Ngurra Nyunjunggamu

Submerged landscape identification and interpretation: Cape Bruguieres Island and North Gidley Island

Thesis

Submitted to Flinders University

for the degree of Masters of Maritime Archaeology

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August 2020

Table of Contents

ABSTRACT

Between 2017 and 2019, the Deep History of Sea Country project (DHSC) executed a survey strategy designed to identify submerged landscapes preserving archaeological features in Murujuga Sea Country (MSC). The strategy proved successful and two submerged sites were identified; a large artefact assemblage on a Pleistocene aeolianite base in the Cape Bruguieres Channel and a lithic artefact identified in association with an underwater spring in the Flying Foam Passage. This study focused on the landscape of the Cape Bruguieres Channel. No peer reviewed studies have been conducted in the Cape Bruguieres area. As such, this study conducted landscape surveys in the area encompassing the CBC to gather data on the integrated onshore and offshore archaeological record of Cape Bruguieres and North Gidley Islands to determine if these materials are related. The landscape data can then be reintegrated into the DHSC survey methodology to determine the potential for further submerged archaeological material to be preserved in the study area that can be targeted with future archaeological study. Pedestrian and drone surveys conducted on Cape Bruguieres Island and North Gidley Island revealed that seed species were targeted by past Aboriginal communities and that a change in focus from terrestrial to marine resources, linked to marine transgression, is represented in the landscape. Large intertidal artefact scatters and quarry sites were identified on Cape Bruguieres Island with high potential for the preservation of submerged archaeological landscapes.

STUDENT DECLARATION

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Jerem Leach

2020

ACKNOWLEDGEMENTS

I would like to sincerely thank Jonathan Benjamin, for taking me into the fold, and making a dream of 10 years come true. Your enthusiasm is contagious.

To John McCarthy, for sharing your wealth of knowledge on 3D modelling and helping steer me through the dark times when I was lost at sea.

A huge thanks to Chelsea Wiseman, your all-round ability and professionalism are inspiring.

A big thank you to all the members of the DHSC that I worked with, Dr Madeline Fowler, Dr. Sean Ulm, Dr Jo McDonald, Dr Mick O'Leary, Dr Ken Mulvaney, Emma Beckett and Patrick Morrison.

And a massive thank you to Dr Wendy Van Duivenvoorde for convincing me to study maritime archaeology and recommending me for this project.

Thank you to the Murujuga Aboriginal Corporation for allowing me the privilege of walking with your Ancestors, on your sacred Country.

LIST OF FIGURES

ABBREVIATIONS

CBC	Cape Bruguieres Channel
DHSC	Deep History of Sea Country
LGM	Last Glacial Maxim
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
MSL	Mean Sea Level
pXRF	portable X-Ray Fluorescence
UWA	The University of Western Australia

1 Introduction

1.1 Deep History of Sea Country

Between 2017 and 2019, the Deep History of Sea Country project (DHSC) executed a survey strategy designed to identify submerged landscapes preserving archaeological features in Murujuga Sea Country (MSC). This was achieved through the development of landscape modelling based on the regional terrestrial archaeological record and the identification of areas protected from the most destructive impacts of marine transgression. The DHSC deployed a range of remote sensing capabilities over six field campaigns in MSC to accomplish this task. In addition, the research strategy incorporated capabilities to recover archaeological, geological and geochronological samples to build a chronology of the submerged palaeo-environment (Benjamin et al. 2018:5–8; Benjamin et al. 2020:5; Veth et al. 2019:16–21).

Benjamin et al. (2020:5) defined five key considerations that were essential to the success of this iterative approach:

1. Identify archaeological features in the Cape Bruguieres landscape that indicate what resources were utilised by past Aboriginal communities;
2. Gather contextual evidence for the interpretation of the Cape Bruguieres Channel assemblage;
3. Identify lithic resources from which the Cape Bruguieres Channel assemblage may have been sourced;
4. Identify archaeological features that provide chronological information for when past Aboriginal communities were active in the Cape Bruguieres Channel landscape;
5. Identify locations for future submerged landscape investigation;

The methodology employed by the DHSC proved successful and two submerged sites were identified; a large artefact assemblage on a Pleistocene aeolianite terrace in the Cape Bruguieres Channel and a lithic artefact identified in association with an underwater spring in the Flying Foam Passage (Figure 1.1) These sites represent the first confirmed archaeological sites identified in a submerged marine context in Australia. This study focuses on the landscape encompassing the Cape Bruguieres Channel.

