Part 5

Bringing Submerged Site Archaeology to the Surface: Theoretical and Methodological Challenges of Integrating Terrestrial and Underwater Records

Session 4 (l to r): Erich Christopher Fisher, Ashley Lemke, Angela Maria Rodriguez Schrader, Helen Farr, John O'Shea. Watch the session: [***EN add DOI here***]

UMMAA at 100: Michigan's Mark—Past, Present, and Future

October 1, 2022

Bringing Submerged Site Archaeology to the Surface: Theoretical and Methodological Challenges of Integrating Terrestrial and Underwater Records (Session 4)

Abstract: Archaeologists have long been interested in climate change, particularly its impact on global sea level. The world's extensive continental shelves preserve a record of human occupation and movement that is inaccessible to land-based research. The same holds true for the Great Lakes, where the seesaw of glacial melt waters and isostatic rebound worked to first expose and then submerge large tracts of habitable land. University of Michigan geologist George Stanley was among the first to identify and study the changing character of the post-glacial Great Lakes. He was joined in this work by the curator of Great Lakes archaeology, Emerson Greenman, who saw the potential for discovering and dating early human occupation in the region that was associated with the lower lake levels.

Archaeology now has the tools and technology to begin the serious investigation of ancient submerged sites globally. Yet the challenge is not simply how to discover such sites, but how the unique kinds of evidence preserved underwater can be integrated with the more accessible and longer established archaeological record on land. How can the finds from both contexts be made compatible and woven together to create a more comprehensive view of the human past? Such research necessarily invokes the full range of archaeological theory, from relatively low-level formation processes to higher level analytical and synthetic modeling.

In this session, an international panel of archaeologists at the leading edge of submerged site investigations will consider the implications for archaeological method and theory and how the incorporation of results from submerged sites will change our understanding of the terrestrial archaeological record.

continued

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Watch the session: [***EN add DOI here***]

Chapter 13

Bringing Submerged Site Archaeology to the Surface: An Introduction

by John O'Shea

Archaeologists are keenly aware of climate change and the impact it has had on human communities in the past. Coastlines are some of the most productive environments on earth, and human exploitation of them is a near constant over time. Given worldwide fluctuations in sea level, the boundaries between land and sea—particularly during the Pleistocene—are very different than those observed today (or likely in the near future). As such, ancient landforms and shorelines that are now submerged on the world's continental shelves hold evidence relevant to some of the most important questions facing archaeology. In a similar manner, the seesaw interplay of glacial melt waters and isostatic rebound worked to first expose and then submerge large tracts of habitable land within the early Holocene Great Lakes. University of Michigan geologist George Stanley was among the first to identify the changing character of the postglacial Great Lakes. He was joined in this work by the curator of Great Lakes archaeology, Emerson Greenman, who saw the potential for discovering and dating early human occupation in the region that was associated with the lower lake levels.

Archaeology now has the tools and technology to begin the serious investigation of ancient submerged sites globally. Yet the challenge is not simply how to discover and investigate submerged sites, but how the unique kinds of evidence preserved underwater

Figure 13.1. Pictured is the keelson of the three-masted schooner barge *Mears*, which, along with the schooner barge *Midnight*, ran aground and broke up on Au Sable Point in Lake Huron during a snowstorm in 1889. The wreck was re-exposed during low water in the lake in 2000, which is when the shot was taken. This wreck has been assigned the state site designation 20UH550 (O'Shea 2004).

can be integrated with the more accessible and longer established archaeological record on land. How can the finds from both contexts be made compatible and woven together to create a more comprehensive view of the human past? Such research must necessarily invoke the full range of archaeological theory, from relatively low-level formation processes to higher level analytical and synthetic modeling.

In the papers that follow, an international panel of younger archaeologists at the forefront of this research consider the challenges that the incorporation of submerged landscapes pose for archaeological research design, both on land and underwater, and the potentials this will offer for the better understanding of our human past. The papers consider not only the academic importance of submerged site research, but also the implications such research holds for cultural resource management and for Indigenous peoples around the globe who seek a better representation of their own pasts.

O'Shea, John M.

2004. *Ships and Shipwrecks of the Au Sable Shores Region of Western Lake Huron*. University of Michigan Museum of Anthropology, Memoirs 39. Ann Arbor, Michigan.

Chapter 14

72% and Rising: Exploring the Archaeological Potential of the Submerged Continental Shelf

by R. Helen Farr

Figure 14.1. *Another Place*, art installation on Crosby beach in Liverpool, UK, by Sir Anthony Gormley. Photo: Roy Shakespeare, 2007, Loop Images ltd.

> As the tide begins to flood the foreshore, one hundred cast-iron human sculptures are rapidly submerged; water swirling around legs, torsos, before the final rise that engulfs the human figures until the next ebb of the tide. [**HF query: is this a quote? Source?**]

These sculptures, by the artist Sir Antony Gormley (Figure 14.1)—once a student of archaeology and anthropology—make us think about submergence on a human scale: twice a day many of the sculptures are engulfed by the tide; they weather storm surges and wave action; they are buried and re-excavated, eroded. And felled.

This artwork is both a marking of time—diurnal tides, lunar cycles, and annual equinoxes—and also timeless. It makes us contemplate human activity in the coastal zone during the long durée, questions of permanence, transience, and rising sea levels. The anthropological gaze of a maritime archaeologist, combines with concern for contemporary maritime coastal heritage at threat and interest in once-terrestrial ancient landscapes now submerged.

The challenge of integrating offshore research into the archaeological record

From the human scale to the global, multiple cycles of marine transgression and regression have shaped our coastlines. In many regions of the world, the continental shelf has been repeatedly exposed and inundated, physically changing the distribution of landmass, resources, and marine environment and also having a profound effect on human lives. Vast tracks of inhabitable, and inhabited, terrain on the continental shelves have been inundated due to Holocene sea level rise, meaning that a considerable proportion of the paleoarchaeological record may now be submerged on the continental shelf. Even through repeated transgressions and regressions, in some areas, due to geomorphologic and taphonomic processes, depositional sequences can, and do, survive, with artifacts that can be retrieved from both in situ and derived contexts (Benjamin et al. 2011: xii; Sturt et al. 2018).

By expanding our archaeological research offshore and investigating areas that were once terrestrial and are now flooded by rising sea levels, we can integrate our datasets and our narratives of land and sea to gain a better understanding of human history (Flemming 2020; Ward et al. 2022). However, one of the foremost challenges is *how* to integrate the onshore and offshore archaeological data.

The submerged extent of the continental shelves represent an additional 5% of the total land area currently exposed across the globe (Sturt et al. 2018). In many regions, modern coasts and near-offshore zones were once inland, fully terrestrial landscapes. As such, a conceptual shift towards a landscape approach may help in our quest to integrate the archaeology of the submerged continental shelves into our current narratives of the past. Acceptance that what we are doing is not always *maritime* archaeology but simply *archaeology*, whether underwater or on dry land, helps this integration. The separation between onshore and offshore analysis becomes purely one of methodology, shaped by the research questions we ask and the archaeology we do.

This short paper aims to use an example from the ERC ACROSS project to show how an integrated approach to the onshore and offshore archive can be used to answer archaeological questions, moving us beyond discussions of prospection and potential.

The European Research Council ACROSS Project: Origins of seafaring to Sahul

ACROSS is an ERC-funded project studying seafaring from the Sunda shelf (Island Southeast Asia) to Sahul (modern day Australia and New Guinea) in deep time (Fogg et al. 2020; Kuijjer et al. 2022). This represents some of the earliest evidence for seafaring in global history and ties to questions of human origins and migration (Bird et al. 2019). This research is interdisciplinary and is necessarily underpinned by a study of the changing land and seascapes and the now submerged paleolandscape of the northern Australian shelf (Figure 14.2).

Global changes in relative sea level of ca.130m from the last glacial maximum (LGM) (Grant et al. 2014), have had a profound effect on the movement of people, and on our existing archaeological archive. A considerable proportion of the paleo record has been submerged during the last postglacial marine transgression. Two million square kilometres of what was once potentially inhabitable land on the Sahul shelf is now submerged (Grant et al. 2012).

These submerged landscapes on the continental shelf contain an important, and possibly unique, resource for improving our understanding of human history and environmental change. Through studying these landscapes, we can improve our understanding of a range of themes from sea level rise and climate change to ecology and hydrology of the landscape, to past activity and lived and remembered landscapes through time. When the drowned continental shelf is also recognised as representing a complex hermeneutic landscape, entwining multiple narratives and layers of significant space, its importance to community today can also be perceived.

In many regions with broad continental shelves, the archaeological evidence from known paleo sites located on, or near, coasts today is skewed to the preservation of terrestrial activity; the contemporary paleo coasts are now located far offshore. Without

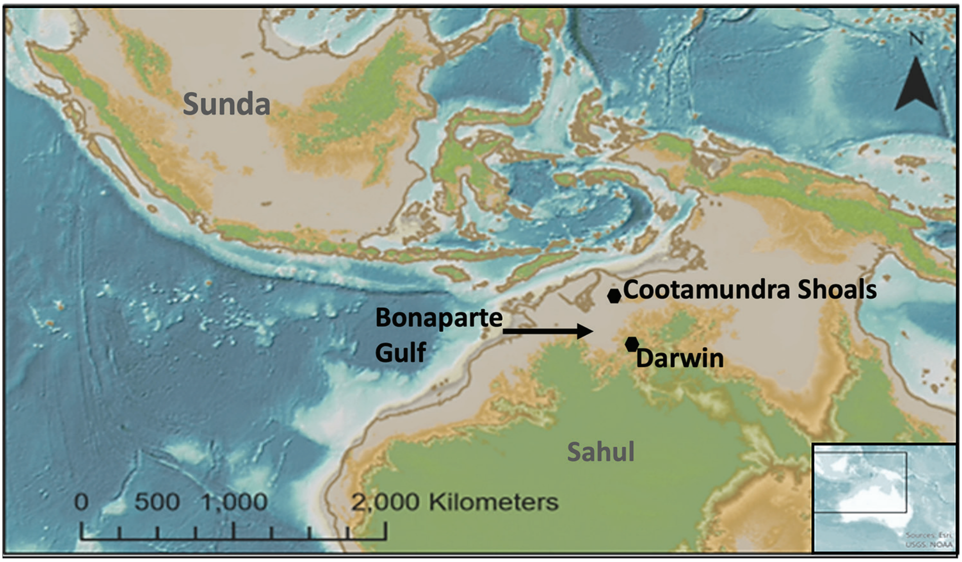

Figure 14.2. Map to show region of study with GEBCO bathymetry. Extent of northern Australian continental shelf marked at the LGM -120 to 130 m below sea level contour; and key locations mentioned in text. **[Could we add more explanation? I.e., does brown indicate land surface exposed during the Last Glacial Maximum (30000 BP?), and green indicates land surface exposed now?]**

investigation of the configuration and paleoenvironment of the once-exposed shelf, or study of the potential site preservation within it, a range of activities are missing from the archaeological record. These include evidence for early seafaring skills and knowledge, marine resource use, or coastal adaptation. As a result, we become "sea blind." Consequentially, questions regarding the role of coastal landscapes—or potential "coastal expressways" within the discourse of peopling the planet (see debates for e.g. Mellars 2006; Appenzeller 2012) and global migration in deep time—are hard to fully address.

The ERC ACROSS project set out to study the submerged paleo shelf of the northern Australian continental shelf in order to address questions about seafaring and connectivity between Sahul and Island Southeast Asia. The project took an interdisciplinary approach, combining ocean and earth science, archaeology, and population movement with Indigenous history and knowledge. Different forms of knowledge and differing ontologies can be difficult to coalesce, but doing so brings richness to the narratives we can tell, both about early seafaring and coastal activities specifically for this project, but also more generally for ocean and earth science, sustainability and the human past.

The chronology and notion of "arrival" of people in Australia is debated, and many Indigenous people understand that they have always been on Country—a term used to describe traditional land, which includes, the air, water, and stories of "Dreaming" (Kingsley et al. 2013). From a "Western science" perspective, migration of people to Sahul from the Sunda shelf occurred as part of a dispersal by anatomically modern humans "out of Africa," with the earliest date ranges on archaeological sites in Australia suggesting that people were in Sahul by ca. 50,000 years and maybe as early as 65,000 years ago (Clarkson et al. 2019). Potentially, this corresponds to Marine Isotope Stage 4 (MIS4) (Grant et al. 2014).

In order to understand the earliest evidence for seafaring between Sunda and Sahul in deep time, we need to first understand where the coasts were located: which areas of the southern Sunda shelf and northern Australian shelf would have been subaerial (dry land) and which inundated at the time of arrival. With the coastal geomorphology forming parameters, analysis can then be undertaken to investigate the seascape, ocean circulation, paleo tidal regimes and winds that would affect crossings between Sunda and Sahul. Computer modeling can also be used to investigate routing, duration of voyages, drift versus propulsion, watercraft technology, and skill (Kuijjer et al. 2022). Furthermore, it is hypothesised that through modeling likely routes, possible "arrival" points or important landmarks into Sahul could be studied—alongside geology, paleocoastal position, and ecological zone—in order to highlight areas of potential activity and preservation on the submerged shelf for future research. In this way, the project aims to integrate multiple data sets to refine our understanding of this early seafaring evidence, merging onshore–offshore narratives of past activity.

Submerged paleolandscape modeling forms a critical step within this project and follows an approach similar to that in the North Sea to create a first order reconstruction of the paleolandscape (e.g. Gaffney et al. 2009); this is then partially chronologically refined through correlation to dated borehole material. Dating of marine transgressions predating the LGM remains the biggest challenge, with refinement of MIS 4–3 sea level curves a priority. The collection of new geophysical survey and subfloor data falls outside the project budget and remit for a region of this size, so extant offshore industry data from Geoscience Australia were used, including both 2D and 3D seismic data and geotechnical data from offshore boreholes.

The location and coverage of industry data directs research locale—however, the difficulties involved in using fragmentary and variable data is not uncommon to archaeologists. Whilst the southern Sunda shelf is narrow and steeply shelving in the region of interest, the northern Australian shelf is broad and relatively shallow, with extensive coverage of marine geophysical survey available directly from industry or within the public domain.

To date, the project has focused on the Bonaparte Gulf region in order to understand changing paleoseascapes and coastal landscapes, with an emphasis on the period between

71–59ka MIS4-3 (Fogg et al. 2020) in order to coincide with the earliest dated archaeology, at a potential 50–65ka (Clarkson et al. 2017).

This region constitutes a large part of the "southern route" identified by Birdsell in 1977 as a key migration route through Island Southeast Asia to Timor or Rote on the Sunda shelf (Birdsell 1977). The region also incorporates the Cootamundra shelves, as investigated by Nic Flemming as part of the Sirius expedition (Flemming 1982, 1983).

In 1982, Flemming and his team explored the submerged Quaternary landscape of the Cootamundra Shoals, 240 km northwest from Darwin. This was one of the first surveys of a submerged Quaternary landscape in Australasia to recognise the cultural importance of offshore landscapes, both for understanding movement into Sahul in deep time but also to understand the changing coastal environment. As early as 1982, Flemming recognised this area for its potential to preserve paleoarchaeology on the submerged shelf (Flemming 1982, 1983).

Forty years on, survey methods have developed, and wider research into submerged landscapes around Australasia have developed momentum, with underwater finds (Benjamin et al. 2020; Dortch et al. 2019) showing that paleoarchaeology can be preserved and discovered in offshore/ nearshore contexts. As such, the Northwest shelf remains an area of great taphonomic interest (O'Leary et al. 2020).

In submerged paleolandscape discourse, the necessity for interdisciplinary and multi-stakeholder collaboration in collection of data and extension of research is key (Flemming et al. 2014). When dealing with shelf-scale landscapes, access to data and expertise for analysis is a necessity if on- and offshore paleolandscape records are to be integrated.

