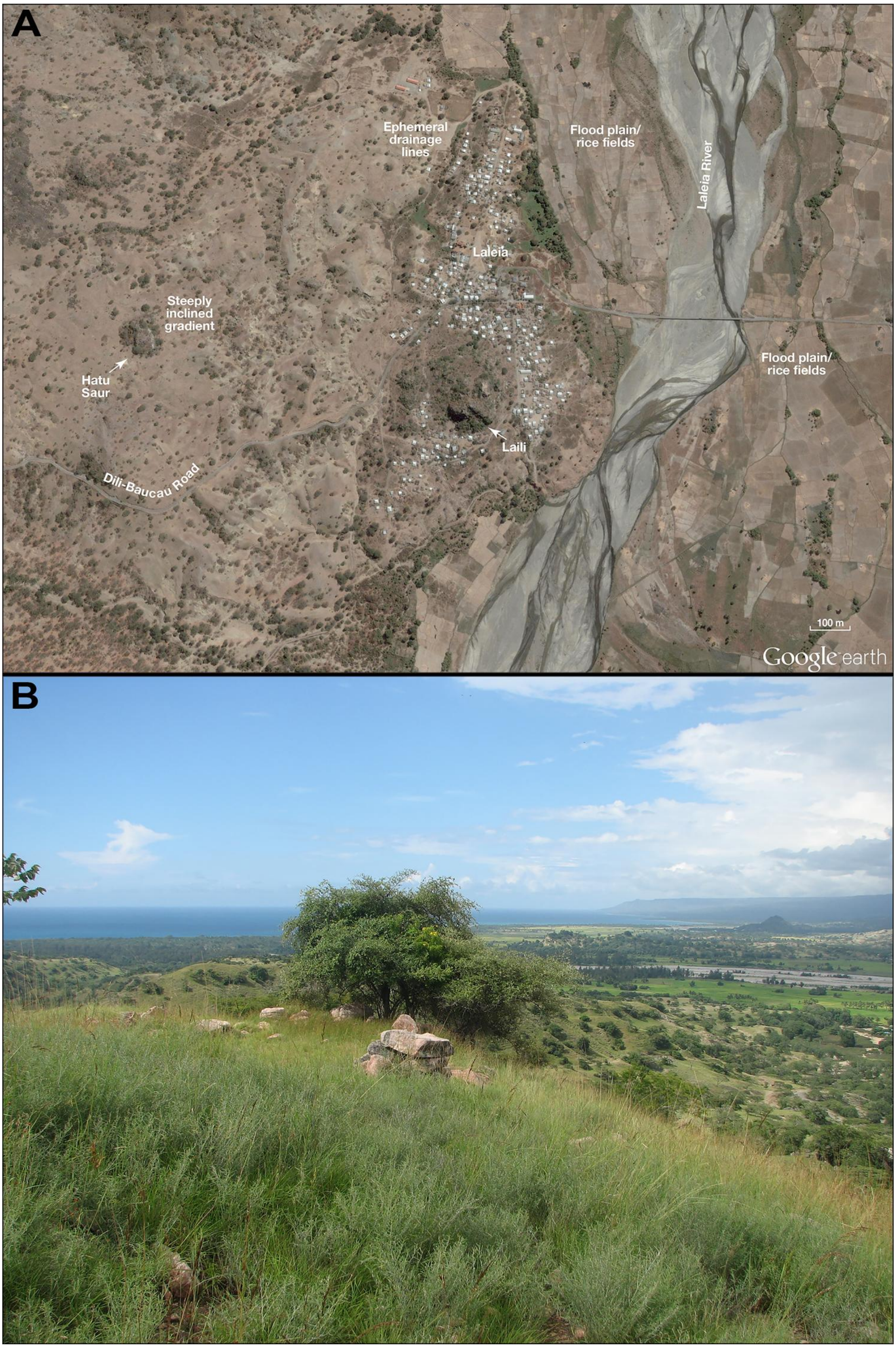

Figure 3. The location of Hatu Saur in relation to the Laleia River. (A) Satellite image from GoogleEarth showing the location of the sites of Hatu Saur and Laili, the village of Laleia and the Laleia River. (B) View from above Hatu Saur, looking north toward the Wetar Strait and east to the Laleia River and rice paddies.

estuarine shell, pottery, and Chinese tradeware (Brockwell et al. 2016; Fenner et al. 2020). Surprisingly, an aceramic stone and shell scatter adjacent to the Laleia River dated unexpectedly early to 9675–9390 cal BP (Wk-28440) (on a surface find of *Tegillarca granosa*). This open site, known as Kampung Baru 1 (new village), perhaps indicates reworking and/or redeposition of older cultural materials during flooding events (see Supplementary Information Table S1). A shell sample (*Telescopium telescopium*), from a shell scatter with pottery sherds on a hilltop adjacent to the mouth of the Laleia River (Kampung Baru 2), was dated to 424–96 cal BP (Wk-28441; Table S1).

The nearby elevated settlement of Leki Wakik has been occupied within living memory. It contains surface scatters of shell, stone, pottery, and Chinese ceramics attesting to its occupation from about AD 1450 until at least 1950 (Fenner et al. 2020, 113, 127); this is consistent with the ages of other fortifications both regionally and elsewhere in Timor-Leste (e.g., Chao 2008; Lape and Chao 2008; O'Connor et al. 2012; O'Connor et al. 2020).

Hatu Saur

Hatu Saur is a small rockshelter, 5 × 8 m, located in a large limestone outcrop about 1 km west of the village of Laleia. It lies 4 km south of the northern coastline, which drops steeply away to the continental shelf (Figures 1 and 3B; O'Connor 2007, 530).

People still use the site to house goats. It also contains a sacrificial *téi* altar (Figures 4 and 5). *Téi* sites mark the presence of non-human or spirit entities considered to be inherently dangerous and associated with a range of protocols, prohibitions, and protective powers (Lape et al. 2020, 52). They are marked by specific physical structures, most commonly by platforms built of layered stones or coral blocks, and a central, carved wooden altar post or, as in this case, a plain, upturned tree root (Figure 4). There is no current knowledge of the nature of this *téi* but the locals still respect its power. As people say, "we live in modern times, but do not ignore the old places." Nevertheless, we were given permission to excavate.

Social and historical context

Anthropology can offer productive insights into past practices where the archaeological record overlaps with cultural memories and mythic narratives of place that local people have retained from ancestral times. For the island of Timor, this means the Late Holocene and the advent of European colonial history from the sixteenth century. Thus, Laleia oral history and stories of origin can add to our understanding of changes in the settled landscape.

To begin with the present demography, the status of Laleia as a sub-district of Manatuto reflects a lengthy history where the settlement was documented as a minor political center allied to the larger neighboring kingdom of Manatuto in the west and with Vermasse immediately to the east (Davidson 1994; Gunn 1999). Each of these political domains were and remain speakers of an Austronesian language, known as Galoli, while a range of local alternate minority Austronesian languages are also used (Hull 2002). The sub-district of Laleia is made up of three villages or *suku*. Population

Figure 4. Hatu Saur rockshelter and excavation photos. (A) Facing southwest, showing the excavation square and nearby téi; (B) excavation and téi showing the stone arrangement around the base of the téi; (C) the excavation square with the south wall bordered by the scale at the top.

numbers are low; the total population was 3089 in 2010 (Timor-Leste 2011, 20), and while some people may be absent as residents in the main cities of Baucau or Dili, the numbers point to historically low population densities over long periods of time.

Kairui village, located some 7 km upstream of the township on the banks of the Laleia River, contains a different ethno-linguistic community, speaking another Austronesian language, referred to as Kairui-Midiki or Oko. Neither the Galolien areas, nor the Kairui language group has ever been the subject of detailed ethnographic research and, hence, there is considerable scope for further anthropological research (e.g., see Hicks 2007).

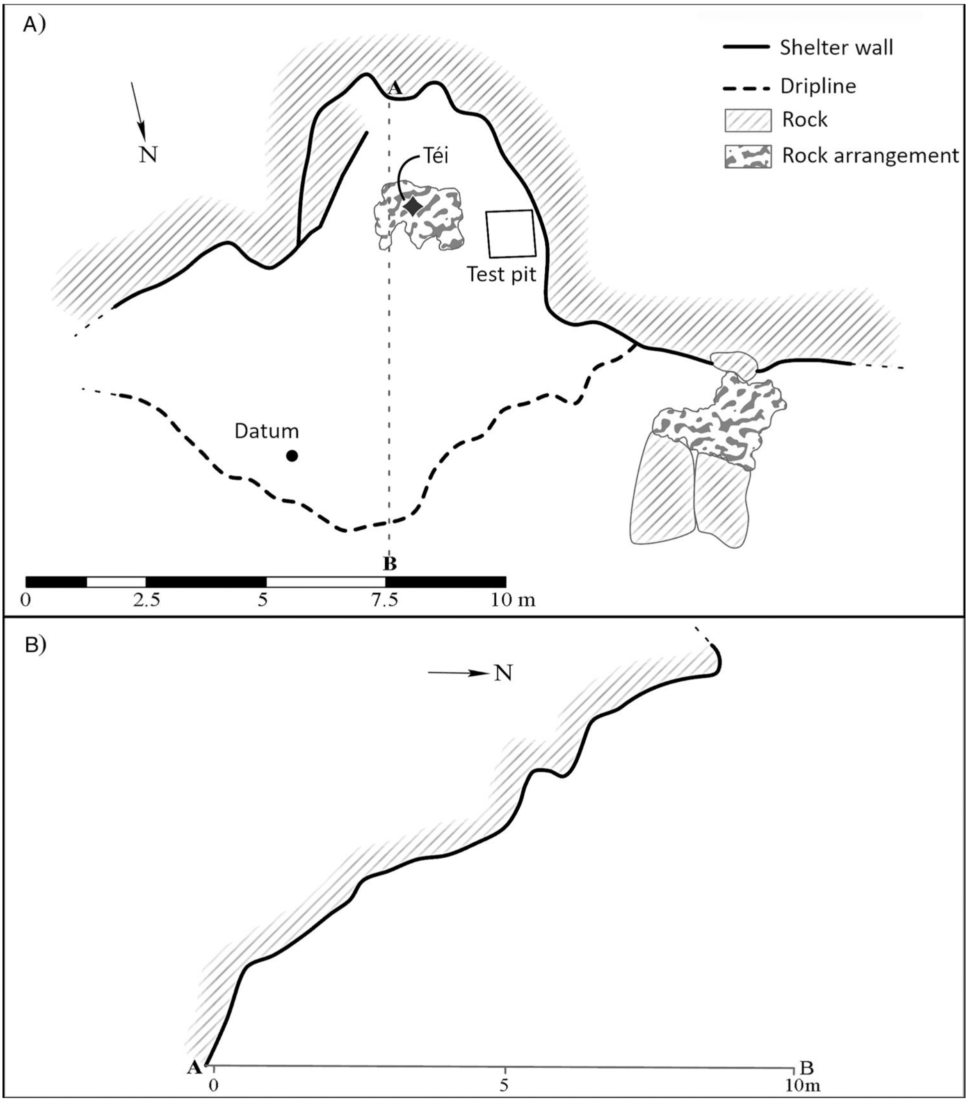

Figure 5. Hatu Saur rockshelter: (A) plan and (B) profile.

Methodology

Anthropology

The archaeological research at Hatu Saur was complemented by anthropological research undertaken for the broader project on forts and fortification in Timor-Leste (see O'Connor et al. 2020). Background historical perspectives drawn from a range of written records and historical studies, along with contemporary census data and oral histories retained by local authorities, were accessed to provide key information on settlement patterns, political history, and aspects of the cultural heritage of Laleia. The key historical sources include detailed analysis of the recorded Portuguese history of the area and shifting power relations (see Davidson 1994; McWilliam 2007; Roque 2010).