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Figure 1.1 Location maps of the study area and sites referenced in text. 1) Cape Bruguieres Island; (2) North Gidley Island; (3) Flying Foam Passage; (4) Dolphin Island; (5) Angel Island; (6) Legendre Island; (7) Malus Island; (8) Goodwyn Island; (9) Enderby Island, from Benjamin et al. 2020:3.

Indigenous Australians represent the oldest continuing cultures on Earth, maintaining an intimate, and unbroken, connection with the material culture that archaeologists study. The recovery of Aboriginal artefacts from a submerged context confirms scientifically, what was already known in Traditional knowledge systems: that the Ngardangali (Aboriginal perople) once walked the now drowned continental shelf (Bradley and Kearney 2018:292; Nutley 2014:260). Benjamin (in Young 2020) described submerged landscape archaeology as the 'last real frontier of Australian Archaeology'. This provides an opportunity to build a uniquely Australian submerged landscape archaeology that values Traditional knowledge systems. Interviews with Traditional Owners will be an integral element of future survey strategies, a method which proved highly successful in the Danish model (Fischer 1993:374). The incorporation of Indigenous and maritime archaeological approaches was tested as part of the 'Relocating Narrunga Project' proving highly successful (Roberts et al. 2013:79). The perception of archaeologists as 'stone tool collectors' with a 'murky history of colonialism and social evolutionism' (Griffith 2018:8-9) still haunts Australian archaeology today; a hangover from early twentieth century frontier archaeology. To disarticulate Australian submerged landscape archaeology from these colonial roots, Indigenous metaphysics must not be silenced or relativised (Sepie 2017:2-8). Nor should it be transformed or exploited as defined in Poka Laenui's (2000:151) five stages of colonisation. The study of submerged landscapes represents a new frontier for Australian archaeology, but it also represents a new stage of encroachment upon sacred land; lands 'from when the world was soft' (Juluwarlu Aboriginal Corporation 1993:2). There is Law in the Sea and Indigenous people carry that Law. Indigenous voices can help shape future submerged landscape studies to ensure that the ocean floor doesn't just become another place where whitefella's 'put all the names on the map and pull all the Country apart' (Anni Karrakayn in Bradley and Kearney 2018:288). A submerged landscape archaeology built on mutual respect for Traditional and Western knowledge systems will foster the most productive outcomes.

1.2 Cape Bruguieres Channel

The Cape Bruguieres Channel is located in the outer islands of Murujuga Sea Country in the Pilbara, North Western Australia. The study area covers the islands bordering the Cape Bruguieres Channel: North Gidley Island and Cape Bruguieres Island (Figure 1.2). The Cape Bruguieres Channel (CBC) is a 2.5km long tidal channel separating Cape Bruguieres Island and North Gidley Island. It has a central U-shaped curve dividing the Pleistocene aeolianite of Cape Bruguieres Island and a cemented calcarenite terrace on North Gidley Island. The terrace is flanked by a modern dune system to the south and west and by ephemeral waterways, rocky slopes and mangroves to the east. Cape Bruguieres Island comprises Pleistocene aeolianite along the channel fringes, with rocky slopes of granophyre to the west and north separated by a sandy beach alcove. The channel is comprised of relict Pleistocene aeolianite and mobile sands. There is a slightly elevated sill in the middle of the channel (Benjamin et al. 2020:9).

The cemented terrace is interpreted as an ebb tidal spit that was formed some 2000 years ago following the regression of a mid-Holocene high stand. This is supported by radiocarbon dates taken from the terrace surface of 2446±65 BP (1791–2141 cal BP; Wk–49709) (Benjamin et al. 2020:10). Marine shells embedded in a marine calcarenite on top of the aeolianite from the CBC floor returned a radiocarbon date range of 44,700 to 26,600 cal BP. This is interpreted as a minimum date range due to contamination from endolithic marine boring organisms following marine transgression, with a probable date for formation of the CBC floor during the Last Interglacial (MIS 5e) age. This would have become an active tidal channel approximately 7,000 years ago following marine transgression (Benjamin et al. 2020:11).