Methodological challenges include the fact that industry data is often collected for those with interests in deeper deposits and bedrock geology rather than the shallower Late Quaternary deposits in which we are interested. Very practically speaking, a large amount of specialist seismic processing is necessary for the data to be useful to those interested in archaeological paleolandscape studies. To bring onshore and offshore data sets together, as well as knowing which questions to ask, projects need to work across disciplines.

Whilst one task involves how to process vast quantities of offshore data, another is created by the difficulties in tying these to chronologies. A few shallow cores and deeper bores holes have been taken through the region, but like the seismic data, they were not collected for archaeological interpretation. As such, whilst the cores do provide boundaries to help calibrate our seismic data, they do not give the precision we would ideally want for our chronological interpretations. Variation in published sea level curves in the time depths we are interested in provide more of a challenge to our interpretation (Spratt and Lisiecki 2015).

With caveats for refinement of the sea level curve and a large quantity of specialist data processing, the ACROSS project undertook an integrated interpretative study of the evolving submerged landscapes for the Late Pleistocene of the Northern Australian Shelf to determine lowstand paleoenvironments and shoreline positions over the last glacial period MIS 1–5e, which included analysis of 16 x 3D datasets, hi-res 2D data, and 100s of 2D lines to stitch them together. This huge data set enables a geomorphological interpretation of the landscapes of potential encounter, over the past 125,000 years, with identification of highstands associated with MIS 1, MIS 3, MIS 5, and lowstands for MIS 2 and MIS 4.

Within this data, it is possible to start to identify more local environmental markers, including reef, beach, estuarine, lagoonal, and fluvial facies associated with the MIS4 lowstand at a time when people were first active in the region.

Within the Bonaparte Gulf itself, we can see dramatically changing landscapes, including fluvial systems that represent major drainages several kilometers across, and estuarine and intertidal features. The depth and location of MIS4 deposits can also be mapped, thus allowing us to broadly map the paleogeography of the northwest shelf through deep time and also map buried deposits where submerged sites could potentially be preserved.

This is just a first step in understanding the changing nature of the coastal environment (Ditchfield et al. 2022). This sort of large survey project crosses multiple communities, states, and countries' waters. So it creates the challenge for how we do this work, at this scale, in the future.

Rising sea levels and cultural heritage

To further integrate the onshore and offshore narratives, we can move discussion beyond the environmental domain and refocus on the human past and human narratives of activity.

ACROSS set out to try to gain a more refined understanding of seafaring in deep time. Understanding activity on land—even land that is now submerged—is one challenge. How we understand seafaring in deep time, when we do not have boats preserved in the archaeological record, is another. Even at this early stage in the human story, maritime space is active and imbued with multiple forms of experience and engagement—entangled with narratives and being, knowledge and tradition, technology and development, movement and travel, economy and daily practice (i.e., McNiven 2003). Our engagement with the ocean occurs at multiple levels from our earliest human history.

This is especially true in Australia, where maritime activity can be traced back to the Late Pleistocene, and maritime oral traditions have been mapped back to the Holocene (Nunn 2018:63; Nunn and Reid 2016). As such, we need to appreciate the deep routes and complexity of this space and these coastal and ocean narratives and be mindful of how maritime cultural heritage forms peoples' identities.

Multiple Indigenous stories along the northern Australian coast talk of seafaring, voyages, and the coastal environments encountered and created. These stories form an intangible maritime cultural heritage of Seacountry that is entangled with knowledge of sea level rise and changes in the marine environment (Leonard et al. 2013; Nunn 2018:106). These narratives reflect the deep heritage of coastal activity and seafaring in the region, which supports discussion of maritime cultural heritage, encounter, and arrival through time.

In many parts of the world, especially Australia, in order to bring the onshore and offshore narratives together we need to work with the Indigenous community (Robinson et al. 2018). Even with refinement of our sea level curves, oceanographic modeling, and seismic processing techniques, our understanding of the submerged continental shelf is incomplete without an understanding of its continued cultural importance and human connection. The interweaving of archaeology, marine science, and cultural heritage allows us to discuss the "Human Ocean," where people's activity and narratives both create Seacountry and adapt to its changes.

Ocean narratives are powerful—they shape law and policy and social and environmental justice. Intangible cultural heritage is often underprivileged within this discourse. When we consider these narratives, we also need to consider whose voice is heard. ACROSS aims to present many narratives, to understand seafaring in deep time within the changing marine and coastal landscape. Such an approach necessitates integration of onshore and offshore data to help appreciate the depth and complexity of people's relationship with the continental shelf—a relationship that encompasses both the long durée of sea level change and the witnessed, contemporary rising seas.

We have recently entered the United Nations Decade of Ocean Science for Sustainable Development 2021–2030 (Isensee 2020:16; Trakadas et al. 2019), and as archaeologists we have a unique set of tools to contribute to some of the big interdisciplinary challenges and sustainable development goals we are faced with today.

One of the UN's actions for the decade includes high-resolution mapping of the oceans. Understanding and mapping sea level rise at a human scale can help us learn about human response to climate change in the past and strengthen our understanding of contemporary and future coastal change. More than this, maritime heritage, both tangible and intangible, plays an important role in forming and maintaining community, identity, and wellbeing, which are also issues addressed by the UN's Ocean Decade program.

Many maritime communities living in low-elevation coastal zones today are susceptible to increasing hazards, whether through societal development, inequality, or natural hazards. These include climate change, increasing flood risks, altered hydrology, rising sea level, pollutants, plastics, and acidification of waters. These not only affect the lived environment but can lead to the loss of tangible and intangible heritage at a time when heritage itself can provide people with a sense of security in a changing world (Kingsley et al. 2013; Sofaer et al. 2021). With ca. 40% of the global population living within 100 km of the coastline (Cohen et al. 1997), this is a considerable number of people whose land, livelihood, and heritage could be threatened by these increasing coastal hazards. So, whilst we face the challenge of understanding coastal change and rising sea level in our narratives of past activity, we also face the challenge that rising sea levels present to heritage today.

ACROSS acknowledges the Aboriginal and Torres Strait Islander peoples as the traditional custodians of the seas and lands on which we undertake our research. And we pay our respects to elders past, present, and emerging.

References

Appenzeller, T.
2012. Human migrations: Eastern odyssey. *Nature* 485:24–26. DOI: 10.1038/485024a

Benjamin, J., C. Bonsall, C. Pickard, and A. Fischer, editors
2011. *Submerged Prehistory.* Oxbow Books, Oxford, UK.DOI:10.2307/j.ctvh1dx0v.

Benjamin, J., M. O'Leary, J. McDonald, C. Wiseman, J. McCarthy, E. Beckett, P. Morrison, et al.
2020. Aboriginal Artefacts on the Continental Shelf Reveal Ancient Drowned Cultural Landscapes in Northwest Australia. *PLOS ONE* 15(7): e0233912. DOI:10.1371/journal.pone.0233912.

Bird, M.I., S.A. Condie, A. O'Connor, D. O'Grady, C. Reepmeyer, S. Ulm, M. Zega, F. Saltré, and C.J.A. Bradshaw
2019. Early Human Settlement of Sahul Was Not an Accident. *Scientific Reports* 9(1): 8220. DOI:10.1038/ s41598-019-42946-9.

Birdsell, J.B.
1977. The recalibration of a paradigm for the First peopling of greater Australia. In *Sunda and Sahul: Prehistoric Studies in Southeast Asia, Melanesia and Australia*, edited by J. Allen, G. Golson, and R. Jones, pp. 113–167. Academic Press, New York.

Clarkson, C., Z. Jacobs, B. Marwick, R. Fullagar, L. Wallis, M. Smith, R.G. Roberts, et al.
2017. Human Occupation of Northern Australia by 65,000 Years Ago. *Nature* 547 (7663):306–310.

Cohen, J.E., C. Small, A. Mellinger, et al.
1997. Estimates of Coastal Populations. *Science* 278:1209–1213. DOI:10.1126/science.278.5341.1209c

Ditchfield, K., S. Ulk, T. Manne, R.H. Farr, D. O'Grady, and P. Veth
2022. Framing Australian Pleistocene coastal occupation and archaeology. *Quaternary Science Reviews* 293:107706.

Dortch, J., E. Beckett, A. Paterson, and J. McDonald
2019. Stone Artefacts in the Intertidal Zone, Dampier Archipelago: Evidence for a Submerged Coastal Site in Northwest Australia. *Journal of Island and Coastal Archaeology* 16(2–4):509–523. DOI:10.1080/15564894.2019.1666941.

Flemming, N.
1982. The Sirius Expedition: Cootamundra Shoals Survey, 1982 Expedition Report.

1986. A survey of the late Quaternary landscape of the Cootamundra Shoals, north Australia: a preliminary report. *Proceedings of the Seventh International Diving Science Symposium of CMAS*, pp. 149–180.

2008. *AIMA (Australasian Institute for Maritime Archaeology) Newsletter* 27(3):15–22.

2020. Global experience in locating submerged prehistoric sites and their relevance to research on the american continental shelves. *The Journal of Island and Coastal Archaeology* 16(2–4):261–289. DOI:10.1080/15564894.2020.1781712.

Flemming, N.C., M.N. Çağatay, F.L. Chiocci, N. Galanidou, H. Jöns, G. Lericolais, T. Missiaen, et al.
2014. Land beneath the Waves: Submerged landscapes and sea level change. A joint geoscience-humanities strategy for European Continental Shelf Prehistoric Research. Position Paper 21 of the European Marine Board. Edited by N.C. Chu & N. McDonough, 171. European Marine Board, Ostend, Belgium.

Fogg, A., J. Dix, and R.H. Farr
2020. Geophysical Mapping of Coastal Landscape during the Last Glacial Cycle, NW Shelf Australia. In *NSG2020 4th Applied Shallow Marine Geophysics Conference* 1:1–4. European Association of Geoscientists & Engineers, Belgrade, Serbia. DOI:10.3997/2214-4609.202020073

Gaffney, V.L., S. Fitch, and D.N. Smith.
2009. *Europe's lost world: the rediscovery of Doggerland.* Research Report No. 160. Council for British Archaeology. York, UK.

Grant, K.M., E.J. Rohling, M. Bar-Matthews, A. Ayalon, M. Medina-Elizalde, C. Bronk Ramsey, C. Satow, and A.P. Roberts
2012. Rapid coupling between ice volume and polar temperature over the past 150,000 Years. *Nature* 491(7426):744–747. DOI:10.1038/nature11593.

Grant, K.M., E.J. Rohling, C.B. Ramsey, H. Cheng, R.L. Edwards, F. Florindo, D. Heslop, F. Marra, A.P. Roberts, M.E. Tamisiea, and F. Williams
2014. Sea-level variability over five glacial cycles. *Nature Communications* 5(1):5076, pp. 1–9. DOI: 10.1038/ncomms6076.

Isensee, K., editor
2020. *Global Ocean Science Report 2020: charting capacity for ocean sustainability.* International Oceanographic Commission. UNESCO Publishing, Paris. ISBN: 9-789231-004247 IOC-UNESCO.

Kingsley, J., M. Townsend, C. Henderson-Wilson, and B. Bolam
2013. Developing an Exploratory Framework Linking Australian Aboriginal Peoples' Connection to Country and Concepts of Wellbeing. *International Journal of Environmental Research and Public Health* 10(2):678– 698. DOI: 10.3390/ijerph10020678.

Kuijjer, E., I. Haigh, R. Marsh, and R.H. Farr
2022. Changing tidal dynamics and the role of the marine environment in the maritime migration to Sahul. *PaleoAnthropology*. Special Issue: The Impact of Upper Pleistocene Climatic and Environmental Change on Hominin Occupations and Landscape Use, Part 1. DOI: 10.48738/2022.iss1.105.

Leonard, S., M. Parsons, K. Olawsky, and F. Kofod
2013. The role of culture and traditional knowledge in climate change adaptation: Insights from East Kimberley, Australia. *Global Environmental Change* 23(3):623–632. DOI:10.1016/j.gloenvcha.2013.02.012.

McNiven, I.
2003. Saltwater People: Spiritscapes, Maritime Rituals and the Archaeology of Australian Indigenous Seascapes. *World Archaeology* 35(3):329–349. DOI:10.1080/0043824042000185757.

Mellars, P.
2006. Going east: new genetic and archaeological perspectives on the modern human colonization of Eurasia. *Science* 313:796–800.

Nunn, P.D.
2018. *The Edge of Memory: Ancient Stories, Oral Tradition and the Post-Glacial World.* Bloomsbury, London.

Nunn, P.D., and N.J. Reid
2016. Aboriginal Memories of Inundation of the Australian Coast Dating from More than 7000 Years Ago. *Australian Geographer* 47(1):11–47. DOI:10.1080/00049182.2015.1077539.

O'Leary, M.J., V. Paumard, and I. Ward
2020. Exploring sea country through high-resolution 3D seismic imaging of Australia's NW shelf: Resolving early coastal landscapes and preservation of underwater cultural heritage. *Quaternary Science Reviews* 239:106353. DOI:10.1016/j.quascirev.2020.106353.

Robinson, D.S., C.L. Gibson, and J.W. King
2018. *Developing Protocols for Reconstructing Submerged Palaeocultural Landscapes and Identifying Native American Archaeological Sites in Submerged Environments. Best Practices.* US Department of the Interior, Bureau of Ocean Energy Management, Pacific OCS Region. Camarillo, CA: OCS Study BOEM 2018–055.
[RH Farr: the citation I find online has a fourth author and was published in Rhode Island (not CA). Can you double check this reference?]

Sofaer, J., B. Davenport, M.L. Stig Sørensen, E. Gallou, and D. Uzzell
2021. Heritage sites, value and wellbeing: learning from the COVID-19 pandemic in England. *International Journal of Heritage Studies* 27(11):1117–1132. DOI: 10.1080/13527258.2021.1955729.

Spratt, R.M., and L.E. Lisiecki
2016. A Late Pleistocene sea level stack. *Climate of the Past* 12:1079–1092. DOI:10.5194/cp-12-1079-2016, 2016.

Sturt, F., N.C. Flemming, D. Carabias, H. Jöns, and J. Adams
2018. The Next Frontiers in Research on Submerged Prehistoric Sites and Landscapes on the Continental Shelf. *Proceedings of the Geologists' Association* 129(5):654–683. DOI:10.1016/j.pgeola.2018.04.008.

Trakadas, A., A. Firth, D. Gregory, D. Elkin, U. Guerin, J. Henderson, J. Kimura, et al.
2019. The Ocean Decade Heritage Network: Integrating Cultural Heritage within the UN Decade of Ocean Science 2021–2030. *Journal of Maritime Archaeology* 14(2): 153–165. DOI:10.1007/s11457-019-09241-0.

Ward, I., A. Bastos, D. Carabias, H. Cawthra, R.H. Farr, A. Green, and F. Sturt
2022. Submerged Palaeolandscapes of the Southern Hemisphere (SPLOSH) – What is emerging from the Southern Hemisphere? *World Archaeology* 54(1):6–28. DOI: 10.1080/00438243.2022.2077822.

Chapter 15

The Challenge to Find the First Direct Evidence of Coastal Foraging During a Glacial Maximum in Africa

by Erich Christopher Fisher

Introduction

At some point in time between 162,000 and 167,000 years ago, a small group of highly mobile people occupied a small, dark, and narrow cave in southern Africa. This group was not large—perhaps no bigger than an extended family, with less than 20 men, women, and children who moved throughout the landscape collecting seasonal foods and other resources for their survival. At that time, the cave these people were inhabiting was located about 5 km away from the coastline, and the coastal plain, spread out in front of the site, provided ample opportunities to forage and hunt. There they collected firewood and plant foods like tubers and corms, and they hunted for terrestrial game that included common large ungulates like springbok, wildebeest, and eland. They also collected coastal foods from intertidal zones. Among other sea foods, the brown mussels that they brought back to the site were cooked, consumed, and dumped along the cave walls with discarded stone tools, bones, and nubs of pigment crayons made from red ochre. To that group of people, those activities would have been routine. Yet unknown to them was that a few millennia earlier, that cave had been an inland cave, located dozens of kilometers from the sea. A few millennia later, that pattern would repeat itself as global sea levels dropped again and the people who inhabited that same site during those times lived very different lives than their coastal ancestors.