Perspectives on the past were also recorded from local customary authorities—people known to have detailed ethno-historical knowledge of their respective communities and origins. They included lengthy interviews with local knowledgeable custodians for Laleia proper, namely Manuel da Costa and Tome de Sousa, who spoke on behalf of the Galolien language community, and Roberto Ximenes, who was a senior authority (and in future years village head) for the Kairui-speaking community on the Laleia River to the south.

Excavation

A 1 × 1 m square test pit was excavated in spits averaging 5 cm to a depth of approximately 1.85 m. Below this depth, the increase in large limestone blocks resulted in variable spit depths and volumes (spits 37–39). The excavation reached a total depth of about 2.1 m (see Supplementary Table S2); unexpectedly deep given the small size of the shelter (Atkinson 2012, 1) (Figure 5). In the southwest portion of the test pit, bedrock was reached as indicated by the sloping limestone in proximity to the cave wall (Figure 6). In

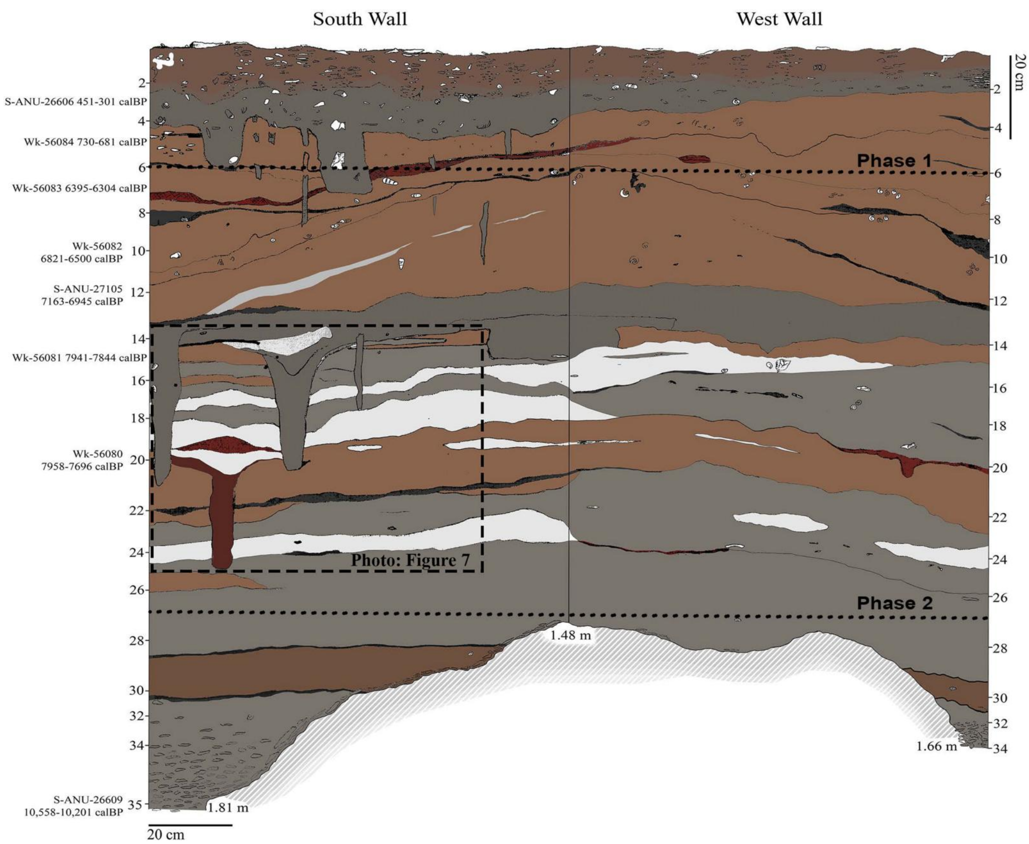

Figure 6. Hatu Saur stratigraphy of the south and west walls of the excavation. Numbers down the side of the section indicate the extent of the excavated spits. Maximum depths reached in each corner are indicated. The extent of the photo from Figure 7 is shown.

Figure 7. Hatu Saur excavation wall photos. (A) Mid-portion of the South Wall. (B) Mid-portion of the North Wall.

the northeast toward the rockshelter entrance, however, where the excavation reached its maximum depth, deposit may continue below the large limestone blocks. Excavation was discontinued at this depth as extension would have required the excavation to be enlarged and the blocks removed. The deposit was wet sieved though a 1.5 mm wire mesh screen and finds were dried and sorted by category (bone, stone, shell, etc.). All finds were then shipped for laboratory analysis at the Australian National University (ANU) in Canberra.

Laboratory analysis

Radiocarbon dates

All dates discussed herein were calibrated in OxCal v4.4 (Bronk Ramsey 2009a) with the Marine20 curve (Heaton et al. 2020) for marine shell dates and a mixed U(0.50) curve, combining the IntCal20 (Reimer et al. 2020) and SHCal20 (Hogg et al. 2020) curves for charcoal, as recommended for dates from the Inter-Tropical Convergence Zone (Hogg et al. 2020; Marsh et al. 2018). Marine shell dates were calibrated without a ΔR correction as these data are currently unavailable for Timor and the few known local reservoir effects from the wider region suggest there is significant variability (Southon et al. 2002). However, we note that, while varied, these regional ΔR values cover a range of less than ±100 years, so would not appreciably alter the millennial scale patterns reported here.

For the Hatu Saur chronology, the radiocarbon dates were also placed within a depositional model in OxCal v4.4 (Bronk Ramsey 2009a) to interpolate age–depth associations within our record. This depositional model assumes a Poisson accumulation of sediment (Bronk Ramsey 2008), calculated from the available age data by averaging the model over many values of *k* (Bronk Ramsey and Lee 2013), allowing flexibility (or randomization) to these sedimentation rates over time. Owing to the inconsistent volume excavated from the 1 × 1 m test pit, due to changing spit depths and uneven intrusion of limestone blocks and bedrock toward the base of the excavation, excavated spit weight (kg) was used as a proxy for depth. The model interpolation rate was set to a single date per spit (i.e., 50 kg).

For charcoal dates, we applied the *Charcoal Plus* t-type Outlier Model with a prior outlier probability of 10%, which is specifically designed to account for the inbuilt age of charcoal (i.e., old wood effect), while also allowing for some stratigraphic movement in an archaeological context (Bronk Ramsey 2009b; Dee and Bronk Ramsey 2014). The *General* t-type Outlier Model with a prior outlier probability of 5% was used for the marine shell date (S-ANU-26609), following commonly used modeling procedures for general archaeological dates (Bronk Ramsey 2009b; Wood et al. 2016). The model was constructed with three sequential phases within a single sequence corresponding to the three main phases of occupation identified based on a combination of the stratigraphy, cultural assemblages, and radiocarbon dates (see stratigraphic interpretation below). Phases were separated by double boundaries to allow for the possibility of significant changes in sedimentation rates and/or gaps (e.g., hiatus) in the chronostratigraphic record.

Paleogeography

As in the study of nearby Laili cave by Hawkins et al. (2017), we reconstructed the local coast for the period of ca. 10,500 years ago (basal level) to model changing access to coastal and marine resources over time. To reconstruct the paleo-extent of Timor's northern coastline, we utilized the adjusted sea level model for the region calculated by Kealy et al. (2018) from the Lambeck and Chappell (2001) model and a regional tectonic uplift rate of 0.5 m per thousand years. According to uplift studies by both Chappell and Veeh (1978) and Cox (2009) for the region of Manatuto, a rate of 0.5 m/ka fits well with their local estimates. We therefore determined a relative sea level of −40 m below present levels for the period at ca. 10,500 years ago.

The latest global bathymetric model (GEBCO 2023) 15 arc-second dataset was utilized to extract the −40 m contour and, in combination with higher resolution elevation data for the present land extent (USGS 2013), we reconstructed the paleogeography of the Manatuto region at ca. 10,500 BP. We then used this to extract elevation profiles between Hatu Saur and the paleo-coast. Two profiles were extracted, one for the shortest, most direct linear distance, and another for a simple slope-based least cost path. Both the least cost analysis and the elevation profile extraction were completed in ArcGIS Pro v.2.4. The least cost path analysis utilized just the single variable of slope, extracted directly from the reconstructed paleogeography, with degree of slope equated directly to cost.

Stone artifacts

The only lithic artifacts counted and analyzed were retouched flakes, complete unretouched flakes over 15 mm maximum dimension, and cores. Those remaining (debitage, broken pieces) were not counted but weighed in bulk by spit. Most attributes were recorded with simple empirical measurements (i.e., length, width, thickness, weight) and notes on presence or absence of certain attributes (i.e., use wear, heat damage, raw material type).

Invertebrate fauna

Mollusks were identified by morphology and sorted by species, counted, and weighed. Results were entered onto a spreadsheet according to minimum number of individuals (MNI). Where molluskan shells were broken, MNIs were based on the most commonly preserved part of the shell for each taxon, and the same part was used consistently throughout. While this method potentially underestimates the true number of specimens, it ensures that no individuals are counted more than once where pieces of one shell may be distributed over more than one excavation unit. Examples of shell taxa that could not be identified at ANU were sent to Dr Richard Willan (Curator Emeritus of Molluscs, Museum and Art Gallery of the Northern Territory, Darwin) for final determination (Brockwell et al. 2016). Non-molluskan invertebrates were identified by comparison with specimens from the ANU Archaeology and Natural History (ANH) Osteology Laboratory reference collection and weighed.

Shell artifacts

Shell artifacts were examined for traces of manufacture and use, and each was given a unique number for the purpose of analysis and description. Photographs of the artifacts (superior and inferior surfaces plus both sides) were taken with a Canon EOS 400D digital camera. A Dino-Lite digital microscope was used to examine the surfaces for traces of manufacture and/or use at low magnification. Mitutoyo (CD-6″CX) digital calipers with the jaws covered in a layer of plastic coating to prevent damage to the artifacts were used to measure each implement. Identification of taphonomic and anthropogenic traces was based on previously analyzed shell artifact assemblages from the region (e.g., Langley and O'Connor 2015, 2016; Langley et al. 2016).

Vertebrate fauna

Tetrapod skeletal elements were identified to the lowest taxonomic level possible. Fish and reptile remains were identified by comparison with the ANU ANH Osteology Laboratory reference collection. In addition, murid skeletal material was identified to taxon by comparison with extinct archaeological and fossil specimens collected from previous ANU expeditions. The vertebrate assemblage was quantified using the number of identified specimens (NISP).

Chronostratigraphy

Stratigraphic interpretation

The excavation revealed a complex stratigraphy of well-defined layering with numerous features, such as distinct hearths and post holes. Bioturbation features were also evident, particularly in the upper half of the deposit in phases 2 and 3. The stratigraphy at Hatu Saur (Figures 6 and 7) is grouped into three major stratigraphic units based broadly on similarities and distinctions in their sedimentary characteristics, as well as trends in abundance of cultural materials.

Phase 1 corresponds with the lowest levels of the deposit (spits 39–28). It spans about 500 years and contains the oldest cultural materials recovered. It is distinctive for its low density of cultural materials (e.g., lithics) but with notable recovery of marine/coastal fauna. The sediments in phase 1 are characterized by grayish brown silty sand (10YR 5/1), interbedded with dark brown organic-rich layers and lenses of dense charcoal that are horizontally bedded and extend across the entire excavation square. From ca. 160 cm below the surface (spit 34) in phase 1, there is an increase in abundance of fragmentary limestone inclusions as the excavation approached its maximum depth. Limestone bedrock was reached in the southwest corner in spits 30–29. Numerous large (e.g., >0.5 m^2) limestone blocks were encountered throughout from spit 37 and increasingly occupied more of the excavation square until excavation ceased in spit 39 at 213 cm in the northeast corner, where bedrock was not confirmed.