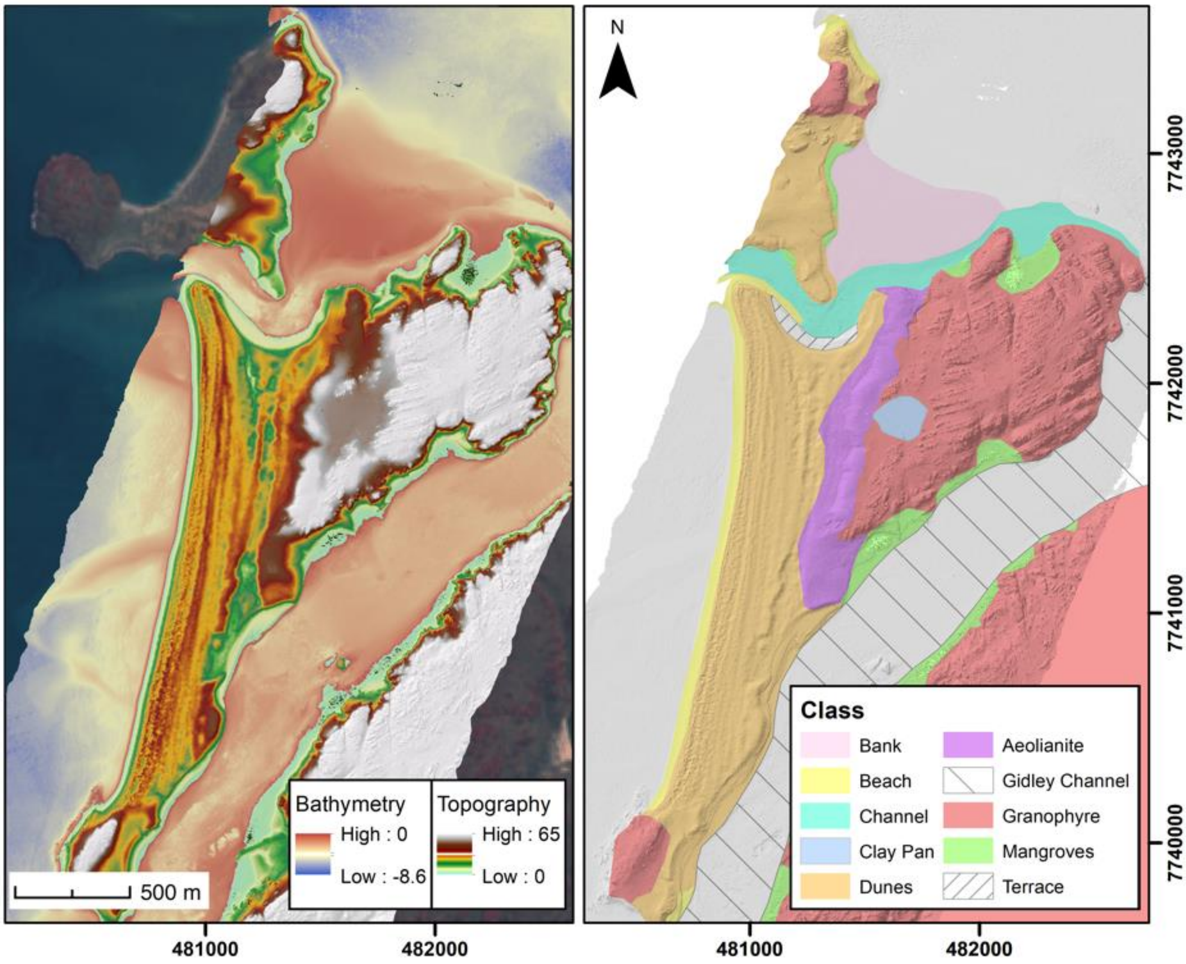

Figure 1.2 Bathymetry, geomorphology and geology of Cape Bruguieres Island (north) and North Gidley Island (south), from Benjamin 2020:10.

The CBC was targeted for detailed investigation due to its sheltered location and its proximity to archaeological features including lithic material, shell refuse and stone structures on the adjacent calcarenite terrace and an intertidal quarry site on northwest Cape Bruguieres Island. Diver investigation and pedestrian surveys revealed the presence of 269 submerged lithics (Figure 1.3). The assemblage was recorded on a relict Pleistocene Aeolianite base to a depth of 2.4m below mean sea level (MSL) (Benjamin 2020:9). Following post-field analysis, it was confirmed that 190 of the lithics were identified in a permanently submerged context, while 79 lithics were recorded in the intertidal zone along the mid-channel sill or outer edges of the channel. A second assemblage comprising 455 lithics was recorded on the calcarenite terrace, contiguous with the southern boundary of the channel (Benjamin 2020:11). A small sample of each assemblage underwent portable X-Ray fluorescence (pXRF) analysis. The CBC assemblage is comprised of rhyodacite, consistent with local bedrock geology of both Cape Bruguieres Island and North Gidley Island. The terrace assemblage is primarily constituted of rhyodacite; however, two artefacts were identified as andesite, which can be found outcropping on nearby Malus and Lewis Islands (Benjamin 2020:12). Though both the CBC and terrace assemblage are similar in material composition, they differ statistically in size. The submerged assemblage is more massive and dominated by artefacts in the 6–12 cm range while artefacts in the 2–8 cm range are more prevalent in the terrace assemblage.