Although these events are imaginary, they are based on detailed archaeological research at the site of Pinnacle Point cave PP13B near Mossel Bay, South Africa. There, excavations have revealed the earliest evidence for systematic coastal foraging during a brief climatic pulse within glacial Marine Isotope Stage 6, which brought the coastline within daily foraging range of the cave (Marean et al. 2007). Later periods of the Pleistocene prehistoric record, and its paleoenvironmental and paleoclimatic contexts, have been filled in by research in neighboring caves at Pinnacle Point—namely Crevice Cave and caves PP5-6, PP9c, and PP9b (Bar-Matthews et al. 2010; Karkanas et al. 2015; Marean 2010; Marean et al. 2006). Elsewhere along the South African coast, excavations at other sea caves—like Klasies River, Yesterfontein, Die Kelders, and Hoedjiespunt—have revealed additional detailed insights about when, where, and how early modern humans learned to use coastal aquatic resources (Dusseldorp and Langejans 2013; Jerardino 2016a; Kyriacou et al. 2014, 2015; Langejans et al. 2012; Marean 2011, 2014, 2015, 2016; Will et al. 2016).

These discoveries, mainly in South Africa, have helped shift the global perception of coastal and aquatic resources from being marginal foods—desirable only under the direst circumstances—to being regarded as a key component in the survival and evolution of the modern human lineage during the Pleistocene (see also Erlandson 2001). But just how influential were coastlines to Pleistocene hunter-gatherers? Gravel-Miguel et al. (2022), for example, have argued that coastal archaeological sites may appear to be occupied more often than inland sites simply because coastlines naturally have a more restricted geography. Jerardino (1995, 2016b) has also questioned interpretations of coastal foraging intensity using potentially misleading proxies like shell density. So, is the modern enthusiasm for coastal zones and their resources warranted? Were these places panaceas for humans, as some regard them, or are they red herrings for archaeologists?

Coastlines, Climate Change, and Chasms

Until recently, questions like these could neither be answered nor even broached. The reason was because early coastal foraging records were limited almost entirely to interglacial periods, leaving great chasms of uncertainty surrounding the glacial periods. The reason for this bias is due to three variables: climate change, human behavior, and archaeological visibility. During the Pleistocene, global sea levels fluctuated dramatically (Roberts et al. 2012; van Andel 1989; Waelbroeck et al. 2002). The expansion of polar sea ice during glacial periods lowered global eustatic sea levels. When sea levels dropped, coastlines expanded outward, exposing previously submerged land on the continental margins. How much the coastlines changed, and the amount of land that was exposed, depended on the topography of the continental margin.

In southern Africa, the broad and gently sloping continental margins meant that small changes in sea level height translated into large changes of coastline location across the south and west coasts (Dingle and Scrutton 1974; Scrutton 1973). Geospatial modeling, for example, has predicted that as much as 80,000 km^2 of land may have been exposed on South Africa's continental shelf during glacial maxima when sea levels were lowest (Fisher et al. 2010). The exposed landmass is estimated to have been equivalent in size to the modern island of Ireland today, potentially supporting populations of large grazing fauna and possibly even now-extinct migratory ecosystems (Marean et al. 2020).

Complicating matters further is basic human behavior. Many important archaeological sites that preserve records of early coastal foraging would have been located 20–100 km inland during glacial times. Archaeological and modern ethnographic studies worldwide have shown that coastal foraging is dependent upon the time that it takes hunter-gatherers to travel to the coast from a base camp, typically no further than the distance a person can walk out and back in one day (8–10 km) (Bailey and Craighead 2003; Buchanan et al. 1984; Erlandson 2001; Jerardino 2003; Parkington et al. 1988). If prehistoric hunter-gatherers really did prefer coastal environments and resources, as many researchers have hypothesized, then the coastline would have been too far away from these sites to support systematic coastal foraging during glacial periods and also for many shorter periods during interglacial phases. These people would have needed to move out onto the exposed continental platforms during periods of low sea levels to remain within foraging distance to those coastlines.

And yet, rising sea levels during interglacial periods—and ultimately at the onset of Termination-I (~14 ka) leading into the Holocene—would have then resubmerged all previously exposed land on the continental margins. The result in many parts of the world was a near catastrophic loss of archaeological records documenting coastal occupation and resource use dating to glacial periods. This is certainly the situation in southern Africa. Large changes in coastlines have made it practically impossible to conduct detailed studies about how hunter-gatherers utilized coastal zones during glacial periods or across glacial-interglacial boundaries. This is the primary reason why the bulk of coastal hunter-gatherer research has focused on either interglacial periods of the Pleistocene and the Holocene or short-term sea level transgressions during glacial phases. It is not that these times were exceptionally important in human prehistory; they are simply the only records that have been available to researchers.

Having only short and disconnected insights, which are also heavily biased towards interglacial periods, means that researchers are unable to test hypotheses across glacial and interglacial phases. Most importantly, it means that the long-term implications of coastal foraging and resource use on human biobehavioral evolution during the Pleistocene remain effectively unknown.

Filling in the Gaps

One way to fill in these gaps is by studying submerged sites. This is the approach taken at many places around the world and with greater frequency and success (e.g. Bailey et al. 2017; Easton et al. 2021; Evans et al. 2014; Faught and Smith 2021; Flemming 2021; Galili et al. 2020; Lemke 2021; O'Shea 2021a, 2021b). In South Africa, Early Stone Age artifacts have been collected underwater, but underwater archaeology itself has only been conducted since 1988 and in a much more restricted capacity—mainly on historic European shipwrecks (Werz 2003). More recently, diving surveys of the now-submerged Paleo-Agulhas Plain on the south coast of South Africa identified successions of subaerial and submerged paleodune and paleobeach deposits for paleoenvironmental reconstructions (Cawthra et al. 2015; Cawthra et al. 2016). These surveys have also identified submerged cave and cliff formations that would have been linked to the nearby Pinnacle Point caves.

However, no archaeological remains have been observed to date around Pinnacle Point. The most likely reason is the Agulhas current. One of the fastest in the world, the consistent flow path of the Agulhas current on the southern African seaboard becomes a chaotic jet of water further south, as it interacts with numerous other currents before turning back on itself in the Agulhas Retroflection Zone (Lutjeharms 2006). These forceful and turbulent water conditions simultaneously scour the seafloor and rework marine sediments on the shelf. The result is a turbulent and low visibility environment. This environment impedes underwater archaeology by creating poor working conditions for researchers while destroying fragile archaeological deposits.

An alternative approach is to seek out places where records of glacial coastal foraging may still be preserved on land. As hypothesized in Fisher et al. (2020), places with exceptionally narrow continental shelfs could have constrained past coastline changes within the limits of hunter-gatherer foraging radii during periods of low sea levels. Key to this approach is the offshore topography of the continental shelf, but while this is certainly important, it is equally important to also find places where onshore environments also provided the resources to support prehistoric human occupations and preserved the archaeological sites. This is the approach taken by the Mpondoland Paleoclimatic, Paleoenvironment, Paleoecology, and Paleoanthropology Project (P5 Project). Since 2011, P5 has studied the Mpondoland region in South Africa's Eastern Cape Province, documenting over two dozen open-air and rockshelter sites that range in age from the

Early Stone Age to historic European shipwrecks. Details about these sites and excavations are described in Fisher et al. (2013).

The continental shelf offshore Mpondoland is exceptionally narrow, only ~8 km wide. This means that during glacial periods, sites located on the modern coastline would have still been within foraging distance to the glacial coast. The modern environment in Mpondoland is also diverse. Located in the Indian Ocean Coastal Belt (IOCB) biome, the region is a well-known area for plant and animal biodiversity. This modern vegetation includes a mosaic of sourveld grasslands located on the ancient raised coastal terraces; bushveld vegetation in gullies and rocky outcrops; coastal forests on coastal dunes; and scarp forest in riverine canyons (Mucina et al. 2006). There are also horizontally bedded quartzitic sandstone cliffs at the coast and along waterways, which support the frequent formation of rockshelters that preserve archaeological deposits.

In 2013, P5 set out to test if glacial coastal foraging records were preserved in Mpondoland, specifically targeting deposits dating to the Last Glacial Maximum (LGM: 26.5–19 ka) (Clark et al. 2009). The reason was threefold. First, the LGM was the period of maximum global ice volume during the Pleistocene, and global sea levels were as much as 125 m below modern levels, exposing huge tracts of previously submerged lands on continental margins. Second, because of low sea levels, no direct evidence of coastal occupation or foraging had yet been documented in Africa dating to the LGM. Third, from a pragmatic point of view, the LGM is also relatively easier to study compared to earlier glacial periods because it is within the limits of modern radiocarbon dating. Thus, chronological studies would be able to utilize radiocarbon dating alongside other dating methods to resolve uncertainties within archaeological sequences.

Waterfall Bluff

In 2020, we published the results of a multiyear, multidisciplinary study documenting the first direct evidence of coastal foraging during the LGM in Africa (Fisher et al. 2020). This evidence was recovered from the site of Waterfall Bluff, a large coastal rockshelter located 24 m above sea level next to the Mlambomkulu waterfall (Figure 15.1). The archaeological records show that the rockshelter was occupied repeatedly—but not necessarily continuously—from 36,000 years ago to the middle Holocene. Notably, there were well-preserved deposits dating to the Last Glacial Maximum, the Last Glacial / Interglacial Transition, and the Early Holocene, providing key snapshots of human activity across the end of the Pleistocene and into the Holocene (Figure 15.2). Details about all excavation methods, stratigraphic sequences, and dating can be found in Fisher et al. (2020).

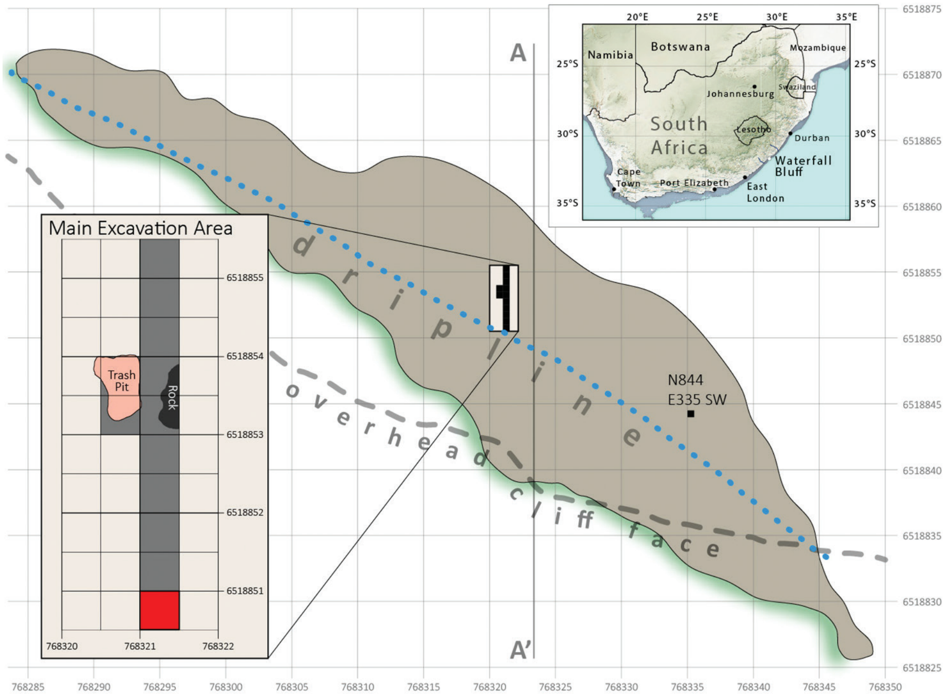

Figure 15.1. Plan map of the Waterfall Bluff rockshelter, showing the location of the main excavation trench in the center of the site. The inset shows the location of Waterfall Bluff within South Africa.

What Waterfall Bluff provides is an insight—albeit still very limited—into life along a coastline during a glacial maximum. What was this life like? First, let us consider the landscape and the climate. Today, Waterfall Bluff terminates in a precipitous cliff at the shoreline (Figure 15.3). During the LGM, when sea levels were up to 125 meters lower than today, this would have exposed the entire continental shelf seaward, and with it ~8 km of new land. Marine mapping of this now-submerged shelf suggests that it had low topographic relief. Incisions on the submerged shelf, which align with modern river channels, also indicate that there were numerous active paleo river systems during the LGM, providing a source of freshwater.

The types of plants that grew on the glacial landscape during the LGM provides important clues to the climate. Leaf wax carbon isotopes, plant pollen, and plant phytoliths suggests that fynbos vegetation and C3 grasses expanded during the LGM. The presence of these vegetation types also implies increased local winter rainfall and cooler temperatures,

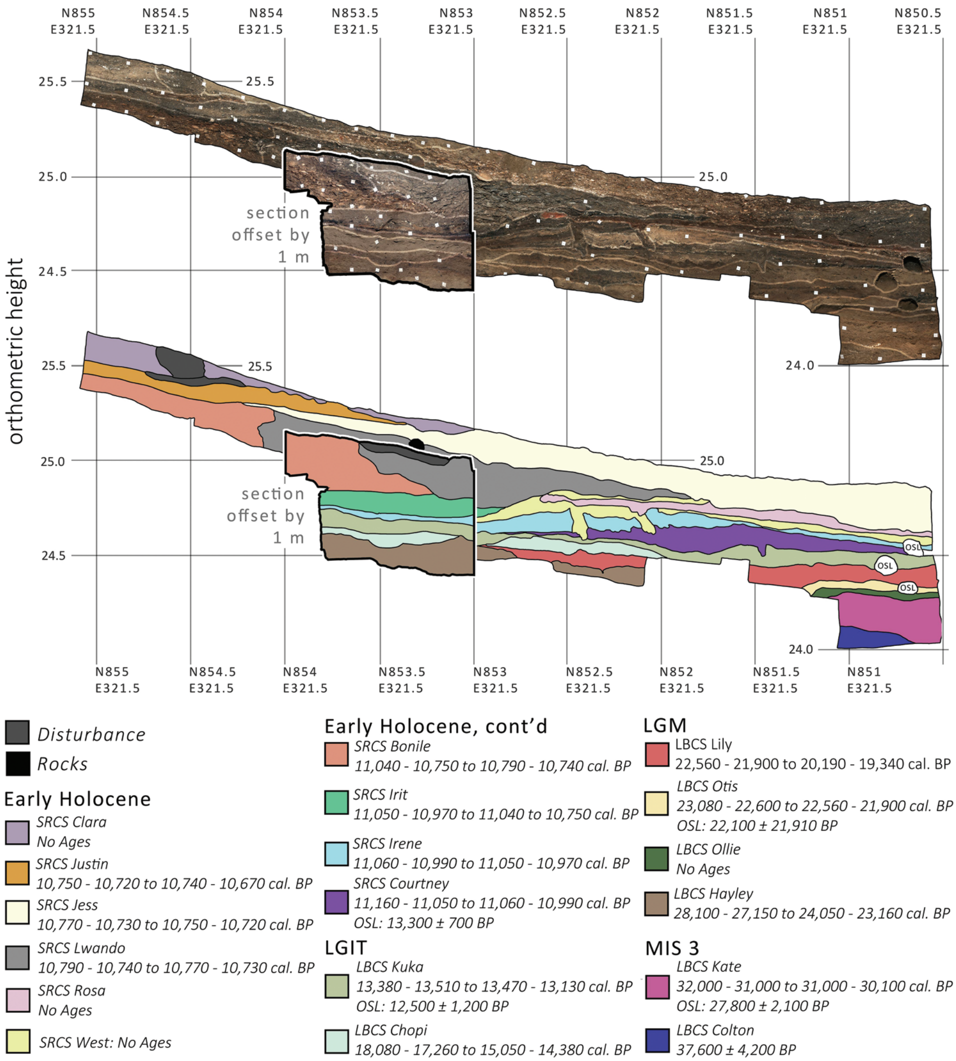

Figure 15.2. Composite view of the stratigraphy at Waterfall Bluff along the E321.5 section line. At top is the high-resolution, color-corrected photomosaic of the stratigraphy. Below is a generalized diagram of the different stratigraphic subaggregates. At the bottom of the image are the different Bayesian modeled ages and OSL ages for the subaggregates.