Phase 2 is the most extensive portion of the deposit corresponding with spits 27–7 (135–28 cm below surface). The transition from phase 1 to phase 2 is made distinct by the sudden increase in lithics but with a slight decline in shell and an increase in fish remains. Overall, the largest amount of cultural material was recovered from phase 2, which spans ca. 2500 years. This phase is comprised of yellowish red silty sand (5YR 4/6), as well as interbedded sequences of white ash (10YR 8/1), brownish gray silty sand (10YR 5/1-5/2), reddish-brown to dark reddish-brown (2.5 YR 5/3 through to 2.5/4) baked sediments, and dark brown burnt organic layers (10YR 3/3) with occasional charcoal fragments. As such, phase 2 represents the remains of multiple well-preserved fire/-hearth events interbedded with organic-rich sediments. It is largely horizontally bedded in the lower half of the phase (spits 27–13/12); however, above spits 13–12 there is a noticeable slope to the deposit away from the back wall of the shelter toward the entrance in the northeast that continues through until the end of phase 2 (spit 7). These upper, sub-horizontally bedded layers are also distinct for the appearance of concentrated lenses of coarse, angular limestone inclusions, discontinuous across the excavation, but most evident in the east wall toward the dripline. Phase 2 also contains multiple disturbance features, restricted to the lower, horizontally bedded layers, which are interpreted as posthole features and pits (Figures 6 and 7).

Phase 3, the final phase of the Hatu Saur sequence, corresponds to the top six spits covering ca. 700 years of occupation. It is distinguished by the significant decrease in marine/coastal fauna (e.g., fish, shellfish), as well as freshwater shell. The sediments in phase 3 are comprised of loose, organic-rich topsoil, which grades from a gray-brown (10YR 5/1) silty sand, containing small limestone fragments, into a reddish brown (2.5YR 4/3) silty sand with an increasing abundance of goat dung and leaf litter in the upper three spits. Phase 3 sees the return of horizontally bedded sediments and includes a possible hearth, preserving ash and charcoal in the northwest portion of the excavation square. Phase 3 also has bioturbation features and several possible pit features in the south section.

Age–depth chronology

Nine radiocarbon dates were obtained for Hatu Saur, five on charcoal and four on marine shell (Table 1; Brockwell et al. 2016). These nine dates were divided into our three occupation phases, based on a combined interpretation of the stratigraphy, cultural assemblage patterns, and the dates themselves. The results of our depositional model incorporating these dates (Figure 8, Table 2) suggest the following chronostratigraphic interpretation of occupation.

Table 1. Radiocarbon dates from the Hatu Saur excavation.

Site	Spit	Phase	Depth below surface (cm)	Lab code	Material	Radiocarbon age	Age range cal BP (95.4%)	$\Delta^{13}C$	$F^{14}C\%$
Hatu Saur	3	3	13.9	S-ANU-26606	charcoal	315 ± 25	451–301	−26.8 ± 0.6	96.2 ± 0.3
Hatu Saur	5	3	17–24	Wk-56084	charcoal	814 ± 15	730–681		90.4 ± 0.2
Hatu Saur	7	2	28–33	Wk-56083	charcoal	5575 ± 15	6395–6304		50.0 ± 0.1
Hatu Saur	10	2	43–48	Wk-56082	*Tegillarca granosa*	6407 ± 15	6821–6500	−0.1 ± 0.6	45.0 ± 0.1
Hatu Saur	12	2	59	S-ANU-27105	charcoal	6165 ± 40	7163–6945	−22.53 ± 1.22	46.4 ± 0.2
Hatu Saur	15	2	69–71	Wk-56081	charcoal	7074 ± 15	7941–7844		41.5 ± 0.1
Hatu Saur	20	2	93–98	Wk-56080	*Turbo sp.*	7559 ± 16	7958–7696	2.5 ± 0.6	39.0 ± 0.1
Hatu Saur	35	1	170–175	S-ANU-26609 / S-ANU-26539	*Tegillarca granosa*	9650 ± 45 / 9645 ± 45	10,558–10,201 / 10,553–10,198	3.4 ± 1.4 / 3.0 ± 0.7	30.1 ± 0.2 / 30.1 ± 0.2
Hatu Saur	39	1	209–213	Wk-56079	*Cardiidae sp.*	9595 ± 18	10,471–10,175	1.4 ± 0.6	30.3 ± 0.1

Dates were calibrated in OxCal v4.4 using the latest Marine20 curve (Heaton et al. 2020) for the marine shell samples and a combination of the IntCal20 (Reimer et al. 2020) and SHCal20 (Hogg et al. 2020) curves for the charcoal dates, as recommended for this part of the world (Hogg et al. 2020; Marsh et al. 2018).

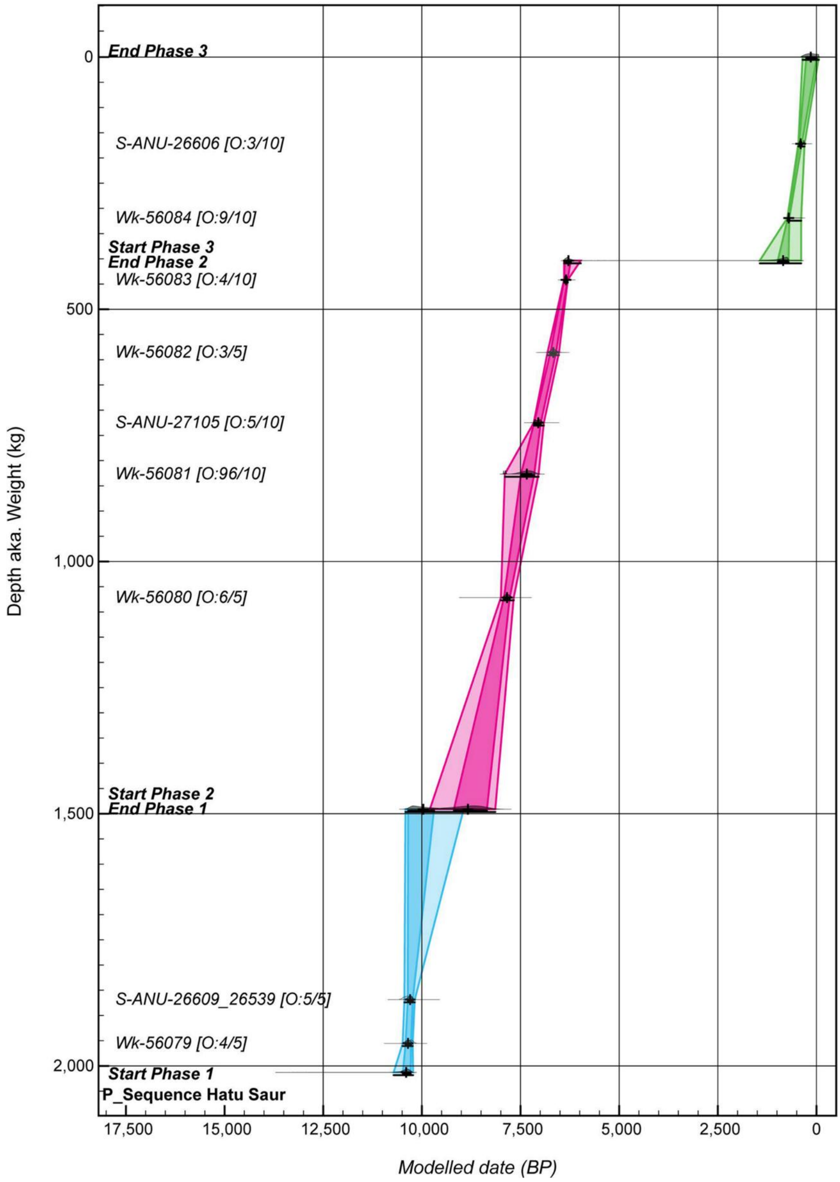

Figure 8. Age–depth chronostratigraphic model for Hatu Saur produced in OxCal v4.4. Phase 1 deposition rate is shown in blue, phase 2 in pink, and phase 3 in green. The brackets beneath the distributions represent the 95.4% probability range. Prior and posterior outlier probabilities are given in brackets following the sample name in the form [O: posterior/prior]. See Table 2 for further details.

Phase 1: Early Holocene (spits 39–28)

The occupation record at Hatu Saur begins in phase 1 with a median modeled age of 10,400 BP (10,715–10,222 cal BP at 95.4% probability) for the start of deposition (Table 2). Phase 1 continues for ca. 500 years with a median modeled end date of 9964 BP (10,415–8940 cal BP at 94.5%), spanning a depth of 78 cm with a total of 925 kg excavated deposit (Tables 1 and 2 and Table S3).

Table 2. Results of the age–depth chronological model for Hatu Saur obtained with OxCal v.4.4.

				Modeled (BP)				Unmodeled (BP)				*Indices*	
Phase	Spit	Weight (kg)[a]	Name	68.3%	95.4%	mean	median	68.3%	95.4%	mean	median	*P*	*C*
3	1	0	**End phase 3**	258–10	351–60	147	144						*97.7*
	3	171.8	**S-ANU-26606**	440–372	460–302	392	401	430–310	451–301	382	390	*96.6*	*99.6*
	5	319	**Wk-56084**	725–688	739–388	691	703	726–689	730–681	706	706	*91.2*	*99.1*
	6	403.4	**Start phase 3**	980–707	1437–389	901	845						*94.4*
2	7	403.5	**End phase 2**	6382–6225	6395–5974	6246	6285						*99.3*
	7	441.7	**Wk-56083**	6392–6309	6397–6303	6348	6348	6392–6308	6395–6304	6349	6347	*95.8*	*99.9*
	10	585.6	**Wk-56082**	6743–6601	6816–6525	6671	6671	6744–6586	6821–6500	6663	6665	*96.8*	*99.9*
	12	725	**S-ANU-27105**	7155–6986	7165–6910	7051	7051	7157–6989	7163–6945	7057	7057	*94.9*	*99.6*
	15	826.7	**Wk-56081**	7489–7152	7898–7043	7364	7341	7935–7866	7941–7844	7894	7889	*3.7*	*95.8*
	20	1071.6	**Wk-56080**	7919–7774	7998–7673	7853	7842	7913–7776	7958–7696	7833	7836	*93.7*	*99.7*
	27	1491.1	**Start phase 2**	9188–8351	9797–8140	8889	8833						*99.7*
1	28	1491.2	**End phase 1**	10,347–9691	10,415– 8940	9849	9964						*99.8*
	35	1868.5	**S-ANU-26609/26539**	10,358–10,231	10,442–10,180	10,299	10,297	10,447–10,268	10,541–10,212	10,368	10,366	*95.4*	*99.9*
	39	1955.3	**Wk-56079**	10,412–10,277	10,486–10,232	10,353	10,350	10,374–10,222	10,471–10,175	10,307	10,301	*96.5*	*99.9*
	39	2012.8	**Start phase 1**	10,481–10,284	10,715–10,222	10,428	10,400						*99.1*
			P_Sequence Hatu_Saur										

Indices for the model are P—outlier probability with values closer to 0 indicating greater outlier probability; and C—model convergence with higher values indicating less/faster MCMC iterations required to give a stable solution to the model.

[a]Weights for phase boundaries represent the maximum accumulated weight for that spit, while weights for radiocarbon dates are the mid-point for the spit. See Supplementary Table S2 for full excavation details.

Phase 2: Middle Holocene (spits 27–7)

Phase 2 begins 8833 BP (9797–8140 cal BP at 95.4% probability) based on the median date from our depositional model (Table 2). This is the most extensive phase at Hatu Saur spanning ca. 2500 years, with a depth of ca. 107 cm and a total of 1088 kg excavated deposit. It terminates at 6285 BP (6395–5974 cal BP at 94.5%), based on the median modeled date (Tables 1 and 2 and Table S3).

Phase 3: Historic (spits 6–1)

The final period of occupation in phase 3 begins after the eleventh century AD with a median modeled start date of 845 BP (1437–389 cal BP at 95.4% probability; ca. 1105 AD) and continues until the Colonial Period at 144 BP (351–60 cal BP at 95.4%; ca. 1806 AD). It is ca. 28 cm deep with 403 kg of deposit (Tables 1 and 2 and Table S3).

A difference analysis in OxCal v.4.4, comparing the modeled end date for phase 1 and start date for phase 2, and end of phase 2 and start of phase 3, was conducted to determine the likelihood of hiatus in the record between phases 1 and 2, and 2 and 3 (Table S4). This analysis found a statistically significant difference between the phase 2–3 dates (at 95.4% probability), indicating that there is a gap in our chronostratigraphic record between these two phases. A statistically significant difference between phases 1 and 2 was identified with 68.3% probability; however, this difference was not recovered as significant at 95.4% probability. While a comparison of modeled median dates for the boundary between these two phases suggests a gap of ca. 1130 years, the lack of any radiocarbon dates between spits 34 and 30 limits the resolution achievable for this portion of the model, and the current inability to determine a significant difference at 95.4% probability.

Archaeological results

The Hatu Saur deposit contained stone artifacts, and vertebrate and invertebrate faunal remains. Sparse earthenware pottery was recovered from the top three spits of phase 3 (< 4 g) and a few fragments of Chinese tradeware were found on the surface.

Stone artifacts

Two types of lithic raw material were used at Hatu Saur, chert (92%; n = 428) and obsidian (8%; n = 35). Chert artifacts (Figure 9) were recovered from all levels of the deposit at Hatu Saur. They range in color from red, through brown and black. Obsidian artifacts appear from spit 17 onwards, with most appearing in spits 8 and 7 (Tables S5–S7; Cooling 2012, 36). The obsidian found in Hatu Saur is a geochemical match for Reepmeyer et al. (2011; see also Reepmeyer et al. 2016, 2019) Group 1 obsidian, coming from a yet unknown off-island source. It first appears in other sites in Timor-Leste, and on Alor and Kisar islands to the north and east, between ca. 17,000 and 12,000 BP (O'Connor et al. 2022). The lithic assemblage contains a high percentage of unretouched flakes relative to retouched flakes and cores (Table S6). All artifact numbers are low in phase 1 (spits 39–28). There is a large peak in stone artifacts at the end of phase 2

Figure 9. Selection of lithics recovered from the Hatu Saur excavation. Unifacially retouched flakes from: (A) spit 3; (B) spit 15; (C) spit 7; and (D) spit 4.

(spit 7), after which they drop off, although numbers are higher in phase 3 than in phase 1 (Figure 10).

Invertebrate fauna

Shellfish

The shellfish assemblage has been analyzed in detail elsewhere (Brockwell et al. 2016). The site contained a mixture of marine, mangrove, and freshwater molluskan species (total NISP = 28,027; total weight = 19.5 kg, including unidentified marine shell). The main marine shellfish species are *Chiton* sp., rock dwellers that, along with *T. granosa*, *Nerita* spp., and *Turbo* spp., are all found in the intertidal zone in shallow water. The most common mangrove species were *Telescopium telescopium*, *Terebralia palustris*, and *Geloina erosa*. There was only one species of freshwater or brackish mollusk, *Stenomelania* sp. Freshwater shellfish occur in low numbers and sporadically in phase 1, steadily increasing in abundance throughout phase 2 with a peak between spits 14 and 7. They then reduce drastically in phase 3 (spits 6–1). There was a peak in mangrove and marine species in the middle of phase 1 (spit 35) ca. 10,300 years BP. The end of phase 1 and the first half of phase 2 have low overall shellfish numbers, generally

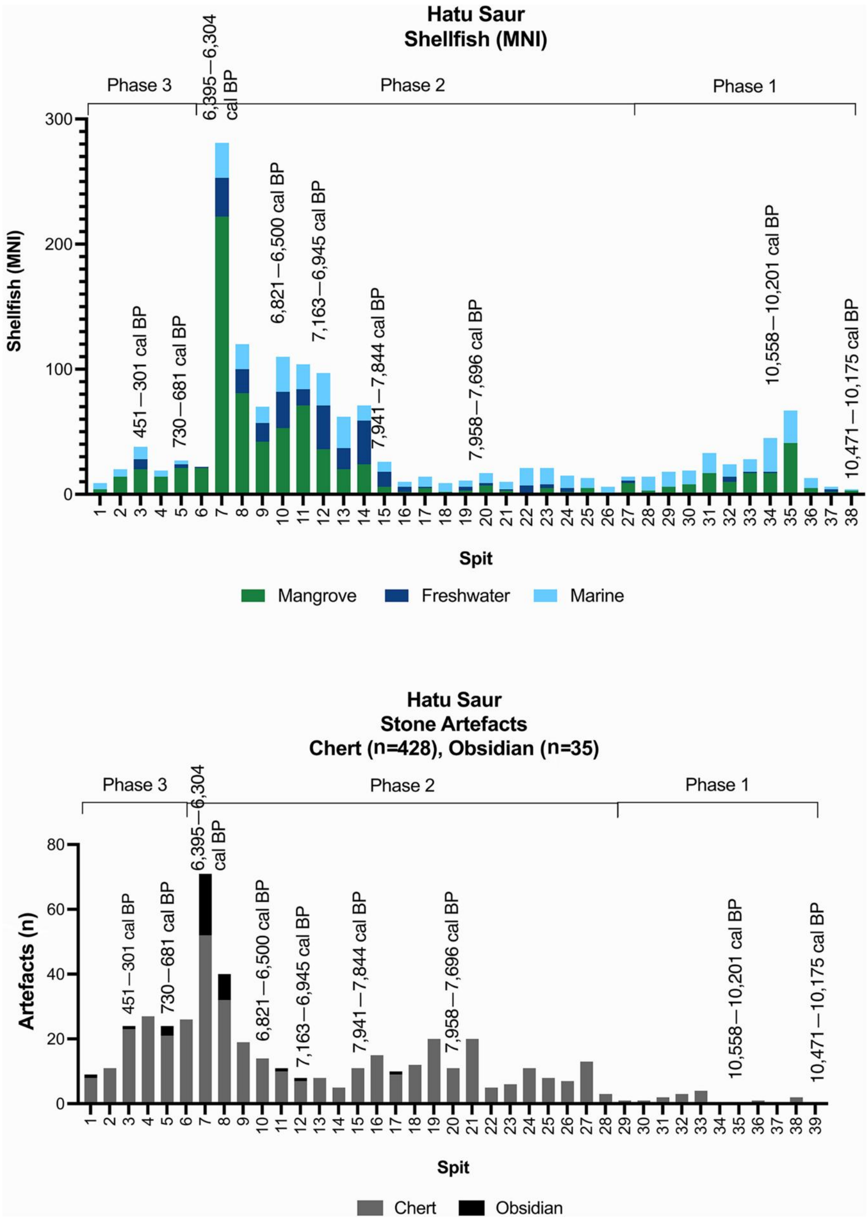

Figure 10. Graphs showing the results of the mollusk and lithic analyses from Hatu Saur. See Supplementary Tables S5–S11.

dominated by marine species. The second half of phase 2 sees the greatest abundance of shellfish (spits 14–7), with mangrove species dominating from this point on (spits 11–1). Shellfish abundance declines in phase 3 (Figure 10; Brockwell et al. 2016).

Non-molluskan invertebrates

Both sea urchin (Echinoidea) and crab/lobster (Decapoda) invertebrate remains were also recovered from the Hatu Saur excavation (Figure 11). The majority of the

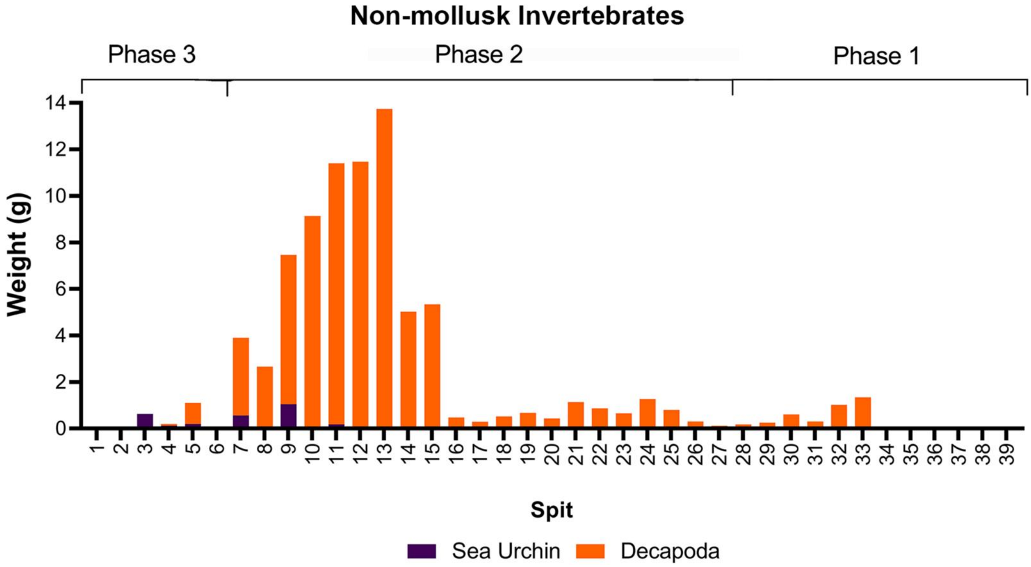

Figure 11. Graph showing the results of the non-mollusk invertebrate analyses from Hatu Saur. See Supplementary Table S12.

Decapoda were comprised of crab carapace remains and present throughout all three phases of the assemblage. Decapoda abundance closely corresponds with that of shellfish, with a peak in the second half of phase 2. Small quantities of sea urchin were confined to the second half of phase 2 and phase 3.

Vertebrate fauna

In total, 1018 vertebrate remains were recorded from Hatu Saur, mostly concentrated in the first half of phase 2 (spits 25–11) (Figure 12); nearly half of which were burnt. Only nine out of 575 (NISP) fish bones could be identified to taxa, all of which are marine species, including parrotfish (Scaridae), snapper (Lutjanidae), shark/ray (Elasmobranchii), and ray (Myliobatoidei). Fish are found throughout the deposit but are most abundant in the first half of phase 2 (spits 27–11).

Terrestrial mammal, amphibian, reptile, and bird remains were recovered in much smaller quantities. Small rat (murid) bones were found consistently throughout the sequence (NISP = 34). Giant rats (giant murid) occurred sporadically in low numbers (NISP = 15) throughout phases 1 and 2 (spits 32, 27, 24, 23, 22, 18, 17, and 9) but are absent in phase 3. Megabats (Pteropodidae) were identified in the first half of phase 2 (spits 26–12) (NISP = 21) and are entirely absent in phases 1 and 3, while microbats (Microchiroptera) were recovered in very small numbers (NISP = 8) in phase 2 (spits 20, 19, 17, and 7). Juvenile pig bones (*Sus* sp.) are present only in the top two spits of phase 3 (NISP = 9). A small juvenile carnivore tooth (cf. canid) was also identified from spit 3.