Figure 15.3. Two different views of Waterfall Bluff. (Top) An aerial view of the landscape and cliff face with the Mlambomkulu Waterfall. Note the presence of sourveld grasslands in fire-exposed areas and coastal thickets and forests along canyons, cliff faces, and in fire-protected areas. Waterfall Bluff is located to the right of the waterfall. (Bottom) A view of the excavations in the main trench within the rockshelter, looking towards the Mlambomkulu Waterfall in the background.

but leaf wax hydrogen isotope values suggest low total rainfall overall. Nonetheless, multiproxy paleoenvironmental analyses show that in spite of the cooler, drier conditions, all modern vegetation zones were still present during the LGM (Esteban et al. 2020). Podocarpus/Afrocarpus forests likely grew along the steep riverine slopes, perhaps even on the cliffs around Waterfall Bluff. Thicket and woody vegetation would have grown in other fire-protected areas, while dry and hygrophilous grasslands likely dominated the escarpments and much of the continental shelf. At the coast, there would also have been patches of coastal forests.

Vegetation types like Podocarpus/Afrocarpus forests, though, have high water demands. While the cooler temperatures may have favored lower evapotranspiration, it is also possible that there was sustained soil moisture from factors like sea mist. Furthermore, the paleoriver incisions on the submerged shelf also indicate that freshwater actively flowed through these rivers during the LGM when the shelf was fully exposed. Today, modern river catchments rarely extend beyond 10 km from the coastline. So even though the source of water may have differed (i.e., winter vs summer rainfall), and the overall amount of water may have been less, it appears that there may have been a coastline-focused water cycle driving precipitation, freshwater drainage, and soil moisture along a narrow coastal band. This water cycle would have supported freshwater rivers and local vegetation types, including forests and, by proxy, plant and animal resources, which all ultimately supported the people.

Living within these different vegetation zones would have been a variety of grazing and browsing herbivores, among other animals. A preliminary zooarchaeological study from Waterfall Bluff, for example, has identified eland (*Tragelaphus onyx*) and common duiker (*Sylvicapra grimmia*) remains from LGM layers. Eland implies open woodland and grassland habitats, whereas exclusive browsing species like common duiker would have lived in bushy and forested environments. Thus the fauna also point to a mosaic of environments surrounding the rockshelter during the Pleistocene–Holocene transition, including grasslands, bushy, and forested environments (Oster et al. in prep).

LGM hunter-gatherers, though, did not survive exclusively on terrestrial resources. Excavations at Waterfall Bluff have documented abundant evidence of coastal foraging. Mineralogical analysis and scanning electron microscopy, for example, have been used to reveal the microscopic nacreous remains of Mytilidae shell within decalcified LGM and other layers around the dripline (Oertle et al. 2022). Further inside the rockshelter, where stratigraphic and fauna preservation is greater, excavations have yielded numerous shellfish and fish bone remains from nearly all anthropogenic deposits. However, preservation and representation remains greatest in Early Holocene deposits, compared to the Pleistocene deposits.

Evidence of coastal intertidal foraging during the Last Glacial Maximum is dominated by brown mussel (*Perna perna*), with smaller quantities of limpets and few Natal rock oysters (*Saccostrea cucullata*). The fish taxa are from species common today in estuarine environments. Intriguingly, a single tooth from a leopard seal (*Hydrurga leptonyx*) has also been discovered in LGM layers (Oster et al. in prep). Leopard seals live on pack ice around Antarctic and sub-Antarctic islands. In the 20th century, there were only three recorded instances of leopard seals near South Africa, and there are no known specimens of leopard seals from archaeological deposits. While one tooth is obviously a poor sample size, it is still intriguing to consider that if there ever was a time period where one may expect a range expansion of an Antarctic species, then the LGM would be an ideal candidate. Sea surface temperatures were around 3° C lower than today (Caley et al. 2011), so the expansion of polar ice may have accommodated a previously unrecorded range expansion of leopard seals at this time.

There is also evidence for how the LGM coastline was utilized. An ongoing ethnographic study of contemporary wood foraging demonstrates that modern amaPondo coastal foragers—mainly women—often harvest wood for fires and implements on the same trips to collect marine intertidal resources. The forage—both terrestrial and marine—is usually collected at or near river mouths and in estuarine environments, not unlike the habitats inferred from the taxa in the archaeological fish assemblage at Waterfall Bluff. Furthermore, analysis of archaeological charcoal from LGM layers has even identified wood species endemic to coastal forests (Esteban et al. 2020). These data create yet another tangible link between the present and the past and between the archaeological records at Waterfall Bluff and the coast during the glacial maximum. Taken together, the findings from Waterfall Bluff suggest that people during the LGM may have targeted estuarine environments for a variety of resources—shellfish, fish, and wood, at least—a pattern that is not unlike the modern amaPondo forgers today.

Conclusions

The research from Waterfall Bluff provides a limited yet insightful glimpse into the lives of some prehistoric hunter-gatherer groups who lived along the South African coastline during the Last Glacial Maximum. Basic questions still remain unanswered, though. How many groups of hunter-gatherers used the site, for example? How closely did they hew to the coastline during the LGM? Was Waterfall Bluff itself used more often as a residential base or as a logistical camp? Also, what were the proportions of terrestrial to marine foods and plant to animal foods for those coastal hunter-gatherers?

Nonetheless, even at this early stage of research, there are two important conclusions that can be drawn. First, in spite of the very limited data set, there is as yet no evidence that coastal hunter-gatherers at Waterfall Bluff lacked resources for their survival or that they had to travel long distances for those resources. Everything that has been documented to date could have been found locally. This observation is at odds with the apparent regionwide redistributions of hunter-gatherer populations inland during the LGM on account of climatically driven changes in resource availability (for references, see Fisher et al. 2020).

Second, that LGM coastal foragers were collecting fuel wood from coastal habitats, perhaps near estuaries and river mouths, where they also collected shellfish and fish, suggests that hunter-gatherers viewed their coastline less like a specialty seafood shop and more like a one-stop convenience store. The main draw of places like Waterfall Bluff for LGM hunter-gatherer groups, therefore, may not have been the presence of one resource versus another, but the combination of all the resources within a centralized location. Other terrestrial fauna, plus additional plant resources—like corms, tubers, fruits, and edible leaves—would have also been available on the exposed continental shelf or inland around the site.

P5 research at Waterfall Bluff provides a window into hunter-gatherer behavior across a glacial/interglacial phase in a persistent coastal context, which has never before been studied in southern Africa. Although still in early stages, this research demonstrates that records of coastal foraging from glacial maxima do still exist on land. It just takes a very specific set of circumstances to accommodate the accumulation of the archaeological record, in the first place, and subsequent preservation to the present day.

References

Bailey, G.N., and A.S. Craighead
2003. Late Pleistocene and Holocene coastal palaeoeconomies: a reconsideration of the molluscan evidence from Northern Spain. *Geoarchaeology* 18:175–204.

Bailey, G.N., J. Harff, and D. Sakellariou
2017. Under the sea: archaeology and palaeolandscapes of the continental shelf. Coastal Research Library 20. Springer.

Bar-Matthews, M., C.W. Marean, Z. Jacobs, P. Karkanas, E.C. Fisher, A.I.R. Herries, K. Brown, H.M. Williams, J. Bernatchez, and A. Ayalon
2010. A high resolution and continuous isotopic speleothem record of paleoclimate and paleoenvironment from 90 to 53 ka from Pinnacle Point on the south coast of South Africa. *Quaternary Science Reviews* 29(17–18):2131–2145.

Buchanan, W.F., J.E. Parkington, T.S. Robey, and J.C. Vogel
1984. Shellfish, subsistence and settlement: some western Cape Holocene observations. In *Frontiers: Southern African Archaeology Today*, edited by M. Hall, G. Avery, D.M. Avery, M.L. Wilson, and A.J.B. Humphreys, pp. 121–130. British Archaeological Reports International Series 207.

Caley, T., J.H. Kim, B. Malaize, J. Giraudeau, T. Laepple, N. Caillon, K. Charlier, H. Rebaubier, L. Rossignol, I.S. Castaneda, S. Schouten, and J.S.S. Damste
2011. High-latitude obliquity as a dominant forcing in the Agulhas current system. *Climate of the Past* 7(4):1285–1296.

Cawthra, H.C., J.S. Compton, E.C. Fisher, M.R. MacHutchon, and C.W. Marean
2015. Submerged shorelines and landscape features offshore of Mossel Bay, South Africa. Geological Society, London, Special Publications 411(1):219–233.

Cawthra, H., J. Compton, E. Fisher, and C. Marean
2016. Former land surfaces and palaeoshorelines on the Mossel Bay continental shelf, South Africa. *Quaternary International* 404(Part B):195.

Clark, P., A. Dyke, J. Shakun, A. Carlson, J. Clark, B. Wohlfarth, J. Mitrovica, S. Hostetler, and A. McCabe
2009. The Last Glacial Maximum. *Science* 325(5941):710–714.

Dingle, R.V., and R.A. Scrutton
1974. Continental Breakup and Development of Post-Paleozoic Sedimentary Basins Around Southern Africa. *Geological Society of America Bulletin* 85(9):1467–1474.

Dusseldorp, G.L., and G.H.J. Langejans
2013. Carry that weight: coastal foraging and transport of marine resources during the South African Middle Stone Age. *Southern African Humanities* 25:105–135.

Easton, N.A., C. Moore, and A.R. Mason
2021. The archaeology of submerged prehistoric sites on the North Pacific Coast of North America. *The Journal of Island and Coastal Archaeology* 16(1):118–149.

Erlandson, J.M.
2001. The archaeology of aquatic adaptations: paradigms for a new millennium. *Journal of Archaeological Research* 9(4):287–350.

Esteban, I., M.K. Bamford, A. House, C.S. Miller, F.H. Neumann, E. Schefuß, J. Pargeter, H.C. Cawthra, and E.C. Fisher
2020. Coastal palaeoenvironments and hunter-gatherer plant-use at Waterfall Bluff rock shelter in Mpondoland (South Africa) from MIS 3 to the Early Holocene. *Quaternary Science Reviews* 250:106664.

Evans, A.M., J.C. Flatman, and N.C. Flemming, editors
2014. *Prehistoric archaeology on the continental shelf: a global review*. Springer, New York.

Faught, M.K., and M.F. Smith
2021. The magnificent seven: Marine submerged precontact sites found by systematic geoarchaeology in the Americas. *The Journal of Island and Coastal Archaeology* 16(1):86–102.

Fisher, E., R. Albert, G. Botha, H. Cawthra, I. Esteban, J. Harris, Z. Jacobs, A. Jerardino, C. Marean, F. Neumann, J. Pargeter, M. Poupart, and J. Venter
2013. Archaeological reconnaissance for Middle Stone Age sites along the Pondoland Coast, South Africa. *PaleoAnthropology* 104–137.

Fisher, E., M. Bar-Matthews, A. Jerardino, and C. Marean
2010. Middle and Late Pleistocene paleoscape modeling along the southern coast of South Africa. *Quaternary Science Reviews* 29(11–12):1382–1398.

Fisher, E.C., H.C. Cawthra, I. Esteban, A. Jerardino, F.H. Neumann, A. Oertle, J. Pargeter, R.B. Saktura, K. Szabó, S. Winkler, and I. Zohar
2020. Coastal occupation and foraging during the last glacial maximum and early Holocene at Waterfall Bluff, eastern Pondoland, South Africa. *Quaternary Research* 97:1–41.

Flemming, N.C.
2021. Global experience in locating submerged prehistoric sites and their relevance to research on the American continental shelves. *The Journal of Island and Coastal Archaeology* 16(1):170–193.

Galili, E., B. Rosen, M.W. Evron, I. Hershkovitz, V. Eshed, and L.K. Horwitz
2020. Israel: Submerged Prehistoric Sites and Settlements on the Mediterranean Coastline—the Current State of the Art. In *The Archaeology of Europe's Drowned*

Landscapes, edited by G. Bailey, N. Galanidou, H. Peeters, H. Jöns, and M. Mennenga, pp. 443–481. Coastal Research Library, Volume 35. Springer International Publishing, Cham.

Gravel-Miguel, C., J. De Vynck, C.D. Wren, J.K. Murray, and C.W. Marean
2022. Were prehistoric coastal sites more intensively occupied than inland sites? Using an agent-based model to understand the intensity of prehistoric coastal occupation, and what it means for studies on the evolution of the coastal adaptation. *Quaternary International* 638–639:148–158.

Jerardino, A.
1995. The problem with density values in archaeological analysis: a case study from Tortoise Cave, Western Cape, South Africa. *South African Archaeological Bulletin* 50:21–27.

2003. Pre-colonial settlement and subsistence along sandy shores mouth of Elands Bay, West Coast, South Africa. *South African Archaeological Bulletin* 58(178):53–62.

2016a. On the origins and significance of Pleistocene coastal resource use in southern Africa with particular reference to shellfish gathering. *Journal of Anthropological Archaeology* 41:213–230.

2016b. Shell density as proxy for reconstructing prehistoric aquatic resource exploitation, perspectives from southern Africa. *Journal of Archaeological Science*: Reports 6:637–644.

Karkanas, P., K. Brown, E. Fisher, Z. Jacobs, and C. Marean
2015. Interpreting human behavior from depositional rates and combustion features through the study of sedimentary microfacies at site Pinnacle Point 5-6, South Africa. *Journal of Human Evolution* 85:1–21.

Kyriacou, K., J.E. Parkington, A.D. Marais, and D.R. Braun
2014. Nutrition, modernity and the archaeological record: Coastal resources and nutrition among Middle Stone Age hunter-gatherers on the western Cape coast of South Africa. *Journal of Human Evolution* 77:64–73.

Kyriacou, K., J.E. Parkington, M. Will, A.W. Kandel, and N.J. Conard
2015. Middle and Later Stone Age shellfish exploitation strategies and coastal foraging at Hoedjiespunt and Lynch Point, Saldanha Bay, South Africa. *Journal of Archaeological Science* 57:197–206.

Langejans, G.H.J., K.L. van Niekerk, G.L. Dusseldorp, and J.F. Thackeray
2012. Middle Stone Age shellfish exploitation: Potential indications for mass collecting and resource intensification at Blombos Cave and Klasies River, South Africa. *Quaternary International* 270(0):80–94.

Lemke, A.
2021. Submerged prehistory and anthropological archaeology: Do underwater studies contribute to theory? *The Journal of Island and Coastal Archaeology* 16(1):5–26.

Lutjeharms, J.R.E.
2006. *The Agulhas Current.* Springer-Verlag, New York.

Marean, C.W.
2010. Pinnacle Point Cave 13B (Western Cape Province, South Africa) in context: The Cape Floral kingdom, shellfish, and modern human origins. *Journal of Human Evolution* 59(3–4):425–443.

2011. Coastal South Africa and the coevolution of the modern human lineage and the coastal adaptation. In *Trekking the Shore: Changing Coastlines and the Antiquity of Coastal Settlement*, edited by N.F. Bicho, J.A. Haws, and L.G. Davis, pp. 421–440. Springer, New York.

2014. The origins and significance of coastal resource use in Africa and Western Eurasia. *Journal of Human Evolution* 77:17–40.

2015. An Evolutionary Anthropological Perspective on Modern Human Origins. *Annual Review of Anthropology* 44(1):533–556.

2016. The transition to foraging for dense and predictable resources and its impact on the evolution of modern humans. *Philosophical Transactions of the Royal Society B*: Biological Sciences 371(1698):20150239.

Marean, C.W., M. Bar-Matthews, J. Bernatchez, E. Fisher, P. Goldberg, A. Herries, Z. Jacobs, A. Jerardino, P. Karkanas, T. Minichillo, P. Nilssen, E. Thompson, I. Watts, and H. Williams
2007. Early human use of marine resources and pigment in South Africa during the Middle Pleistocene. *Nature* 449(7164):905–908.

Marean, C.W., M. Bar-Matthews, P.J. Nilssen, E.C. Fisher, A. Herries, and P. Karkanas
2006. Paleoclimatic context of the origins of modern humans in South Africa: Based on speleothems isotopic records. *Geochimica et Cosmochimica Acta* 70(18).

Marean, C.W., R.M. Cowling, and J. Franklin
2020. The Palaeo-Agulhas Plain: Temporal and spatial variation in an extraordinary extinct ecosystem of the Pleistocene of the Cape Floristic Region. *Quaternary Science Reviews* 235:106161.

Mucina, L., C. Scott-Shaw, M. Rutherford, K. Camp, W. Matthews, L. Powrie, and D. Hoare
2006. Indian Ocean Coastal Belt. In *The vegetation of South Africa, Lesotho, and Swaziland*, edited by L. Mucina and M.C. Rutherford, pp. 568–583. South African National Biodiversity Institute, Pretoria.

Oertle, A., K. Szabó, S. Gaqa, H.C. Cawthra, I. Esteban, J. Pargeter, and E.C. Fisher
2022. Peering into the unseen: Novel methods in identifying shell taxa from archaeological micro-fragments. *Journal of Archaeological Science* 147:105667.

O'Shea, J.
2021a. Submerged prehistory in the Americas: Methods, approaches and results. *The Journal of Island and Coastal Archaeology* 16(1):1–4.

2021b. Micro-regional approaches for submerged site archaeology. *The Journal of Island and Coastal Archaeology* 16(1):103–117.

Parkington, J., C. Poggenpoel, W. Buchanan, T. Robey, T. Manhire, and J. Sealy
1988. Holocene coastal settlement patterns in the western Cape. In *The Archaeology of Prehistoric Coastlines*, edited by G. Bailey and J. Parkington, pp. 22–41. Cambridge University Press, New York.

Roberts, D.L., P. Karkanas, Z. Jacobs, C.W. Marean, and R.G. Roberts
2012. Melting ice sheets 400,000 yr ago raised sea level by 13 m: Past analogue for future trends. *Earth and Planetary Science Letters* 357–358(0):226–237.

Scrutton, R.A.
1973. Structure and evolution of the sea floor south of South Africa. *Earth and Planetary Science Letters* 19(2):250–256.

van Andel, T.
1989. Late Pleistocene Sea Levels and the Human Exploitation of the Shore and Shelf of Southern South Africa. *Journal of Field Archaeology* 16(2):133–155.

Waelbroeck, C., L. Labeyrie, E. Michel, J.C. Duplessy, J.F. McManus,K. Lambeck, E. Balbon, and M. Labracherie
2002. Sea-level and deep water temperature changes derived from benthic foraminifera isotopic records. *Quaternary Science Reviews* 21(1–3):295–305.

Werz, B.E.J.S.
2003. Cape of Storms or Cape of Good Hope? The development of maritime archaeological research in South Africa and prospects for the future. In *Maritime Heritage*, edited by C.A. Brebbia and T. Gambin. Transactions on The Built Environment, Volume 65. DOI: 10.2495/MH030071. WIT Press, UK.

Will, M., A.W. Kandel, K. Kyriacou, N.J. Conard
2016. An evolutionary perspective on coastal adaptations by modern humans during the Middle Stone Age of Africa. *Quaternary International* 404(Part B):68–86.

Chapter 16

A Consideration of Underwater Archaeological Research Design

by Ashley Lemke

It was an honor to celebrate the University of Michigan Museum of Anthropological Archaeology (UMMAA) on its one hundredth birthday! In the 100 years of Michigan archaeology, perhaps the best-known achievement of the Museum is its creation and consistent use of anthropological archaeology: An archaeology that is embedded with cultural, biological, and linguistic approaches and methods and one that is conducted scientifically and rigorously, while addressing the broadest span of research questions. As a graduate student at UMMAA from 2008 to 2016, I was trained in this approach and have continued to apply it in my own research—most notably, when writing my dissertation in the Ruthven Museum on submerged ancient sites in the North American Great Lakes, I found myself asking, "What would Binford do?" (Figure 16.1). How would Lewis Binford approach underwater archaeology? How could I make underwater archaeology anthropologically relevant and fuse UMMAA traditions with cutting-edge interdisciplinary research on submerged landscapes? During the conference, when I was revisiting UMMAA, I revisited these questions as well.

How does one conduct anthropological archaeology underwater? The first hurdle to this approach is the long-established tradition of historical particularism in underwater archaeology (Bass 1983). This is not surprising, given that underwater archaeology has

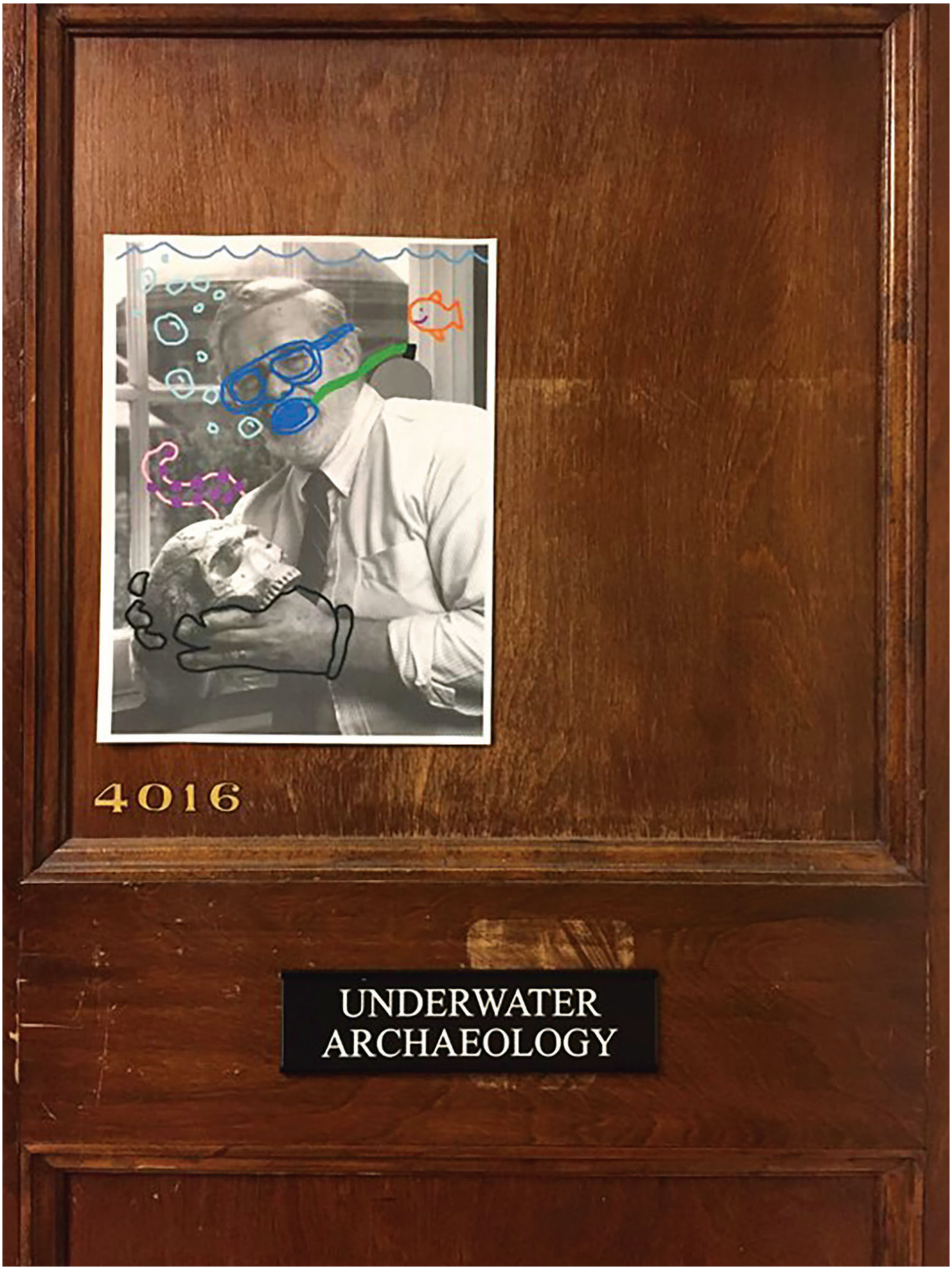

Figure 16.1. Picture of Lewis Binford on Ruthven Museum door, 2016.

often been synonymous with shipwreck archaeology. Indeed, although sites that were much older have been known from submerged contexts since the 1800s, most underwater research has focused on shipwreck investigations. And for these sites, historical particularism is required. While it is clear that many of the physical methods used for exploring shipwrecks can also be used for investigating ancient sites, their intellectual examination does differ in many fundamental aspects, including relevant theory, scale, formation processes, and context (see Lemke 2021; Lemke and O'Shea 2022). These differences between sites of disparate ages simply reflect the same divergence between historical and prehistorical site investigations on land. Due to these differences in the practice of archaeology underwater, crafting research designs for specific time periods and regions/projects has been essential. Importantly, the field of submerged landscapes—or prehistoric, or pre-contact underwater archaeology—considered a nascent subdiscipline in 2011 (Gusick and Faught), has made critical leaps and bounds in discoveries, site investigations, and methods development, but most importantly in being accepted as a viable branch of archaeology by archaeologists across the globe. Over a decade beyond nascent, what are the big problems still facing submerged prehistory? How should we design our research?

Prehistorians of submerged landscapes have argued (correctly) that certain general models are not appropriate or accurate for application in all regions—for example, sea level curves are extremely specific and wildly variable from place to place—but there is still an issue of crafting research designs that are generally applicable; more specifically, creating sampling strategies that can be usefully applied by cultural resources managers. Right now, within the larger context of significant investment in infrastructure by the federal government of the United States, creating a huge need for cultural resources managers working on land, there is also a critical gap in the workforce of underwater archaeologists, or even archaeologists with a basic understanding of underwater sites and technique—particularly as development projects increasingly encounter water or, in some cases, are directly underwater, such as wind farm construction on the continental shelves. While coming a long way from nascent, submerged landscapes are still difficult to investigate, sites are still occasionally difficult to find, and in general the known data from underwater contexts is still not often integrated with the more accessible and longer established archaeological record on land. While it's now clear that a holistic understanding of the past requires data from both land and underwater, cultural resources management practices that have long been established for terrestrial projects do not have an equivalent for offshore work.

This is a problem. Underwater sites and submerged landscapes are critical in their own right as intellectual problems and for the novel data they preserve but also for incorporating into models generated from terrestrial data. How do we test models of landscape use, mobility, subsistence practices, trade/exchange networks, and ritual spaces without considering a large part of the ancient landscape? Models that do not consider the entire landscape available at the time of prehistoric occupation are incomplete at best, and any testing of these models will be insufficient without offshore work. For example, it is now clear that some cultural historical models, such as the peopling of the western hemisphere, require revision after the incorporation of submerged data (Halligan et al. 2016). And while offshore work is challenging, there are sufficient examples of submerged finds and landscapes that demonstrate this research is worth the effort.

Essentially, we are left with two problems for conducting anthropological archaeology underwater. First, submerged landscapes preserve novel data to address some of our biggest questions about the past (Lemke 2021), but how do we connect the submerged and terrestrial records? Particularly when some submerged landscapes lie in theoretical and methodological vacuums (see case study below). Second, beyond theoretical applications and modeling past lifeways, cultural resources management (CRM) requirements are outpacing the field, meaning that methodological advances and data insights from academic research are out of sync with federal guidelines and work force expertise. The need to manage resources is happening before best practices for their discovery and investigation are developed.

These two problems cover the gamut of research questions—the first dealing with the "how" and "why" questions about the past and the second dealing with the "what, where, and when" questions (outlined by Binford 1964). All of these require the full range of archaeological theory, from relatively low-level formation processes to higher lever analytical and synthetic modeling. Essentially, the crux of anthropological archaeology—in this case we just happen to be underwater. So how do we bring Binford 1964 to 2023 and go underwater? How do we tackle these questions and go further? In addition to our how, why, what, where, and when questions, issues of science and heritage, education, accessibility, diversity, inclusion, and community partners can be added to this equation to create anthropological underwater archaeology today. In order to outline what this may look like, a very brief case study is presented below and then used as a starting point for discussing underwater archaeology research design and moving on to suggestions for the future.

Similar to fluctuations in global water levels since the end of the last ice age, the five Great Lakes in North America experienced oscillations in their coastlines as water budgets variously increased or decreased with rainfall, runoff, glacial melt, changing outlets, and isostatic rebound. These changes resulted in both highstands and lowstands in each lake. During one of the most dramatic lowstand periods, an additional 250,000 hectares of land was available in the Lake Huron basin, between ~11,500 and 8,300 cal. yr. BP. One unique geological feature exposed at the time became a dryland corridor connecting contemporary Michigan to Ontario, now called the Alpena-Amberley Ridge (AAR). For more than a decade, UMMAA underwater research on the AAR has documented a cultural occupation that dates to ~9,000 cal. yr. BP. Interdisciplinary investigations began with large-scale sonar mapping and survey of the central AAR. These studies have generated data about the unique early Holocene paleoenvironment—including preserved rooted trees, other macro- and microbotanical samples, and peat bogs—demonstrating that the AAR housed a peri-glacial subarctic-like environment on a landform characterized by higher overlooking ridges, broad flat valleys, and narrow choke points lined with glacial eskers. Archaeological research has focused primarily on documenting stone-constructed hunting features such as drive lanes and hunting blinds used for targeting caribou, as well as stone tools and flaking debris (O'Shea and Meadows 2009; O'Shea et al. 2014; O'Shea et al. 2021) (Figure 16.2). Such features are indicative of an engineered landscape, where humans niche-constructed certain areas to increase the yield from and predictability of wild animal resources. Such structures can collectively be referred to as hunting architecture (Lemke 2022), and the Lake Huron structures represent the oldest such features on the planet. Hunting architecture works by relying on traditional ecological knowledge about landscapes and animal behavior, and thus, the underwater setting of the Great Lakes has preserved evidence of early Holocene traditional knowledge (Windle et al. 2023).

In order to assist underwater investigations, the AAR team has expanded to include computer scientists, who have created a virtual world of the AAR when it was dryland. This computer simulation incorporates artificial intelligence and agent-based modeling of caribou migrations across the landform. This virtual world serves as both a data repository and an exploratory tool, as modeling can help predict where additional archaeological sites may be located. Furthermore, the virtual world can be combined with virtual reality (VR), which can help visualize a landscape that no longer exists. One of the most recent developments with the VR is creating an immersive experience, not just for researchers but also community partners and students. For example, the team is working with traditional caribou hunters from the Native village of Kotzebue in Alaska to combine AI with traditional ecological knowledge. In this way, underwater archaeology is embedded with computer science and citizen science/community partnerships to create a collaborative virtual world of an ancient landscape, one that both models past environments and presents Indigenous views by highlighting traditional ecological knowledge.