Low numbers of reptile bones were recovered, including a small snake (Serpentes, NISP = 3), a small squamate lizard (Lacertilia, NISP = 1), and several turtle carapace fragments (Chelonii, NISP = 15), which may be either marine or freshwater (spits 2, 9,

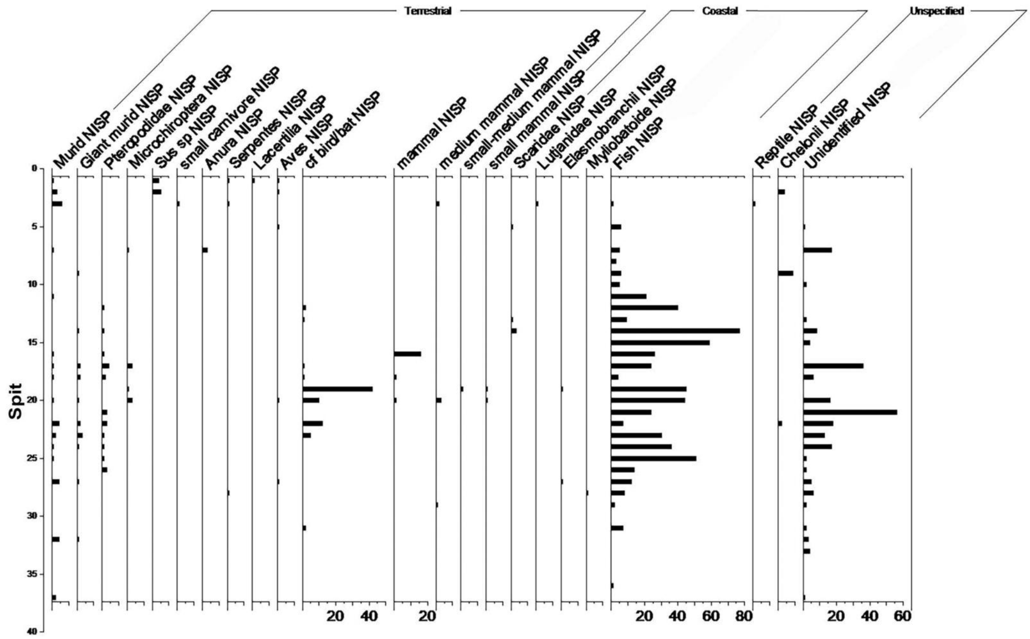

Figure 12. Graphs showing the results of the vertebrate faunal analyses from Hatu Saur. See Supplementary Table S13.

and 22). Three frog (Anura) bones were recovered from spit 7, as were small numbers of bird bones (Aves, NISP = 5), which could not be identified to species.

Shell artifacts

Oliva shell beads

Three *Oliva* sp. were identified in phase 2 (Figure 13). Beads 1 (spit 21) and 2 (spit 20) are intact *Oliva* shell beads, while bead 3 (spit 23) is missing its distal (adapical) section (Figure 14). All three artifacts are black and cracked from incidental burning. Observed use wear found on all three is consistent with each of the shells having been threaded as a necklace, or similar item where each bead is strung longitudinally (Figure 14).

Bead 1 measures 16.07 mm in maximum length and 6.43 mm in width, making it the largest of the *Oliva* shell beads. The perforation has a diameter of 1.53 mm (Figure 14B). The apex has been chipped to create the perforation, leaving small flake scars around the periphery of the distal perforation and a roughly level distal section (Figure 14A and B). Use wear from stringing of the bead is evident from the rounding of the edges of this distal perforation (Figure 14A), but particularly from a wear facet with high polish on the dorsal surface of the proximal (abapical) extremity (Figure 14C).

Bead 2 has a maximum length of 9.36 mm and a maximum width of 4.67 mm. The perforation has a maximum diameter of 1.20 mm. As with bead 1, bead 2 has had its apex removed *via* chipping (Figure 14F). A white residue consistent with ocher (macroscopically) was observed on the right side of the distal section (Figure 14D—indicated with red arrows). The dorsum also exhibits several short oblique striations (Figure 14E—indicated with red arrows). Similar striations were observed in the same location

Figure 13. *Oliva* (1–3) and *Nautilus* (4–10) shell beads recovered from Hatu Saur.

on bead 3 (Figure 14J—indicated with red arrows). These striations were likely caused by the beads rubbing against a coarse surface during wear.

Bead 3 has a maximum length of 7.75 mm and a maximum width of 4.46 mm. The distal extremity of this last *Oliva* bead appears beach-worn (wave-induced abrasion), though the chipped and unsymmetrical distal edge is consistent with having been strung with other beads of similar morphology (where the proximal extremity of the bead above wears down the distal section of the one below; see Langley and O'Connor 2016) (Figure 14I). A red residue consistent with ocher was observed on the proximal extremity (Figure 14H).

Nautilus shell disk beads

Seven *Nautilus* sp. shell artifacts were identified in phase 2 (Figure 13). Beads 4 (spit 16) and 5 (spit 12) are disk bead blanks, while beads 6–10 (spit 7) are finished disk beads (Figure 15). The disk blanks have maximum widths of 6.90 mm (bead 4) and 6.24 mm (bead 5). The perforations have been drilled, indicated by the regular circumference and striations around the perforation walls. Each of the finished beads has been drilled primarily from the dorsal side, before being turned over and the perforation completed by drilling on the opposite side. This method resulted in the unsymmetrical appearance of the perforation (one side having a wider, deeper perforation wall than the other).

The finished beads (Figure 15: beads 6–10), all measure between 4 and 5 mm in maximum width, demonstrating a degree of standardization. Three of the beads (Figure 15: beads 6, 8, and 9) retain at least some of the mantle (the creamy outer shell layer), and

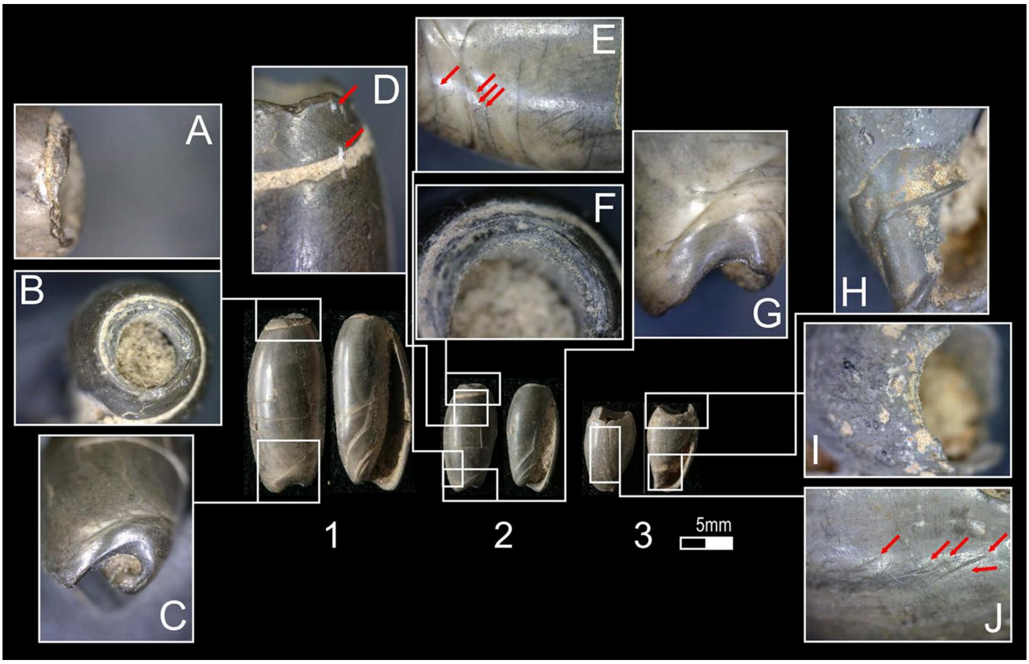

Figure 14. Hatu Saur: *Oliva* sp. shell beads from: (A–C): Details of bead 1; (D–G): Details of bead 2; (H–J): Details of bead 3. Red arrows in D indicate white residue. Red arrows in E and J indicate striations. (A at 50× magnification; B at 75× magnification; C and J at 80× magnification; D at 150× magnification; (E), (F), (G) at 190× magnification; H at 100× magnification; I at 120× magnification).

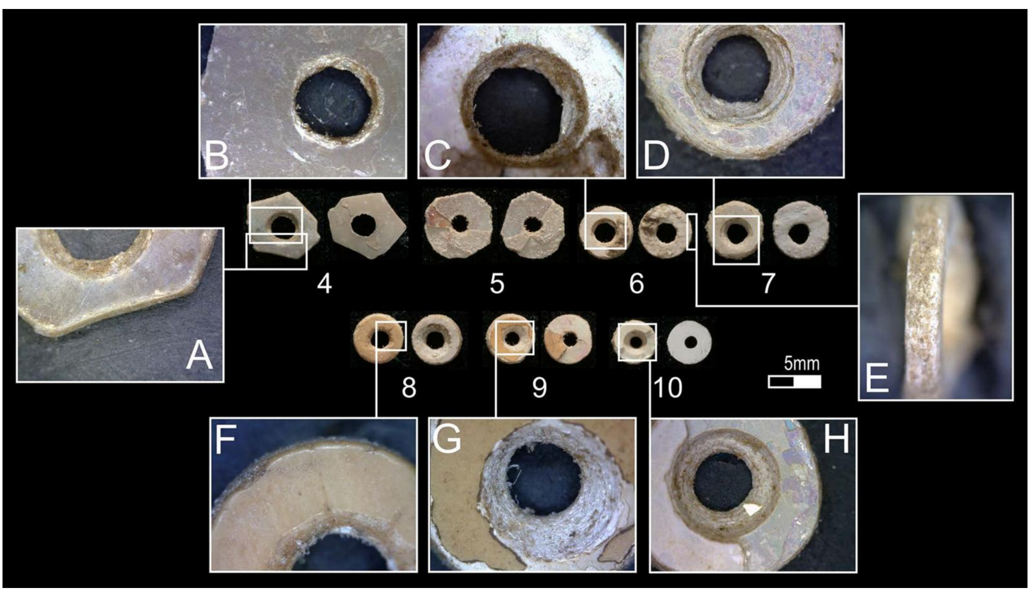

Figure 15. Hatu Saur: *Nautilus* disk beads and disk bead blanks from Hatu Saur: Artifacts 4 and 5 are disk bead blanks. Artifacts 6–10 are finished disk beads. (A, D, E, F at 100× magnification; B, C at 120× magnification; G at 150× magnification; H at 130× magnification).

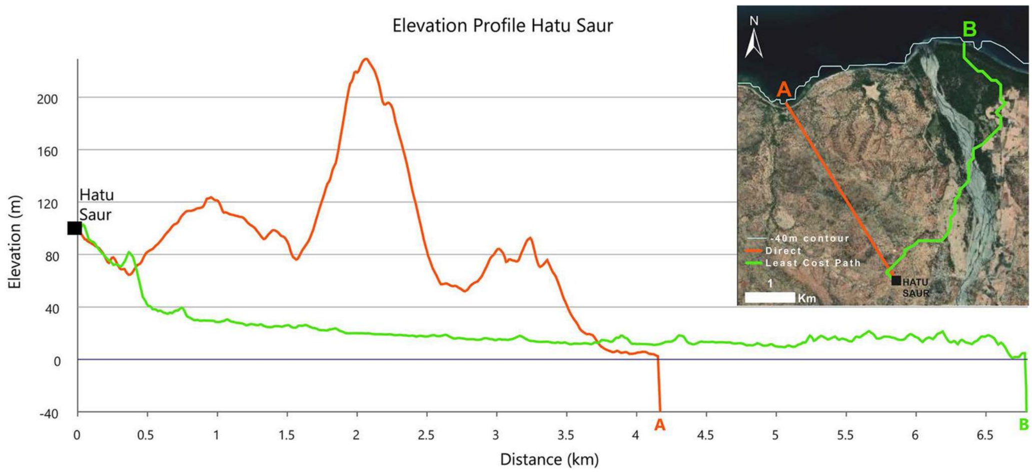

Figure 16. Hatu Saur: Elevation profiles from the site to the coast at ca. 10,500 years ago (i.e., 40 m). Profile A (ORANGE) indicates the most direct "as the crow flies" path, while profile B (GREEN) indicates the least cost path according to slope. The inset (top right) shows the horizontal extent of these paths.

we cannot rule out that the other *Nautilus* artifacts also retained this aspect before entering the archaeological record, as their state of preservation has resulted in the fragmentation of the shell. The beads were finished *via* abrasion of the sides to create the circular form and rounded edges.

Paleogeographic reconstruction

Paleogeographic reconstruction of the Manatuto coast for the period of occupation recorded at Hatu Saur demonstrated that sea level changes over the last ca. 10,000 years have had a negligible impact on the distance between the site and the coast (Figure 16). This small increase in land extent (ca. 40–80 m) in the face of a 40 m drop in relative sea level is due to the steep drop-off in the continental shelf seen along the north coast of Timor (Figure 16; GEBCO 2023). While the coastal drop-off means sea level changes would have negligible impacts on this portion of Timor's coast, sedimentary processes within the local embayment of the Laleia River likely had a more noticeable effect (Brockwell et al. 2016). As observed in the satellite image (Figures 2 and 16), the green shading of vegetation cover at the river mouth indicates a change in surface geology, suggestive of Holocene sedimentary infill within this embayment.