This case study offers lessons relevant to the problems facing submerged landscape archaeology as outlined above. First, models built using terrestrial data from the region do not explain what was below Lake Huron. For example, traditional cultural historical models of the Great Lakes characterize early occupants as small, highly mobile groups of hunter-gatherers using large, fluted point technologies, similar to Paleoindian time periods in other regions. Technology is stated to change to lanceolate points later in the period, with the following Archaic period characterized by notched and stemmed points. To

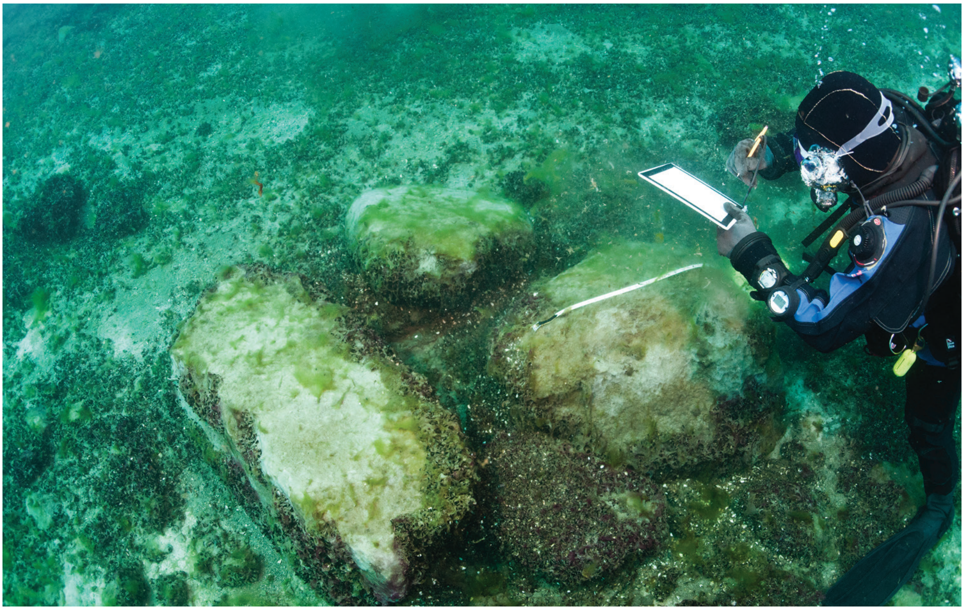

Figure 16.2. Archaeologist mapping a hunting feature on the Alpena-Amberley Ridge, Lake Huron.

date, no large bifaces or biface fragments (fluted or otherwise) have been recovered from archaeological sites on the AAR. While two obsidian flakes are the likely the byproduct of bifacial manufacture/maintenance (O'Shea et al. 2021), other lithics are more indicative of a microtool tradition, unknown from the terrestrial Great Lakes record. Furthermore, terrestrial models particularly focused on high mobility do not account for the niche-constructing behaviors evidenced by the AAR structures. Hunting architecture sites anchor populations to certain spots on the landscape, at least for the part of the year, and sites on the AAR display evidence of use both in the fall and spring (O'Shea et al. 2013). One of the biggest problems with terrestrial models is indeed the lack of a rich archaeological record dating to the early Holocene on land in this immediate area, precisely because much of that record now lies underwater. With just the terrestrial record alone, there is no extensive culture history for this time period that provided expectations for what sites and material culture would look like. Indeed, the lacunae in these models is not too surprising, given that most of the landscape from this time period was flooded. In this case, terra incognita really translated to aqua incognita.

In addition to a lack of relevant expectations for what may be found, methodologically the sites in Lake Huron also presented a different problem. The early Holocene sites in Lake Huron are among the deepest (100 ft, 30 m) and farthest offshore (50 mi, 80 km) of any submerged landscapes sites. Conducting deep-water archaeology presented unique challenges, as well as the cold-water temperatures of the Great Lakes. For example, an airlift that was designed to excavated ancient submerged sites in Florida karstic sink holes and rivers was used in Lake Huron; given the dramatic differences in water temperature, it froze.

Overall, this case study reveals two important points: 1) that the models for this region are incomplete and need the incorporation of submerged data, and 2) that there are new answers to the "what" "when" and "where" questions. Surely these same lessons will be borne out in other contexts. For example, early human habitation of the North American Southeast had to be refined after the 16,000-year-old discoveries submerged at the Page-Ladson site; current research in Australia is having a similar effect; and data gleaned from offshore contexts all over the world may upend regional models. While there may be occasional so-called "unicorn" finds that are the result of truly unique events, most of the submerged sites so far date to time periods that are either unknown or poorly preserved on land, and thus complement and complete the record. In many ways, the acknowledgement that the underwater record is *not* special is what's most important; it can be investigated just like sites on land, providing new cultural historical data and ultimately theoretical insights into the past—an understanding we've long had for shipwreck archaeology, which is now hopefully applied to other submerged landscapes.

But what about the second problem? With the increasing demand for cultural resources review in submerged settings, how do we summarize methodological insights and best practices for documenting submerged sites? Particularly when each case may be methodologically unique? It's clear that our models are incomplete without underwater data, but CRM doesn't test models, it doesn't pick its research areas, and they are working in a similar situation to the above case study, where cultural historical models did not work anyway. How do we aid CRM practitioners in locating submerged sites on preserved submerged landscapes to ultimately manage them? **There is a disconnect or outpacing of the rate of innovation in submerged landscape studies and creating general guidelines and best practices for finding sites with the immediate need to managing them. [Revise for clarity?]** Particularly in the United States, there are so few underwater archaeologists with any training in submerged landscapes that they are all employed full-time and working on numerous projects simultaneously. While there are some guidelines in existence, they are largely the work of individual underwater archaeologists on a state-by-state basis. For example, some (but not all) coastal states (such as Texas, Florida, and Virginia) have had state underwater archaeologists. These practitioners have had to create guidelines for their states de novo. At the federal level, most recently, the Bureau of Ocean Energy Management has established and revised guidelines as well, but in general, most of these guidelines were created for shipwrecks. Imagine if cultural resources management practices were only designed to detect and document historic structures.

While the current problems facing CRM of underwater sites in the United States is more **drastic given infrastructure developed [Missing word?],** the current inadequate workforce could have been predicted. For example, panels at both the Society for American Archaeology Annual Meeting and the Society for Historical and Underwater Archaeology Annual Meeting in 2016 and 2018 discussed the real lack of educational pathways for students interested in pursuing submerged prehistory in the US. Essentially, the few programs that exist are focused on nautical archaeology and do not always incorporate geoarchaeology and/or remote sensing methods that are essential for submerged landscape research. Graduates from these programs employed in CRM do not have the necessary skills for investigating pre-contact or Indigenous sites, although from the employer's perspective all underwater archaeology may appear the same. Unfortunately, there is no immediate solution, as training takes time, and certainly universities are not known for fast and/or simple changes to curriculum and programs. What changes could be made?

Suggestions include adding underwater archaeology classes at the undergraduate level. Even an introductory course can familiarize students who may go into CRM with the basic methods and approaches. Additionally, adding underwater field schools and/or hybrid field schools that cover both terrestrial and underwater settings would be a wonderful training opportunity. Importantly, either of these options could be designed without a scuba diving component. Scuba diving presents a financial barrier to instructors teaching field schools; it is also a liability issue. Furthermore, while most programs can offer a field school experience—even small sociology and anthropology departments—these same programs will often not have the ideal support and/or resources for diving, including a dive safety officer, dive locker/equipment, safe diving protocols, scientific diving classes, etc. While there is no replacement or substitute for scuba diving, current requirements are only increasing in CRM rather than decreasing. For example, some projects are requiring commercial diving certifications that go beyond even what most professional underwater archaeologists working the US currently have. Instead, basic field schools can be run without diving to introduce students to methods and approaches for finding and documenting submerged sites, including remote sensing techniques that are essential and cannot be taught properly inside a classroom (Figure 16.3). Such field schools are also more accessible options, decreasing the cost and removing ablelist assumptions (see Lemke et al. 2022). Alumni of these field schools may not be divers, but they will be competent to know what basic methods can be used, what cultural materials may be likely to preserve, how to approach the problem, and how to conduct basic CRM in submerged settings. If students get interested in underwater archaeology after these field schools, they can go on to get diving certified.

These and other solutions are important, as well as more innovative and immediate solutions that will hopefully come online soon. Aready data is being missed because

Figure 16.3. Underwater Archaeology Field School instruction taking place dockside in Alpena, Michigan, in Thunder Bay National Marine Sanctuary. Undergraduate students received hands-on training piloting a remote operated vehicle (ROV), which is used to photodocument and map submerged archaeological sites.

there are simply not enough people with the necessary skills to do this work. Worst-case scenarios may see guidelines and requirements slacken. If there is no workforce to fill these positions, state governments and other regulatory bodies may decrease the requirements, putting submerged sites in critical danger.

Overall, research designs for submerged landscapes will benefit from an anthropological approach—one that places new data into modeling and theoretical applications. Ultimately submerged landscapes can further elucidate time periods that are poorly understood, complement the terrestrial record, and provide a better understanding of the past. Research should be designed to be interdisciplinary, such as the Lake Huron project, which included archaeologists, paleoenvironmental specialists, computer scientists, and community partners. The next generation of anthropological archaeologists should be trained in basic literacy in underwater contexts. Communication between colleagues working at these sites is key, particularly so that lessons can be shared and general guidelines crafted.

References

Bass, George
1983. A Plea for Historical Particularism in Nautical Archaeology. In *Shipwreck Archaeology*, edited by Richard A. Gould, pp.91–104. University of New Mexico Press, Albuquerque.

Binford, Lewis R.
1964.A Consideration of Archaeological Research Design. *American Antiquity* 29(4):425–441.

Gusick, Amy, and Michael Faught
2011.Prehistoric Archaeology Underwater: A Nascent Subdiscipline Critical to Understanding Early Coastal Occupations and Migrations Routes. In *Trekking the Shore: Changing Coastlines and the Antiquity of Coastal Settlement*, edited by Nuno F. Bicho, Jonanthan A. Haws, and Loren G. Davis, pp.27–50. Springer, New York.

Halligan, J. J., M.R. Waters, A. Perrotti, I.J. Owens, J.M. Feinburg, M.D. Bourne, B. Fenerty, B. Winsborough, D. Carlson, D.C. Fisher, T.W. Stafford, and J.S. Dunbar
2016.Pre-clovis occupation 14,550 years ago at the Page-Ladson site, Florida, and the peopling of the Americas. *Science Advances* 2(5):e1600375.

Lemke, Ashley
2021.Submerged Prehistory and Anthropological Archaeology: Do underwater studies contribute to theory? *Journal of Island and Coastal Archaeology* 16(1):5–26.

2022.*The Architecture of Hunting: The Built Environment of Hunter-Gatherers and its Impact on Mobility, Property, Leadership, and Labor*. Texas A&M University Press, College Station.

Lemke, Ashley, and John O'Shea
2022.Drowning the Pompeii Premise: Frozen Moments, Single Events, and the Character of Submerged Archaeological Sites. *World Archaeology* 54(1):142–156.

Lemke, Ashley, Nicole Grinnan, and Jay Haigler
2022. Getting Your Feet Wet: Barriers to Inclusivity in Underwater Archaeology and How to Break Them. *Advances in Archaeological Practice* 10(2):129–139.

O'Shea, John M., and Guy Meadows
2009. Evidence for Early Hunters beneath the Great Lakes. *Proceedings of the National Academy of Sciences*, 106(25):10120–10123.

O'Shea, John M., Ashley K. Lemke, and Robert Reynolds
2013. "Nobody Knows the Way of the Caribou": *Rangifer* Hunting at 45° North Latitude. *Quaternary International* 297:36–44.

O'Shea, J. M., A.K. Lemke, E. Sonnenburg, R.G. Reynolds, and B. Abbott
2014. A 9,000-year-old Caribou Hunting Structure beneath Lake Huron. *Proceedings of the National Academy of Sciences* 111(19):6911–6915.

O'Shea, J.M., A.K. Lemke, B.S. Nash, E.P. Sonnenburg, J.R. Ferguson, A.J. Nyers, and D.J. Riebe
2021. Central Oregon Obsidian from a Submerged early Holocene Archaeological Site beneath Lake Huron. *PLOS ONE* 16(5): e0250840.

Windle, Morgan, Ashley Lemke, and Henny Piezonka
2023. *How to Hunt, How to Herd? Exploring Human–*Rangifer *Interactions and Applications of Traditional Ecological Knowledge in Archaeology*. Paper presented at the Kiel Conference 2023: Scales of Social, Environmental, and Cultural Change in Past Societies, Kiel, Germany.

Chapter 17

The Submerged Prehistoric Archaeological Record in South America: Determining Potential Sites

by Angela Maria Rodriguez-Schrader and Sebastian Fajardo

Introduction

Maritime archaeologists aim to understand how landscapes and seascapes were perceived, understood, used, and modified by those who occupied these spaces (Crumlin-Pedersen 1996; Westerdahl 1992). The remains of the past human activity in these areas and its effects on the landscape extends beyond the visible sea surface and coastal areas. Changes in coastal geomorphology and sea level cause material remains of past marine and coastal activities to be deposited on or below the seafloor (Sturt et al. 2016). The diverse seascapes and coastal regions, along with the immense expanse of the South American continent, and the relatively recent growth of maritime archaeology in the region, underline the need for proposing models to facilitate the identification of potential submerged archaeological sites. In this context, we introduce a model that may use local parameters to assist in determining areas where our search for archaeological occupation in South America should be intensified.

Changes in sea level since the Last Glacial Maximum (LGM) in South America are very complex and heterogeneous due to regional differences in neotectonics, eustasy, and isostasy (Shugar et al. 2014:170). South America shows a relatively wide and low-gradient continental shelf on the east for the Atlantic coast and a relatively narrow and steep-gradient continental shelf on the west coast for the Pacific Ocean (Sturt et al. 2018; Ward et al. 2020). This variability causes sea levels to change heterogenously across the continent. For example, over the past 6,000 years, the relative sea levels in the Caribbean Sea have probably remained above a depth of 5 meters compared to the present levels. Moreover, it seems that in this specific region, the relative sea level has never gone below the -25 m isobath in the last 12,000 years (Lambeck et al. 2002). In contrast, sea levels in the Chilean coast could have been at least 120 m less than today at some points during the last 20,000 years (Carabias et al. 2014; Cartajena et al. 2013, 2020; López et al. 2018; Ward et al. 2022). Together, the changes in sea level and local geomorphological dynamics in the coastal areas resulted in several coastal landscape scenarios during the Holocene.

Maritime archaeology and the study of submerged prehistoric sites are relatively new fields in South America. In Colombia, as an illustration, a recent survey conducted by the Instituto Colombiano de Antropología e Historia (ICANH) revealed that out of 20 researchers engaged in projects associated with Submerged Cultural Heritage, and possessing varying degrees of postgraduate education, only half of them reported actively conducting research in this domain. Remarkably, merely three of these researchers possessed more than a decade of experience in the field (ICANH, personal communication 2022).

These factors contribute to a decrease in the quantity of studies focused on identifying submerged prehistoric sites, consequently leading to a limited number of such sites being documented in South America (Figure 17.1). Along the Atlantic coast, some chance findings have been reported along the southern Brazilian coast (Aires and Lopes 2012), as well as an intertidal site studied in the southern Pampas region in the La Olla site, Argentina (Blasi et al. 2013). For the Pacific coast, there are no reports of submerged prehistoric sites, but a Late Pleistocene submerged paleolandscape has been identified in Quintero, in the Valparaiso region of Chile (Cartajena et al. 2020).

Maritime archaeology in South America still requires incorporating into formal models the variables that influenced past human activities along paleocoastal areas. This is crucial for accurately assessing the potential for discovering new archaeological sites. Looking at fluctuations in sea level at a local scale is a first approach that can provide a better understanding of coastal and landscape changes. This, coupled with mapping currently known early coastal (or near coastal) prehistoric sites and simulations of past population distributions, can assist in determining the potential location of other areas with a submerged archaeological record. Integrating these variables and other local parameters within models and theory derived from human behavioral ecology can help to determine

Figure 17.1. Map of South America with locations of sites mentioned. ***[EN: Rio Grande do Sul is not mentioned in the text: should we remove it from map?]***

the location of sites and the nature of interactions between human populations and their environments from an adaptive perspective (Smith 1992:21). Within this theoretical perspective, the ideal free distribution (IFD) model has been used in island environments to assess whether human settlements were established in an orderly, adaptive, decision-making process that prioritizes areas with the greatest qualities (Fajardo et al. 2020; Kennett and Winterhalder 2006; Kennett et al. 2006; Kennett et al. 2009; Winterhalder et al. 2010). By bringing together the ecological variability, models, and simulations, we propose that new potential sites could be identified and thus provide a basis to conduct new research in such places.

Examples of sites from South America

South America has few reports of submerged prehistoric archaeological sites (Figure 17.1). Researchers in Brazil have reported the presence, along the southern coast, of fossils and other findings that wash ashore as a result of fishing activities at depths around 20 m and the erosion of fossiliferous concentrations at depths up to 10 m caused by autumn and winter storms (Aires and Lopes 2012; Buchmann et al. 2002; Lopes 2013; Lopes and Buchmann 2011). These deposits were formed during "episodes of sea-level lowstand related to glacial cycles. The intervening sea level transgressions eroded the deposits and reworked the fossils" (Lopes and Buchmann 2011:27) and represent evidence of a much larger continental shelf than previously thought, thus representing a greater area suitable for occupation. Shell mounds and shell middens represent other possible sources of information and are found all along the coast of Brazil, some in intertidal settings or in relation to estuarine-lagoon systems (Klokler et al. 2021; Wagner and da Silva 2014).

La Olla site, located along the southeastern Pampean marine coast in Argentina, is a remarkably well-preserved location. It is believed to have served as temporary camp or activity areas for processing marine mammals (Bayón et al. 2011; Prates et al. 2013). The site is found in the intertidal zone near a mixohaline marsh and was occupied between approximately 7400 and 6480 BP, as indicated by studies conducted by Bayón and Politis (2014) and documented by Blasi et al. (2013). The site is made up of four sectors (LO1, LO2, LO3, LO4), which have been exposed and studied during different intervals. From the LO1 site, anatomically and taxonomically determinable faunal remains were recovered (n=300), a few stone artifacts (n=38), a wooden one, and one made quickly from a southern fur seal (*Arctocephalus australis*) bone (Blasi et al. 2013:1556). LO2 was exposed for only a short period of time but presents comparable artifact types and faunal remains, although they were recovered in lower numbers. Sectors LO3 and LO4 were exposed for several weeks, enabling the collection of 13 wooden artifacts, 3 bone artifacts, and 14 stone artifacts, as well as abundant plant macroremains (n=35) and faunal bones (n=315) (Blasi et al. 2013:1556).

On the Pacific coast of South America, the site GNL Quintero 1 (GNLQ1) is situated along the central coast of Chile. The site consists of a very well-preserved bone assemblage with great taxonomic variety, including extinct megafauna, small mammals, and birds. It is located 650 m offshore at a depth of 13 m and was dated between 29,000 and 21,000 BP, during a period when the sea level was at least 120 m less than today. Extensive work has been carried out during various field seasons, allowing detailed zooarchaeological studies, paleolandscape reconstructions, in situ high-resolution recording, and the application of conservation and preservation methodologies for submerged bone materials (Carabias et al. 2014; Cartajena et al. 2013, 2020; López et al. 2018; Ward et al. 2022). It is important to highlight that only two possible bone cut marks (López et al. 2016, 2018) have been identified on the materials recovered from this site. Even so, GNLQ1 represents the possibility of preservation of other similar sites on this coast (Ward et al. 2022:7–8).

Potential for other submerged prehistoric sites in South America

In South America, some of the earliest prehistoric records are associated with coastal settlements and present evidence of aquatic resource use (Erlandson 2001), such as Monte Verde in Chile (Dillehay 1997) and the Quebrada Jaguay (Sandweiss et al. 1998) and Quebrada Tachuay (Keefer et al. 1998) in Perú. These sites support the interpretation of coastal environments as an integral part of occupation strategies of space and use of existing resources (Inda et al. 2011:234).

At the Río de la Plata basin, for instance, the coast was configured considerably differently at 11,000–10,000 BP, since the sea was then located at least 60 m below its current level (Inda et al. 2011:231). The rise of the sea level during the Early Holocene caused the remains of the coastal occupations corresponding to that period to become submerged. However, from this point on, the archaeological evidence indicates a close relationship between human groups and coastal landscapes, which translates to the location of the deposits and the type of resources exploited (Inda et al. 2011:231), especially since this was a very rich ecosystem, where large herbivores and mollusks and fish, as well as a wide range of vegetation, were easily available (López et al. 2004). Although there are a number of sites recorded along the Río de la Plata basin (Gianotti et al. 2017; Inda et al. 2011; López and Gascue 2007; López et al. 2004), and prehistoric artifacts from the Pleistocene–Holocene transition have been found on beaches—thought to come from underwater sites that were disturbed by storms and subsequently redeposited on the shores (Sturt et al. 2018:672)—little further research has been done.

Other sites that have been identified in coastal settings provide meaningful information regarding the short-term adaptations made by coastal communities because of changes in relative sea level and the landscapes they inhabited. One example of such sites was identified in the Pearl Islands archipelago, located in the Panamá Bay in the eastern tropical Pacific Ocean. The most ancient site, on Pedro González Island, revealed a shell-bearing midden indicative of a preceramic occupation, estimated to have occurred around 6200 to 5600 BP. The research, which entailed pedestrian surveys, subsurface soundings, and small excavations, unveiled evidence of a diverse subsistence strategy encompassing both marine and terrestrial resources (Cooke et al. 2021; Martín et al. 2016; Martínez-Polanco et al. 2022; Pearson et al. 2021). The inhabitants utilized marine creatures like turtles, dolphins, and snakes, as well as terrestrial animals like iguanas and dwarf deer (Pearson et al. 2021). This suggests a mixed economy focused on exploiting a variety of local resources. Recent extensive bathymetric and geological research describes the process of eustatic sea level increase in the Gulf of Panama, specifically focusing on the formation of the Pearl Islands and Taboga archipelagos during the late Pleistocene and Holocene, starting from the end of the last glacial maximum, around 21 ka BP (Redwood 2020). During this time, the sea level was significantly lower, approximately 130 m below present levels, resulting in the Gulf of Panama being a vast grassy plain (150 km long and 200 km wide) referred to as the Las Perlas drowned plain (Redwood 2020:15). The process of island formation began around 11,000 BP, when water levels in the bay rose to approximately -40 m below the mean sea level (MSL) (Redwood 2020). Around 10000 to 9000 BP, a narrow strait emerged, connecting the archipelago with the Darien coast, resulting in the formation of a single large "mega-island." Subsequently, between 9000 and 8300 BP, Pedro Gonzalez Island and its counterpart, San Jose Island, gradually separated from each other (Cooke et al. 2021). Following this period, human movements between the Pearl Islands and the mainland would have primarily occurred by sea (Pearson et al. 2021; Redwood et al. 2020).

Integrating results

The identification of potential submerged prehistoric archaeological sites requires having a clear idea of how relative sea level (RSL) has affected the area of study. This requirement, which is demonstrated by the evidence recorded so far in South America, is crucial to pinpointing specific locations and optimizing resources to conduct field research.

The Holocene in the Caribbean and the Atlantic coast of South America showed a relatively rapid and consistent sea level rise of about 7–8 millimeters per year (Milne et al. 2005:1197). In its initial stages, this rise was predominantly attributed to global factors. As time progressed, the subsiding lithosphere beneath the Caribbean Sea assumed a notable role, responding to the melting of the Laurentide Ice Sheet (Cooper and Peros 2010:1226–1227).

Khan et al. (2017) further narrowed the rates of change of RSL in the Caribbean over 1-ka time slices by looking at multiple sea level indicators (mangrove peat, microbial mats, beach rock, and acroporid and massive corals) from 20 different regions within the Caribbean. During the early Holocene, the most rapid changes in RSL were observed with varying rates across different locations: the Orinoco, for instance, has one of the highest rates, at about 10.5 ± 0.5 m/ka, and Panamá has the lowest rate, with a minimum of 8.2 ± 0.7 m/ka (Table 17.1). As time progressed into the mid to late Holocene, the rate of RSL rise decreased, not surpassing 2.4 ± 0.4 m/ka in any location from 7000 BP to the present due to reduced meltwater input (Khan et al. 2017:13–36).

These results suggest that precolumbian communities were significantly affected by sea level rise, especially considering that human colonization of the Caribbean likely began around 6000 BP (Napolitano et al. 2019). Therefore, Indigenous communities in the region experienced a sea level increase of at least 5 m before Columbus' arrival in late 15th century (Cooper and Peros 2010). While this regional perspective highlights the Caribbean's potential as a study area for examining human responses to sea level rise, it's important to acknowledge that local variations—like changes in coastal vegetation, erosion, bathymetry, and tectonic activity—play a crucial role along individual coastlines (Keegan 1995).

The regional and local environmental parameters of the coastal variation can be integrated within the IFD model to establish an *in silico* environment to run simulations for potential locations of the population distribution. The model is built on the principles of overcrowding and evolutionary optima (Fretwell and Lucas 1969), and it has been used to analyze the processes of human colonization on islands (Winterhalder et al. 2010), The IFD model explains how populations decide to distribute themselves based on the suitability of the habitats, which is determined by distribution of the whole population and the heterogeneity of resource distribution in the area. The logic behind the model is that habitats create conditions that determine their suitability at a constant rate. This suitability can be quantified using a ranking for all suitabilities across various habitats, based on characteristics crucial for the survival and reproduction of the individuals. The model assumes that population density decreases the suitability of a habitat normally and constantly, and individuals may select their own habitat based on their preferences.

We used the IFD model to analyze the settlement process of the archipelago of San Andrés and Providence islands in the Colombian Caribbean (Fajardo and Rodríguez-Schrader 2017; Fajardo et al. 2020). In this case, the presence of resources that could be found on the coast, especially in the area near the rivers and the mangrove areas, suggests that it is possible that prehistoric archaeological sites are currently submerged (Fajardo

Table 17.1. Average early-, mid-, and late-Holocene rates of RSL change. Only the results for the Caribbean South American coast and Panamá are presented.
Adapted from Khan et al. 2017: Table 4.

Site	Average rate (m/ka)		
	4-0 ka	8-4 ka	12-8 ka
Colombia	0.3 ± 0.3	2.0 ± 0.4	8.7 ± 0.6
Curaçao	0.2 ± 0.3	1.9 ± 0.4	9.2 ± 0.6
Panamá	0.4 ± 0.3	2.4 ± 0.4	8.2 ± 0.7
Western Venezuela	0.2 ± 0.3	1.9 ± 0.3	9.4 ± 0.6
Orinoco Delta	0.1 ± 0.3	1.7 ± 0.3	10.5 ± 0.5
Trinidad	0.2 ± 0.3	2.0 ± 0.3	10.6 ± 0.4
Suriname and Guyana	-0.2 ± 0.3	1.4 ± 0.3	10.9 ± 0.6

and Rodríguez-Schrader 2017), especially when analyzed in comparison with the early dates associated with Miskito groups.

Historical records indicate no documented prehistoric settlements in the San Andrés and Providencia archipelago (Romero 2013). However, it is thought that Miskito hunters and fishermen utilized the territory, establishing temporary ranches on the islands (for gathering turtles, shellfish, larger fish, and various woods), with minimal landscape intervention (Vollmer 1997). Archaeological findings indicate Miskito groups occupied the Caribbean coast of what is now Nicaraguan territory (Balladares 2013; Clemente-Conte and Gassiot 2004, 2015; Tous 2002). The earliest linked occupation, at Cocount's Beach (LP-12), dates to around 307 BP (Clemente-Conte and Gassiot 2004:112). These groups may have formed a hierarchically organized supralocal community around 800–550 BP (Clemente-Conte and Gassiot 2004:119). These findings suggest that Miskito groups could have potentially visited the San Andrés and Providencia islands anytime within the last 3000 years.

To evaluate the IFD model, we created a habitat classification based on the assumption that past sedentary human populations privileged places where access to marine resources, agricultural activities and access to fresh water could be easily combined (Fajardo and Rodríguez-Schrader 2017). The analysis was carried out based on historical information available and multitemporal simulations of population distribution.

The first English puritan settlement in the archipelago was located in San Andrés Island. Contrary to the highest suitability ranking indicating Cove Bay as the most suitable area, the initial European settlers on San Andrés chose the island's western side for its primary port. This port lacked defensibility, unlike the first port established later on Providencia (Newton 1914:227–228). The choice of settlement location in the archipelago was influenced by the defensibility of ports for Puritan companies in the Caribbean. Despite having suitable areas on San Andrés Island, the absence of defensibility deterred early colonial settlement, leading to the island's abandonment and a shift of colonial focus to Providencia Island (Newton 1914:151; Parsons 1985[1956]:34).

The colonization of Old Providence Island was analyzed using the rank suitability distribution **based on the IDF model postulates an agent-based model [Word missing here?]** (Fajardo et al. 2020). The initial simulated populations were always clustered in the northwest of the island, where the largest fertile bay is located. Historic accounts mention that this place sheltered New Westminster, the first European nucleated settlement. This area is also where the largest nucleated community is located today on the island. The English in charge of the colonizing company settled in the most suitable area of the island and established a small settlement (New Westminster) that did not contain the entire population. Most of the growers, who had to turn over half their crops to the company, did not live in New Westminster and made their residences close to their growing areas, while enslaved Africans were not even allowed to establish permanent settlements in the least suitable area of the island (Parsons 1985[1956]:32).

The simulations showed that agent clustering was sensitive to and increased with the initial population. First settlers and settlers prone to gregariousness were concentrated in the most suitable areas, but then population growth resulted in a steady tendency toward dispersion. The results suggested that the colonization process started with an agent cluster in the largest and most suitable area. The spatial distribution of agents maintained a tendency toward randomness as simulation time increased. The findings indicate that utilizing population distribution simulations and a suitability ranking from a formal model like IDF can aid in pinpointing potential archaeological site locations (Fajardo and Rodríguez-Schrader 2017).

Conclusions

In South America, there is a need to conduct more research related to those cultural remains that are part of a submerged prehistoric archaeological record. Even though the potential for the preservation of such sites has been recognized (Sturt et al. 2018; Ward et al. 2022), locating them and studying them presents some challenges (such as lack of funding or even lack of researchers). Still, theoretical approaches, models such as IFD, and simulations of population distributions can present the opportunity to pinpoint areas of interest. When these approaches are combined with data compilation and analysis—such as the one conducted by researchers in eastern Patagonia and Argentina (Elkin et al. 2023)—we can greatly improve our understanding of RSL changes and how it affected the people who bore witness to this phenomenon. Furthermore, it is necessary to emphasize that to truly understand the impact of RSL, it is essential to supplement regional datasets with localized case studies that can reveal how the long-term regional sea level rise might have translated into short-term consequences for local coastal communities (Cooper and Peros 2010:1226–1227).

References

Aires, Alex S.S., and Renato P. Lopes
2012.Representativity of Quaternary Mammals from the Southern Brazilian Continental Shelf. *Revista Brasilera de Palontologia* 15(1):57–66.