During the Last Glacial Maximum (LGM) lowered sea level, the underlying bedrock of this embayment would likely have been exposed, with our paleogeographic reconstruction (Figure 16: −40 m contour) an accurate reflection of this scenario. However, following the scenario of Holocene infill, the low-lying embayment area was likely inundated as sea level continued to rise in the Early Holocene. This probably would have pushed the coastal margin closer to Hatu Saur at this point and, prior to the completion of the infill process, it may have come as much as 2 km closer than we can model here (Figures 2 and 16). Infill during the Holocene would have then steadily extended the coastal margin out until reaching its present-day extent.

Even a ca. 2 km change in distance from Hatu Saur to the coast is unlikely to have had a dramatic impact on its early occupants; however, changes in the coastal environment due to sea level change would have significantly impacted access to coastal resources. The exposure of steep coastal zones during low sea levels likely made access to the coast difficult, while also dictating the types of coastal resources available. As sea levels rose (see the adjusted sea level model for the region by Kealy et al. (2018, figure 2)), however, inundation ca. 8000–7000 years ago of previously exposed coastal areas would have precipitated the establishment of new coastal ecosystems, including mangroves, ill-suited to the steep coastlines of earlier periods. In the Laleia River embayment, this inundation process was likely much more pronounced and, at least initially, mangroves were likely more extensive, before retreating due to increased sedimentary infill.

A comparison of the two elevation profiles produced by our study (Figure 16) clearly demonstrates that, while the "direct" path (A) is significantly shorter than the least cost option (B) by ca. 2.5 km, the extremes in topography make the longer option the most efficient. Although this path would have required a dry or shallow water crossing of the Laleia River, with the exception of wet season flood events, we consider this path easier and the more likely scenario. During the Early to Middle Holocene, prior to the formation of the Laleia embayment (ca. 7000 years ago), the retreat of the coastal margin at this point would have reduced the distance of path B to closely parallel that of path A. Therefore, at all periods of occupation, Hatu Saur would have been less than a 7 km (ca. 2 hr) walk from the coast, and at some stages as little as ca. 4 km.

Discussion

Archaeological interpretation

Hatu Saur was initially occupied around 10,400 BP. This first phase of occupation exhibits very low density use of lithics, while the faunal assemblage demonstrates a focus on marine resources.

There is an increase in freshwater shell in phase 2 between ca. 8000 and 6000 cal BP, corresponding with a wetter period and increased river flow (Reeves et al. 2013). A large peak in artifact numbers also occurs in phase 2 between spits 8 and 7 and suggests increased occupation at the shelter ca. 6500 years BP after sea levels had stabilized. Other regional sites (Glover 1986) have a peak in stone artifacts in the Middle Holocene. The evidence indicates a decline in stone artifact use in phase 3 during the last 800 years.

The high percentage of unretouched to retouched flakes and cores (Table S6) at Hatu Saur is typical of other Timor-Leste sites (Hawkins et al. 2017; Marwick et al. 2016; Shipton et al. 2019). Chert, the dominant raw material at Hatu Saur, is commonly found as nodules on the eroded land surface and as cobbles in the river terraces and beds throughout the region and could have been readily procured by people visiting Hatu Saur (O'Connor and Cooling personal observation). At nearby Laili, where quality chert is similarly available close to the cave, the low ratio of retouched to unretouched artifacts has been argued to show that edge maintenance was not prioritized due to the low cost of procuring raw material. A similar situation no doubt pertained at Hatu Saur suggesting that the site was used episodically by mobile hunter gatherers performing expedient tasks for which sharp flakes would suffice. Obsidian first appears at Hatu Saur ca. 7500 cal BP (Table 2) and continues into the historic period. The presence of the exotic group 1 obsidian implies interisland maritime exchange (O'Connor et al. 2022; Reepmeyer et al. 2011; Reepmeyer et al. 2016, 2019; Shipton et al. 2020).

Evidence from nearby northern Australia suggests warmer/wetter climatic conditions in the Early to Middle Holocene (Reeves et al. 2013; Woodroffe 1988). Increased rainfall causes increased sedimentation, which may have resulted in estuarine infill and encouraged the growth of mangroves, similar to the situation seen on a much larger scale in northern Australia. There is some evidence it was also the case elsewhere in Southeast Asia during that time (Allen 1987; Woodroffe et al. 1985). Increased water levels in the nearby Laleia River would also explain the proliferation of the freshwater gastropods (*Stenomelania* sp.) at this time (Brockwell et al. 2016). The persistence of marine invertebrates from initial occupation ca. 10,400 years BP at Hatu Saur (Figure 10) reflects continued access to coastal resources despite fluctuations in sea level, indicating that distances of up to 7 km were not prohibitive for the inclusion of these resources within the early occupants' subsistence strategy.

Our analysis revealed an apparent correlation between changes in mangrove shellfish abundance at Hatu Saur and temporally associated changes in sea level at the nearby coast. Rising sea levels likely inundated the embayment area at the mouth of the Laleia River during the Early Holocene, possibly resulting in the initial establishment of mangroves on the new coastal margin. This scenario is supported by the abundance of mangrove shellfish during phase 1 at Hatu Saur (Figure 10). Mangrove shellfish then decline in the first half of phase 2, possibly due to shifting coastal margins because of continued sea level rise and embayment infill destabilizing the mangrove systems. The steady increases in mangrove shellfish MNI (Figure 10) in the second half of phase 2 corresponds with sea level stabilization after the LGM ca. 6000 years ago (Kealy et al. 2017, figure 2) and increased sedimentation along the coastal margin, in particular in the embayment area of the local Laleia River, which in turn encouraged the establishment and expansion of mangroves.

The *Oliva* shell beads ($n = 3$) first appear in phase 2 occurring between spits 23 and 20 (ca. 9000–8000 years BP). All the *Nautilus* shell disk beads ($n = 7$) occur between spits 16 and 7, also in phase 2 (ca. 8000–6000 BP). This small collection is like others found further east in Timor, which were modified to be strung as beads (O'Connor 2010). *Oliva* beads have a long history on the island, having been dated to ca. 37,000 years BP but used most intensively between 8000 and 4000 years BP (Langley and O'Connor 2016). Langley and O'Connor (2016, 22) suggest that this period of intensification may be related to sea level stabilization and more abundant inshore resources, which enabled increased settlement and social interaction.

Fish (likely marine) were the most ubiquitous vertebrate remains recovered at Hatu Saur, being most abundant in the first half of phase 2 between spits 25 and 11. Parrotfish (Scaridae), snapper, sharks, and stingrays are all likely to have been caught inshore. Parrotfish, a common herbivorous reef fish, occur between spits 14 and 3 and were likely caught with nets or spears, while the snapper, sharks, and rays were most probably taken using baited hooks.

Stone artifact numbers increase in the latter part of phase 2 in spits 8–7, an increase that is coincident with the peak in marine and mangrove species at this time, suggesting more intensive occupation at Hatu Saur approximately 6400 years BP, perhaps supported by highly productive estuarine environments. The significant reduction in marine invertebrates in phase 3 (since ca. 850 years BP), suggests that use of the rockshelter changed dramatically in the last 800 years. This could be due either to a decline in nearby resources due to changing environmental conditions or the result of changes in resource use following shifts to open village settlements and agricultural practices. Differentiating between these alternate hypotheses is difficult because of the chrono-stratigraphic hiatus identified in the Hatu Saur sequence between phases 2 and 3 (spits 7 and 6).

It is important to note that the low numbers of earthenware sherds from Hatu Saur is quite unlike other sites excavated to the east near Baucau, which contain thousands of sherds (Glover 1986; Oliveira 2008). However, the temporal gap in the Hatu Saur sequence between phases 2 and 3 covers the period associated with the introduction of pottery, found in other Timor-Leste sites (Glover 1986; Oliveira 2008). The missing "pottery unit" in our sequence suggests either a substantial degree of erosion/sediment removal (e.g., O'Connor et al. 2017) from Hatu Saur, or alternatively, that these sites were not used frequently in the Neolithic, likely due to regular occupation occurring in open village settlements.

There was also little pottery recovered from nearby Hatu Wakik, which has an assemblage dated from 5000 years BP (Forestier and Guillaud 2013). Forestier and Guillaud (2013) suggest infrequent use of the site during the Neolithic to explain the paucity of pottery. While similarly low numbers of pottery sherds at Hatu Saur are explained by the hiatus identified in the chronological model, it is interesting to note that the period missing from our record (ca. 6000–1000 BP), overlaps with the period of occupation recovered by Forestier and Guillaud (2013) at nearby Hatu Wakik. The presence of marine shellfish at Hatu Wakik, which is located even further inland than Hatu Saur, also supports the possibility that the sea was closer during the Middle to Late Holocene with subsequent Holocene progradation extending the distance to the coast.

Exotic fauna are only found in the upper three spits of phase 3 at Hatu Saur and include remains of pig and a possible dog (cf. canid; Figure 12), corresponding with the few earthenware pottery fragments. Pig and dog are recent introductions associated with maritime expansion of Austronesian-speaking populations (O'Connor 2015). Piper (2017) argues that pigs were introduced to ISEA between 4000 and 3500 years BP. The oldest known dog remains on Timor are from Matja Kuru 2 in Lautem District to the east and are dated to ca. 3000 years BP (Gonzalez et al. 2013). While evidence for subsistence activities at Hatu Saur (e.g., faunal remains) declines in the last 800 years (phase 3), it is interesting to note that the stone artifacts remain relatively high during this period.

Anthropological interpretations

The results of the anthropological investigations, covering the period of European incursion into Timor-Leste, reveal a rich and complex sociocultural and political history. Local oral history and myths surrounding this time shed light on changes during this period and the continuing importance of stone.

The oral traditions of Laleia and its fortunes under colonial Portuguese rule provide insights into the turbulent history of trade, dependency, and variable fortunes of a modestly sized political domain subject to the shifting fortunes of its more powerful neighbors and allies over the span of history. Much of the extant historical record of Timor-Leste was initiated with the sixteenth century colonial archives. The documents reveal that Portuguese and later Dutch interests (from the seventeenth century) were trading actively with the petty kingdoms along the north coast of Timor, including Laleia, Manatuto, and Vermasse (Adê) (McWilliam 2007). The main attraction was the famed high-quality white sandalwood (*Santalam album*), which grew in abundance on the island and generated large profits for successful traders. Sandalwood, as well as beeswax and slaves, were traded for textiles, ceramics, swords, firearms, and gunpowder. This period, which lasted well into the eighteenth century, was marked by intense and sustained rivalries and violent reprisals between Dutch, Portuguese, and Makassar traders from Sulawesi who became a powerful maritime force with imperial ambitions (Hägerdal 2014).

During the nineteenth century, the *Regulo* (ruler) of Laleia, and its neighbors Manatuto and Vermasse, allied themselves with Portuguese colonial rule and served for generations as *Arrarais* and *Moradores* (*Liaise moradores*), locally elite armed auxiliary militias and reservists acting in support of the Portuguese "civilizing mission" (Roque 2010), to bring Christianity and economic governance to the unruly colony. Periodically reaffirming their "vassalage," these coastal kingdoms were to play an active role in numerous campaigns of pacification against rebellious petty kingdoms in the interior of the island (see Davidson 1994). From the 1860s until the final Portuguese military campaigns against Boaventura, the Ruler of Manufahi in 1912, the Portuguese colonial government waged a succession of violent raids against recalcitrant Timorese domains who defied colonial rule and resisted the punitive agricultural head taxes (*finta/capitacao*) imposed on the population. Raiding parties featured mass looting of enemy strongholds, headhunting, and the enslavement of women and children from enemy groups (Roque 2010). During this period, Kairui village was an independent political center with its own independent *Regulo.*

These disruptive processes and adaptations to the state of endemic warfare and intercommunal violence can be mapped onto the Laleia landscape and enrich what remains of the archaeological evidence. An example is the defensive plateau of Leki Wakik and the remnants of the former settlement of Hubrae, reportedly occupied into the 1930s, with its ceremonial dancing ground used to celebrate headhunting successes and honor the victorious warriors (Manuel da Costa personal communication 2011). The early political alignment with the Portuguese colonial government and Christianity (Catholicism) has meant that many of the older cultural traditions, ancestral knowledge, and ritual association with the land have weakened in contemporary times.

In relation to the mythic origins of Laleia, local knowledge is retained in discontinuous forms of oral narrative of origins. One record focuses on the significance of the outcrop, Hatu Saur, in the expansion of the Galolien-speaking settlers from their initial foothold on the coast (at Gadi Ilin). According to a summary version of the mythology, all the land of Laleia (Laili), including the coast, originally belonged to the ancestors of the Kairui people, and much of it was empty. Gadi (Galolien) settlers on the coast came seeking honey (*bani been*) in the hinterland, carrying with them strike stones (*hatu seu*) to make fire and smoke out the bees. Resting at Hatu Saur, they met a Kairui group. According to the myth, at that time the Kairui were wild and covered in hair and bristles, even on their tongues, and they ate their food raw, having never known fire [*ki* = people, *rui* = bristles]. When the two groups met, the Gadi group shared their honey in return for tubers (*kumbili*) gathered by the Kairui. Gadi used their flint stones (*hatu seu*) to strike a light (to the amazement of the Kairui) and then cooked the tubers and offered them to the Kairui who found them delicious and ate them with relish. By feasting on cooked food, over time their body hair and bristles gradually fell away revealing smooth human skin.

To obtain the wondrous fire, the Kairui agreed to secure the *hatu seu* flintstones in exchange for giving up their prominent outcrop and stone shelter, Hatu Saur. But this exchange was, in reality, a ploy by the Gadi group to secure a more defensive stronghold so they could expand their territory and take over the fertile alluvial river lands controlled by the Kairui. Provoking hostilities, the Gadi eventually attacked the prominent stronghold of Hatu Laili and chased the Kairui away. From that time, the Kairui have lived ca. 7 km to the south along the banks of the Laleia River where they plant rice and work to maintain their own distinctive language and cultural traditions. Contemporary Kairui groups recognize seven original settlements (*aldeia*) comprising the language community, each with its own "story" (Manuel da Costa, Tome de Sousa, and Roberto Ximenes personal communication 2011).

The references here to the hairy, undomesticated Kairui encounter and people living without knowledge of fire is a common cultural theme expressed widely across the Indonesian archipelago (Forth 2008). In the context of this myth at Laleia, we can say at least that it suggests the collision of an organized assertive settler group against a weaker resident community wherein the latter were marginalized by superior forces and pushed aside. The desire for access to fertile alluvial lands by the arriving Gadi suggests that they may already have had some agricultural practices.

Conclusions

Laleia forms a significant archaeological landscape that contributes to our knowledge of north-central Timor-Leste with regional records from the Pleistocene (Laili cave), through the Holocene (rockshelters Hatu Saur and Hatu Wakik), and into the recent past (the walled hilltop site of Leki Wakik and open sites).

Our archaeological and anthropological data indicate significant adaptations in the Laleia riverine region to changes in environmental and sociopolitical conditions that were occurring in Wallacea during the Holocene. Early occupation of Hatu Saur was associated with the exploitation of mainly marine resources, with some estuarine and terrestrial input. The increase of stone artifacts and mangrove shellfish ca. 8000–6000 years BP suggest more intense use of the coastal margin following sea level rise and the establishment of highly productive estuarine environments. Hatu Saur shows a change in occupation from spit 6 onwards (modeled as post 900 years BP), and Hatu Wakik may have been abandoned at a similar time. Questions remain about whether these events were associated with farming and consequent changes in land use and settlement.

The anthropological research has enriched the archaeological evidence from the latest period of occupation with ethnographic and historical interpretations. The origin myth of the "hairy man" may reference the arrival of agriculture, possibly brought by a new group of people. Construction of regional defensive fortifications post 1000 years BP could be associated with increasing foreign influence from Chinese, Makassar, and/or European traders and consequent internal conflict related to access to resources and sociopolitical rivalries. And finally, the decrease in the use of Hatu Saur, post 400 years BP, possibly reflects a reorganization of settlement patterns related to these outside influences.

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References

Allen, H. 1987. Holocene mangroves and middens in northern Australia and Southeast Asia. *Bulletin of the Indo-Pacific Prehistory Association* 7 (0):1–16. 10.7152/bippa.v7i0.11248

Atkinson [Wolfe], L. 2012. *Stratigraphy and geomorphology of the Hatu Sour rockshelter, Timor Leste. Supervised research project in Archaeological Science, ARCH 8030*. Canberra: Australian National University.

Bellwood, P. 2023. *First farmers: The origins of agricultural societies*. Chichester: John Wiley and Sons.

Brockwell, S., S. O'Connor, M. Litster, and R. C. Willan. 2016. New insights into Holocene economies and environments of central East Timor: Analysis of the molluscan assemblage at the rockshelter site of Hatu Sour. *Northern Territory Naturalist* 27:2–12. 10.5962/p.295463

Bronk Ramsey, C. 2008. Deposition models for chronological records. *Quaternary Science Reviews* 27 (1–2):42–60. 10.1016/j.quascirev.2007.01.019

Bronk Ramsey, C. 2009a. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51 (1):337–60. 10.1017/S0033822200033865

Bronk Ramsey, C. 2009b. Dealing with outliers and offsets in radiocarbon dating. *Radiocarbon* 51 (3):1023–45. 10.1017/S0033822200034093

Bronk Ramsey, C., and S. Lee. 2013. Recent and planned developments of the program OxCal. *Radiocarbon* 55 (2):720–30. 10.1017/S0033822200057878

Chao, C.-Y. 2008. A microregional approach to the social dynamics in late prehistoric Manatuto, East Timor, eleventh–eighteenth century. PhD. diss., University of Washington.

Chappell, J., and H. Veeh. 1978. Late Quaternary tectonic movements and sea-level changes at Timor and Atauro Island. *Geological Society of America Bulletin* 89 (3):356–68. 10.1130/0016-7606(1978)89<356:LQTMAS>2.0.CO;2

Cooling, S. 2012. *Investigations of site use through the analysis of the lithic assemblage from the site of Hatu Sour, East Timor. Supervised research project in Archaeological Science, ARCH 8029*. Canberra: Australian National University.

Cox, N. 2009. Variable uplift from Quaternary folding along the northern coast of East Timor, based on U-series age determinations of coral terraces. PhD thesis, Brigham Young University.

Davidson, K. 1994. The Portuguese colonisation of Timor: The final stage, 1850–1912. PhD. diss., University of Melbourne.

Dee, M., and C. Bronk Ramsey. 2014. High-precision Bayesian modelling of samples susceptible to inbuilt age. *Radiocarbon* 56 (1):83–94. 10.2458/56.16685

Fenner, J., M. Litster, T. Maloney, T. S. Lim, S. Hawkins, P. Gaffey, S. Brockwell, A. McWilliam, S. Pannell, R. Willan, and S. O'Connor. 2020. The site of Leki Wakik, Manatuto District, Timor-Leste. In *Forts and fortification in Wallacea: Archaeological and ethnohistoric investigations*, ed. S. O'Connor, A. McWilliam, and S. Brockwell, 101–32. *Terra Australis 53*. Canberra: ANU Press.

Forestier, H., and D. Guillaud. 2013. A limestone outcrop as a landmark of prehistoric settlement in the Manatuto region (East Timor). In *Vol. 1 of Unearthing Southeast Asia's past: Selected papers from the 12th International Conference of the European Association of Southeast Asian Archaeologists*, ed. M. Klokke and V. Degroot, 13–9. Singapore: National University of Singapore.

Forth, G. 2008. *Images of the wildman in Southeast Asia: An anthropological perspective*. London: Routledge.

GEBCO (General Bathymetric Chart of the Oceans). 2023. The GEBCO_2021 Grid. British Oceanographic Data Centre. Accessed August 7, 2023. https://www.gebco.net/data_and_products/gridded_bathymetry_data/gebco_2021/

Glover, I. 1986. *Archaeology in Eastern Timor, 1966–67. Terra Australis 11*. Canberra: Australian National University.

Gonzalez, A., G. Clark, S. O'Connor, and L. Matisoo-Smith. 2013. A 3000 year old dog burial in Timor-Leste. *Australian Archaeology* 76 (1):13–20. 10.1080/03122417.2013.11681961

Gunn, G. 1999. *Timor Lorosae: 500 years*. Macau: Livros do Oriente.

Hägerdal, H. 2014. *Lords of the land, lords of the sea: Conflict and adaptation in early colonial Timor, 1600–1800*. Verhandelingen van het Koninklijk Instituut voor Taal-, Land- en Volkenkunde 273. Leiden: KITLV Press.

Hawkins, S., F. Arumdhati, M. Litster, T. Lim, G. Basile, M. Leclerc, C. Reepmeyer, T. Maloney, C. Boulanger, J. Louys, et al. 2020. Metal-Age maritime culture at Jareng Bori rockshelter, Pantar Island, eastern Indonesia. *Records of the Australian Museum* 72 (5):237–62. 10.3853/j.2201-4349.72.2020.1726

Hawkins, S., S. O'Connor, T. Maloney, M. Litster, S. Kealy, J. Fenner, K. Aplin, C. Boulanger, S. Brockwell, R. Willan, et al. 2017. Oldest human occupation of Wallacea at Laili Cave, Timor-

Leste, shows broad-spectrum foraging responses to Late Pleistocene environments. *Quaternary Science Reviews* 171:58–72. 10.1016/j.quascirev.2017.07.008

Heaton, T., P. Köhler, M. Butzin, E. Bard, R. Reimer, W. Austin, C. Bronk Ramsey, P. Grootes, K. Hughen, B. Kromer, et al. 2020. Marine20—The marine radiocarbon calibration curve (0–55,000 cal BP). *Radiocarbon* 62 (4):779–820. 10.1017/RDC.2020.68

Hicks, D. 2007. The Naueti relationship terminology: A new instance of asymmetric prescription from East Timor. *Bijdragen tot de taal-, land- en volkenkunde / Journal of the Humanities and Social Sciences of Southeast Asia* 163 (2–3):239–62. 10.1163/22134379-90003685

Hogg, A., T. Heaton, Q. Hua, J. Palmer, C. Turney, J. Southon, A. Bayliss, P. Blackwell, G. Boswijk, C. Bronk Ramsey, et al. 2020. SHCal20 Southern Hemisphere calibration, 0–55,000 years cal BP. *Radiocarbon* 62 (4):759–78. 10.1017/RDC.2020.59

Hull, G. 2002. The languages of East Timor: Some basic facts. Accessed August 7, 2023. https://www.scribd.com/doc/243897171/The-Languages-of-East-Timor-Some-Basic-Facts-pdf.