Balladares, Sagrario
2013.Las sociedades antiguas de Nicaragua del 500 A.C. al 800 D.C. *Humanismo y cambio social* 1:88–96.

Bayón, María Cristina, Teresa Manera, Gustavo Politis, and Silvia Aramayo
2011.Following the Tracks of the First South Americans. *Evolution: Education and Outreach* 4: 205–217.

Bayón, María Cristina, and Gustavo G. Politis
2014.The inter-tidal zone site of la olla: Early-middle holocene human adaptation on the pampean coast of Argentina. *In Prehistoric Archaeology on the Continental Shelf: A Global Review,* edited by Amanda M. Evans, Joseph C. Flatman, and Nicholas C. Flemming, pp.115–130. Springer, New York.

Blasi, Adriana, Gustavo Politis, and Cristina Bayón
2013.Palaeoenvironmental reconstruction of La Olla, a Holocene archaeological site in the Pampean coast (Argentina). *Journal of Archaeological Science* 40:1554–1567.

Buchmann, Francisco S., Marcus Seeliger, Letícia Zanella, L.S.P. Madureira, Luis Joze Tomazelli, and Lauro Julio Calliari

2002. Análise batimétrica e sedimentológica no estudo do Parcel do Carpinteiro, uma paleolinha de praia plesitocênica na antepraia atual do Rio Grande do Sul, Brasil. Pesquisas. *Geociências* 28(2):109–115.

Carabias, Diego, Isabel Cartajena, Renato Simonetti, Patricio López, Carla Morales, and Cristina Ortega
2014. Submerged Paleolandscapes: Site GNL Quintero 1 (GNLQ1) and the First Evidences from the Pacific Coast of South America. In *Prehistoric Archaeology on the Continental Shelf: A Global Review,* edited by Amanda M. Evans, Joseph C. Flatman, and Nicholas C. Flemming, pp. 131–150. Springer, New York.

Cartajena, Isabel, Patricio López, Diego Carabias, Carla Morales, Gabriel Vargas, and Cristina Ortega
2013. First evidence of an underwater Final Pleistocene terrestrial extinct faunal bone assemblage from Central Chile (South America): Taxonomic and taphonomic analyses. *Quaternary International* 305:45–55.

Cartajena, Isabel, Patricio López, Diego Carabias, Jennifer Pavez, David Letelier, Renato Simonetti, and Carla Morales
2020. High-resolution digital recording techniques and taphonomic trajectories: Multi-image photogrammetry applied to a drowned Late Pleistocene site in Central Chile (32°S). In *Shared Heritage: Proceedings of the 6th International Congress on Underwater Archaeology (IKUWA6)*, edited by Jennifer A. Rodrigues and Arianna Traviglia, pp. 350–358. Archaeopress Archaeology, Oxford.

Clemente-Conte, Ignacio, and Ermengol Gassiot
2004. ¿En el camino de la desigualdad? El litoral de la costa Caribe de Nicaragua entre el 500 cal. ANE y el 450 cal. NE. *Revista Atlántica-Mediterránea de Prehistoria y Arqueología Social* 7:109–130.

2015. Apuntes sobre formación de sitios a partir de restos arqueomalacológicos. El conchero 4 del sitio Karoline (400 cal BC–300 cal AD) de la costa Atlántica de Nicaragua). In *La Investigación Arqueomalacológica en la Península Ibérica: Nuevas Aportaciones*, edited by Igor Gutiérrez, David Cuenca, and Manuel González, pp. 137–150. Nadir, Santander, Cantabria.

Cooke, Richard G., Máximo Jiménez, Thomas A. Wake, and Juan Guillermo Martín
2021. Impactos de los primeros inmigrantes humanos en los mamíferos y la fauna

terrestre del archipiélago de Las Perlas, Panamá. In *Mucho más que un puente terrestre. Avances de la arqueología en Panamá*, edited by Juan Guillermo Martín and Tomás E. Mendizábal, pp. 213–237. Panamericana Formas e Impresos, S.A, Bogotá.

Cooper, Jago, and Matthew Peros
2010.The archaeology of climate change in the Caribbean. *Journal of Archaeological Science* 37:1226–1232.

Crumlin-Pedersen, Ole
2010.*Archaeology and the Sea in Scandinavia and Britain. A personal account*. Maritime Culture of the North 3. The Viking Ship Museum in Roskilde and The Society of Antiquaries of Scotland, Roskilde.

Dillehay, Tom D.
1997.*Monte Verde, A Late Pleistocene Settlement in Chile, Vol. 2: The Archaeological Context and Interpretation*. Smithsonian Institution Press, Washington, DC.

Elkin, Dolores, Luis A. Borrero, Daniela de Hoz, John McCarthy, and Jonathan Benjamin
2023.First steps in addressing the submerged archaeological evidence in the Patagonian Continental Shelf, Argentina. *Journal of Maritime Archaeology* 18: 85–109.

Erlandson, Jon M.
2001.The Archaeology of Aquatic Adaptations: Paradigms for a New Millennium. *Journal of Archaeological Research* 9(4):287–350.

Fajardo, S., G.J. Hofstede, M. de Vries, M.R. Kramer, and A. Bernal
2020.Gregarious behavior, human colonization and social differentiation: An agent-based model. *Journal of Artificial Societies and Social Simulation* 23(4).

Fajardo, Sebastián, and Angela M. Rodríguez-Schrader
2017.Estudios de impacto ambiental para las obras de protección del litoral de la bahía de Black Sand en la isla de Providencia y para la recuperación de las playas de North End (Spratt Bight), isla de San Andrés. Submitted to FINDETER. Report on file at the Instituto Colombiano de Antropología e Historia (ICANH), Bogotá.

Fretwell, Stephen D., and Henry Lucas Jr.
1969. On territorial behavior and other factors influencing habitat distribution in

birds. *Acta Biotheoretica* 19(1):16–36.

Gianotti, Camila, Andrés Gascue, Laura del Puerto, Hugo Inda, and Eugenia Villarmarzo
2017. Archaeological heritage on the Atlantic coast of Uruguay: heritage policies and challenges for its management in coastal protected areas. In *Public Archaeology and Climate Change*, edited by Tom Dawson, Courtney Nimura, Elías López-Romero, and Marie-Yvane Daire. Pp. 149–161. Oxbow Books, Oxford.

Inda, Hugo, Laura del Puerto, Roberto Bracco, Carola Castiñeira, Irina Capdepont, Andrés Gascue, and Jorge Baeza
2011. Relación hombre-ambiente para la costa estuarina y oceánica de Uruguay durante el Holoceno. Reflexiones y perspectivas. In *El Holoceno en la zona costera de Uruguay* edited by Felipe García, pp. 229–260. Universidad de la República, Montevideo.

Keefer, David K., Susan D. Defrance, Michael E. Moseley, James B. Richardson III, Dennis R. Satterlee, and Amy Day-Lewis
1998. Early maritime economy and El Niño events at Quebrada Tacahuay, Peru. *Science* 281:1833–1835.

Kennett, Douglas, Atholl Anderson, and Bruce Winterhalder
2006. The Ideal Free Distribution, Food Production, and the Colonization of Oceania. In *Behavioral Ecology and the Transition to Agriculture*, edited by Douglas Kennett and Bruce Winterhalder, pp. 265–288. Origins of Human Behavior and Culture. University of California Press, Berkeley.

Kennett, Douglas, and Bruce Winterhalder
2006. Demographic Expansion, Despotism, and the Colonisation of East and South Polynesia. In *Islands of Inquiry: Colonisation, Seafaring and the Archaeology of Maritime Landscapes*, edited by Geoffrey Clark, Foss Leach, and Sue O'Connor, pp. 87–96. Australia National University Press, Canberra.

Kennett, Douglas, Bruce Winterhalder, Jacob Bartuff, and Jon Erlandson
2009. An Ecological Model for the Emergence of Institutionalized Social Hierarchies on California's Northern Channel Islands. In *Pattern and Process in Cultural Evolution*, edited by Stephen Shennan, pp. 297–314. University of California Press, Berkeley.

Khan, Nicole S., Erica Ashe, Benjamin P. Horton, Andrea Dutton, Robert E. Kopp, Gilles Brocard, Simon E. Engelhart, David F. Hill, W.R. Peltier, Christopher H. Vane, and Fred N. Scatena
2017. Drivers of Holocene sea-level change in the Caribbean. *Quaternary Science Reviews* 155:13–36.

Klokler, Daniela, Fernando Ozorio de Almeida, Brena Bowswer, Elizer Botelho, and Paulo Bava de Camargo
2021. The impacts of coastal dynamics on the Saco de Pedra shell midden in northeast Brazil. *Quaternary International* 584: 93–105.

Lambeck, Kurt, Yusuke Yokoyama, and Tony Purcell
2002. Into and out of the Last Glacial Maximum: sea-level change during Oxygen Isotope Stages 3 and 2. *Quaternary Science Reviews* 21(1):343–360.

Lopes, Renato P.
2013. Biostratigraphy of the Pleistocene Fossiliferous Deposits of the Southern Brazilian Coastal Area. *Journal of Mammalian Evolution* 20:69–82.

Lopes, Renato P., and Francisco S. Buchmann
2011. Pleistocene mammals from the Southern Brazilian continental shelf. *Journal of South American Earth Sciences* 31:17–27.

López, José M., and Andrés Gascue
2007. El valle del Arroyo Balizas: Estructuras monticulares y sitios del Litoral Atlántico Uruguayo. *Revista de Arqueología* 2:89–103.

López, José M., Andrés Gascue, and Federica Moreno
2004. La Prehistoria del Este de Uruguay: cambio cultural y aspectos ambientales. *Anales de Prehistoria y Arqueología* 19–20:9–24.

López, Patricio, Isabel Cartajena, Diego Carabias, Carla Morales, David Letelier, and Valentina Flores-Aqueveque
2016. Terrestrial and Maritime Taphonomy: Differential Effects on Spatial Distribution of a Late Pleistocene Continental Drowned Faunal Bone Assemblage from the Pacific Coast of Chile. *Archaeological and Anthropological Sciences* 8(2):277–290.

López, Patricio, Isabel Cartajena, Diego Carabias, Francisco J. Prevosti, Antonio Maldonado, and Valentina Flores-Aqueveque
2018. Reconstructing drowned terrestrial landscapes. Isotopic paleoecology of a late Pleistocene extinct faunal assemblage: Site GNL Quintero 1 (GNLQ1) (32°, Central Chile. *Quaternary International* 463:153–160.

Martín, Juan Guillermo, Richard G. Cooke, Fernando Bustamante, Irene Holst, Alexandra Lara, and Stewart Redwood
2016. Ocupaciones Prehispánicas en la Isla Pedro González, Archipiélago de Las Perlas, Panamá: Aproximación a una cronología con comentarios sobre las conexiones externas. *Latin American Antiquity* 27(3):378–398.

Martínez-Polanco, María F., Florent Rivals, Nawa Sugiyama, Christine A.M. France, Sergio Andrés Castro, Máximo Jiménez-Acosta, Juan Guillermo Martín, and Richard G. Cooke
2022. Human ecological impacts on islands: Exemplified by a dwarf deer (Cervidae: Mazama sp.) on Pedro Gonzalez Island, Pearl Island Archipelago, Pacific Panama (6.2–5.6 kya). *Journal of Archaeological Science* 143:105613.

Milne, Glenn A., Antony J. Long, and Sophie E. Bassett
2005. Modelling Holocene relative sea-level observations from the Caribbean and South America. *Quaternary Science Reviews* 24:1183–1202.

Napolitano, Matthew F., Robert J. Dinapoli, Jessica H. Stone, Maureece J. Levin, Nicholas P. Jew, Brian G. Lane, John T. O'Connor, and Scott M. Fitzpatrick
2019. Reevaluating human colonization of the Caribbean using chronometric hygiene and Bayesian modeling. *Science Advances* 5(12):eaar7806.

Newton, Arthur O.
1914. *Colonising Activities of the English Puritans: The Last Phase of the Elizabethan Struggle with Spain*. Yale University Press, New Haven.

Parsons, James J.
1985[1956]. *San Andrés y Providencia. Una geografía histórica de las islas colombianas del Mar Caribe Occidental*. 2 ed. Banco de la República, Bogotá.

Pearson, Georges A., Juan Guillermo Martín, Sergio A. Castro, Máximo Jiménez Acosta, and Richard G. Cooke

2021. The mid holocene occupation of the Pearl Islands: A case of unusual insular adaptations on the Pacific Coast of Panama. *Quaternary International* 578:155–169.

Prates, Luciano R., Gustavo G. Politis, and James Steele
2013. Radiocarbon chronology of the early human occupation of Argentina. *Quaternary International* 301:104–122.

Redwood, Stewart D.
2020. Late Pleistocene to Holocene sea level rise in the gulf of Panama, Panama, and its influence on early human migration through the Isthmus. *Caribbean Journal of Earth Science* 51:15–31.

Romero, Yuri
2013. Reconocimiento de arqueología submarina no intrusiva para la profundización d elos canales navegables de acceso a las islas de San Andrés y Providencia. Programa de arqueología preventiva y Plan de Manejo. Submitted by Instituto Nacional de Vías. Subdirección Red Nacional de Carreteras. Report on file at the Instituto Colombiano de Antropología e Historia (ICANH), Bogotá.

Sandweiss, Daniel H., Heather McInnis, Richard L. Burger, Asunción Cano, Bernardino Ojeda, Rolando Paredes, Maria del Carmen Sandweiss, and Michael D. Glascock
1998. Quebrada Jaguay: Early South American maritime adaptations. *Science* 281: 1830–1833.

Shugar, Dan H., Ian J. Walker, Olav B. Lian, Jordan B.R. Eamer, Christina Neudorf, Duncan McLaren, and Daryl Fedje
2014. Post-glacial sea-level change along the Pacific coast of North America. *Quaternary Science Reviews* 97:170–192.

Smith, Eric A.
1992. Human Behavioral Ecology: I. *Evolutionary Anthropology* 1(1):20–25.

Sturt, Fraser, Nicholas Flemming, Diego Carabias, Hauke Jöns, and Jonathan Adams
2018. The next frontiers in research on submerged prehistoric sites and landscapes on the continental shelf. *Proceedings of the Geologists Association* 129(5):654–683.

Sturt, Fraser, Tyra Staden, Michael Grant, and Justin Dix
2016. *Determining potential: Onshore/Offshore prehistory (EH 6918).* Submitted

to Historic England. Project 6918. University of Southampton. https://doi.org/10.5284/1041582

Tous, Meritxell
2002. De la Gran Nicoya precolombina a la provincia de Nicaragua, s. XV y XVI. Tesis Doctoral, Departament - Antropologia Cultural i Història d'Amèrica i d'Àfrica, Universitat de Barcelona, Barcelona.

Vollmer, Loraine
1997. *La historia del poblamiento del archipiélago de San Andrés, Vieja Providencia y Santa Catalina.* Ediciones Archipiélago, San Andrés, Isla.

Wagner, Gustavo, and Lucas Antonio da Silva
2014. Prehistoric Maritime Domain and Brazilian Shellmounds. *Archaeological Discovery* 2(1):1–5.

Ward, Ingrid, Alex Bastos, Diego Carabias, Hayley Cawthra, Helen Farr, Andrew Green, and Fraser Sturt
2022. Submerged Palaeolandscapes of the Southern Hemisphere (SPLOSH) – What is emerging from the Southern Hemisphere. *World Archaeology* 54(1):6–28.

Westerdahl, Christer
1992. The maritime cultural landscape. *International Journal of Nautical Archaeology* 21(1):5–14.

Winterhalder, Bruce, Douglas J. Kennett, Mark N. Grote, and Jacob Bartruff
2010. Ideal free settlement of California's Northern Channel Islands. *Journal of Anthropological Archaeology* 29(4): 469–490.

Part 5