Kaharudin, H. A. F., M. Mahirta, S. Kealy, S. Hawkins, C. Boulanger, and S. O'Connor. 2019. Human foraging responses to climate change: Here Sorot Entapa rockshelter on Kisar Island. *Wacana* 20 (3):525–59. 10.17510/wacana.v20i3.783

Kealy, S., J. Louys, and S. O'Connor. 2017. Reconstructing palaeogeography and inter-island visibility in the Wallacean Archipelago during the likely period of Sahul colonization, 65–45 000 years ago. *Archaeological Prospection* 24 (3):259–72. 10.1002/arp.1570

Kealy, S., J. Louys, and S. O'Connor. 2018. Least-cost pathway models indicate northern human dispersal from Sunda to Sahul. *Journal of Human Evolution* 125:59–70. 10.1016/j.jhevol.2018.10.003

Kealy, S., S. O'Connor, D. M. Sari, C. Shipton, M. C. Langley, C. Boulanger, H. A. F. Kaharudin, E. P. B. G. G. Patridina, M. A. Algifary, A. Irfan, and P. Beaumont. 2020. Forty-thousand years of maritime subsistence near a changing shoreline on Alor Island (Indonesia). *Quaternary Science Reviews* 249:106599. 10.1016/j.quascirev.2020.106599

Lambeck, K., and J. Chappell. 2001. Sea level change through the last glacial cycle. *Science* 292 (5517):679–86. 10.1126/science.1059549

Langley, M. C., and S. O'Connor. 2015. 6,500-year-old *Nassarius* shell appliqués in Timor-Leste: Technological and use wear analyses. *Journal of Archaeological Science* 62:175–92. 10.1016/j.jas.2015.06.012

Langley, M. C., and S. O'Connor. 2016. An enduring shell artefact tradition from Timor-Leste: *Oliva* bead production from the Pleistocene to Late Holocene at Jerimalai, Lene Hara, and Matja Kuru 1 and 2. *PloS One* 11 (8):e0161071.

Langley, M. C., S. O'Connor, and E. Piotto. 2016. 42,000-year-old worked and pigment-stained *Nautilus* shell from Jerimalai (Timor-Leste): Evidence for an early coastal adaptation in ISEA. *Journal of Human Evolution* 97:1–16. 10.1016/j.jhevol.2016.04.005

Langley, M. C., S. O'Connor, S. Kealy, and Mahirta. 2023. Fishhooks, lures, and sinkers: Intensive manufacture of marine technology from the Terminal Pleistocene at Makpan Cave, Alor Island, Indonesia. *The Journal of Island and Coastal Archaeology* 18 (1):33–52. 10.1080/15564894.2020.1868631

Lape, P., F. Aziz, D. Ekowati, J. Huff, W. Handoko, A. Huwae, M. Lahallo, S. Latupapua, A. Oktaviana, E. Peterson, et al. 2017. Reframing the Island Southeast Asian Neolithic: Local vs. regional adaptations. In *Austronesian diaspora: A new perspective*, ed. B. Prasetyo, T. Nastiti, and T. Simanjuntak, 65–76. Jogjakarta: Gadjah Mada University Press.

Lape, P., and C.-Y. Chao. 2008. Fortification as a human response to Late Holocene climate change in East Timor. *Archaeology in Oceania* 43 (1):11–21. 10.1002/j.1834-4453.2008.tb00026.x

Lape, P., J. Krigbaum, J. Futch, A. Jordan, and E. Peterson. 2020. The Ira Ara site: A fortified settlement and burial complex. In *Forts and fortification in Wallacea: Archaeological and ethnohistoric investigations*, ed. S. O'Connor, A. McWilliam, and S. Brockwell, 49–66. *Terra Australis 53*. Canberra: ANU Press.

Marsh, E., M. Bruno, S. Fritz, P. Baker, J. Capriles, and C. Hastorf. 2018. IntCal, SHCal, or a mixed curve? Choosing a 14C calibration curve for archaeological and paleoenvironmental records from tropical South America. *Radiocarbon* 60 (3):925–40. 10.1017/RDC.2018.16

Marwick, B., C. Clarkson, S. O'Connor, and S. Collins. 2016. Early modern human lithic technology from Jerimalai, East Timor. *Journal of Human Evolution* 101:45–64. 10.1016/j.jhevol.2016.09.004

McWilliam, A. 2007. Looking for Adê: A contribution to Timorese historiography. *Bijdragen tot de taal-, land- en volkenkunde / Journal of the Humanities and Social Sciences of Southeast Asia* 163 (2–3):221–38. 10.1163/22134379-90003684

O'Connor, S. 2006. Unpacking the Island Southeast Asian Neolithic cultural package and finding local complexity. In *Uncovering Southeast Asia's Past: Selected papers from the 10th International Conference of the European Association of Southeast Asian Archaeologists*, ed. E. Bacus and I. Glover, 4–87. Singapore: NIAS Press.

O'Connor, S. 2007. New evidence from East Timor contributes to our understanding of earliest modern colonisation east of the Sunda Shelf. *Antiquity* 81:523–35.

O'Connor, S. 2010. Continuity in shell artefact production in Holocene East Timor. In *50 years of archaeology in Southeast Asia: Essays in honour of Ian Glover*, ed. B. Bellina, E. Bacus, T. Pryce, and C. Wisseman, 219–33. Bangkok: River Books.

O'Connor, S. 2015. Rethinking the Neolithic in Island Southeast Asia, with particular reference to the archaeology of Timor-Leste and Sulawesi. *Archipel* (90):15–47. 10.4000/archipel.362

O'Connor, S., A. Barham, K. Aplin, and T. Maloney. 2017. Cave stratigraphies and cave breccias: Implications for sediment accumulation and removal models and interpreting the record of human occupation. *Journal of Archaeological Science* 77:143–59. 10.1016/j.jas.2016.05.002

O'Connor, S., A. Barham, M. Spriggs, P. Veth, K. Aplin, and E. St Pierre. 2010. Cave archaeology and sampling issues in the tropics: A case study from Lene Hara cave, a 42,000 year old occupation site in East Timor, Island Southeast Asia. *Australian Archaeology* 71 (1):29–40. 10.1080/03122417.2010.11689382

O'Connor, S., A. McWilliam, and S. Brockwell, eds. 2020. *Forts and fortification in Wallacea: Archaeological and ethnohistoric investigations. Terra Australis 53*. Canberra: ANU Press.

O'Connor, S., S. Kealy, C. Reepmeyer, S. Samper Carro, and C. Shipton. 2022. Terminal Pleistocene emergence of maritime interaction networks across Wallacea. *World Archaeology* 54 (2):244–63. 10.1080/00438243.2023.2172072

O'Connor, S., A. McWilliam, J. Fenner, and S. Brockwell. 2012. Examining the origin of fortifications in East Timor: Social and environmental factors. *The Journal of Island and Coastal Archaeology* 7 (2):200–18. 10.1080/15564894.2011.619245

O'Connor, S., and P. Veth. 2005. Early Holocene shell fish hooks from Lene Hara Cave, East Timor establish complex fishing technology was in use in Island South East Asia five thousand years before Austronesian settlement. *Antiquity* 79 (304):249–56. 10.1017/S0003598X0011405X

O'Connor, S., R. Ono, and C. Clarkson. 2011. Pelagic fishing at 42,000 years before the present and the maritime skills of modern humans. *Science* 334 (6059):1117–21. 10.1126/science.1207703

Oliveira, N. 2008. Subsistence archaeobotany: Food production and the agricultural transition in East Timor. PhD thesis, Australian National University.

Ono, R., H. O. Sofian, A. A. Oktaviana, Sriwigati, and N. Aziz. 2021. Human migration and maritime networks in Northern Wallacea during Neolithic to Early Metal Ages. In *The archaeology of island colonization*, ed. M. Napolitano, J. Stone, and R. DiNapoli, 293–26. Gainesville: University Press of Florida.

Piper, P. 2017. The origins and arrival of the earliest domestic animals in Mainland and Island Southeast Asia: A story of complexity. In *New perspectives in Southeast Asian and Pacific prehistory*, ed. P. Piper, H. Matsumura, and D. Bulbeck, 251–72. *Terra Australis 45*. Canberra: ANU Press.

Reepmeyer, C., S. O'Connor, and S. Brockwell. 2011. Long-term obsidian use in East Timor documented at Jeremalai. *Archaeology in Oceania* 46 (2):85–90. 10.1002/j.1834-4453.2011.tb00102.x

Reepmeyer, C., S. O'Connor, S. Kealy, T. Maloney, and Mahirta. 2019. Kisar, a small island participant in an extensive maritime obsidian network in the Wallacean Archipelago. *Archaeological Research in Asia* 19:100139. 10.1016/j.ara.2019.100139

Reepmeyer, C., S. O'Connor, T. Maloney, S. Kealy, and Mahirta. 2016. Late Pleistocene/Early Holocene maritime interaction in Southeastern Indonesia and Timor-Leste. *Journal of Archaeological Science* 76:21–30. 10.1016/j.jas.2016.10.007

Reeves, J., H. Bostock, L. Ayliffe, T. Barrows, P. De Deckker, L. Devriendt, G. Dunbar, R. Drysdale, K. Fitzsimmons, M. Gagan, et al. 2013. Palaeoenvironmental change in tropical Australasia over the last 30,000 years: A synthesis by the OZ-INTIMATE group. *Quaternary Science Reviews* 74:97–114. 10.1016/j.quascirev.2012.11.027

Reimer, P. J., W. E. N. Austin, E. Bard, A. Bayliss, P. G. Blackwell, C. Bronk Ramsey, M. Butzin, H. Cheng, R. L. Edwards, M. Friedrich, et al. 2020. The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon* 62 (4):725–57. 10.1017/RDC.2020.41

Roberts, P., J. Louys, J. Zech, C. Shipton, S. Kealy, S. Samper Carro, S. Hawkins, C. Boulanger, S. Marzo, B. Fiedler, N. Boivin Mahirta, K. Aplin, and S. O'Connor. 2020. Isotopic evidence for initial coastal colonization and subsequent diversification in the human occupation of Wallacea *Nature communications* 11(1):2068. 10.1038/s41467-020-15969-4

Roque, R. 2010. Headhunting and colonialism: Anthropology and the circulation of human skulls in the Portuguese Empire 1870–1930. *Cambridge imperial and post-colonial studies*. Basingstoke: Palgrave-MacMillan.

Shipton, C., S. O'Connor, N. Jankowski, J. O'Connor-Veth, T. Maloney, S. Kealy, and C. Boulanger. 2019. A new 44,000-year sequence from Asitau Kuru (Jerimalai), Timor-Leste, indicates long-term continuity in human behaviour. *Archaeological and Anthropological Sciences* 11 (10):5717–41. 10.1007/s12520-019-00840-5

Shipton, C., S. O'Connor, C. Reepmeyer, S. Kealy, and N. Jankowski. 2020. Shell adzes, exotic obsidian, and inter-island voyaging in the Early and Middle Holocene of Wallacea. *The Journal of Island and Coastal Archaeology* 15 (4):525–46. 10.1080/15564894.2019.1581306

Southon, J., M. Kashgarian, M. Fontugne, B. Metivier, and W. Yim. 2002. Marine reservoir corrections for the Indian Ocean and Southeast Asia. *Radiocarbon* 44 (1):167–80. 10.1017/S0033822200064778

Timor-Leste. 2011. *Population and housing census, 2010*. Vol. 2 of *Population distribution by administrative areas*. Dili: National Statistics Directorate (NSD) and United Nations Population Fund (UNFPA).

USGS (United States Geological Survey). 2013. *Shuttle Radar Topography Mission (SRTM) void filled 3 arc-second dataset*. Sioux Falls: USGS Earth Resources Observation and Science Center.

Veth, P., M. Spriggs, and S. O'Connor. 2005. Continuity in tropical cave use: Examples from East Timor and the Aru Islands, Maluku. *Asian Perspectives* 44 (1):180–92. 10.1353/asi.2005.0015

Wood, R., Z. Jacobs, D. Vannieuwenhuyse, J. Balme, S. O'Connor, and R. Whitau. 2016. Towards an accurate and precise chronology for the colonization of Australia: The example of Riwi, Kimberley, Western Australia. *PloS One* 11 (9):e0160123. 10.1371/journal.pone.0160123

Woodroffe, C. 1988. Changing mangrove and wetland habitats over the last 8000 years, northern Australia and Southeast Asia. In *Vol. 2 of Floodplains research. Northern Australia: Progress and prospects*, ed. D. Wade-Marshall and P. Loveday, 1–23. Darwin: Australian National University.

Woodroffe, C., B. Thom, and J. Chappell. 1985. Development of widespread mangrove swamps in mid-Holocene times. *Nature* 317 (6039):711–3. 10.1038/317711a0