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Figure 1.3 Cape Bruguieres Channel diver and pedestrian surveys over photomosaic produced with data collected on the lowest astronomical tide of 2019 (above). Artefacts labelled as intertidal and subtidal in relation to the mean low water spring tide, from Benjamin 2020:12.

Where possible, artefacts were recorded in situ, however, a sample assemblage was selected for laboratory analysis. As part of this analysis diagnostic features including weight, maximum dimension, raw material, breadth, thickness, colour and quality, artefact type and the presence of retouch and use wear were recorded. All artefacts exhibited marine growth of which the nature, extent and identifiable species were recorded. A representative sample of this assemblage was hand drawn and 3D modelled (Figure 1.4). Neutron tomography was applied to selected lithics as a non-invasive method to reveal their morphology without marine growth (Benjamin 2020:8). Artefact types identified in the CBC assemblage include mullers, core tools and cores, retouched flakes and two potential grind stones. The terrace assemblage comprises flakes, retouched flakes and cores that were identified proximal with cairns and curvilinear stone structures, constructed from fractured plates of calcarenite beach rock. Benjamin et al. (2020:14) determined that the archaeological material postdates formation of the terrace, which dates activity to within the last 2,000 years. This is further supported by the presence of Baler shells (*Melo sp.*) and *Tegillarca granosa* eroding from deflated midden deposits. A similar archaeological signature is evident throughout the contiguous dune system, indicating this area was an occupation site that provided abundant resources targeted by past Aboriginal communities (Benjamin et al. 2020:14).

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Figure 1.4 Photos and drawings of a sample of stone tools recovered from Cape Bruguieres Channel. Retouched flakes (A11, A29, A44, A30), Core/core tool (A37, A23), Hammerstone/muller (A40), Flaked tool (A10, A20, A34), from Benjamin et al. 2020:13.

The proximity of the CBC assemblage and the terrace assemblage raised questions that the two assemblages could be associated, implying that the submerged assemblage may not have been identified in context. A range of hypotheses were tested based on the geomorphology of the two sites, comparative analysis of the two assemblages and the impacts of severe weather events and tidal action on the integrity of the sites. Benjamin et al. (2020:21) determined that the two assemblages are unrelated and that they represent in-context deposits (see Benjamin et al. 2020:14–21 for more detailed analysis).

Though these two sites are only metres apart, they are essentially seperated by an ocean. The Cape Bruguieres Channel symbolises the transformative impacts of marine transgression on past human societies. At the height of the Last Glacial Maxim 26.5–19 kya, the sea level was approximately 125 m lower than its current level (O'Leary et al. 2019:1). During the subsequent post-glacial sea level rise, approximately two million square kilometres of the Australian continental shelf was inundated (Heap and Harris 2008:564). Recent studies in North West Australia estimate that sea levels stabilised some 2,000 years ago following a highstand approximately two metres above current levels (Benjamin et al. 2020:10). At present, the earliest evidence for human occupation of the Australian continent dates to 65,000 years (Clarkson et al. 2017:307), suggesting that evidence for some 60,000 years of Australia's coastal and hinterland archaeological history, including the first arrival of humans and their early migrations, now lies in a submerged context. It has long been recognised that these coastal environments provided important refugia for humans, plants and animals during past glacial periods (Bailey et al. 207:146; Bailey and Flemming 2008:2154). Williams et al. (2018:146) analysed archaeological data of the Australian hinterland and concluded that large-scale migration resulted in the abandonment of the continental shelf as sea levels rose. In the Pilbara this pattern has also been acknowledged. It has been recognised in the transition of representations in the rock art from terrestrial to marine species (McDonald 2015:128; Mulvaney 2015:338) and in the change in shellfish exploitation from mangrove species to sandy beach species during the mid-Holocene (McDonald 2018:267). This archaeological signature should also be evident in submerged landscapes. Improved technological capabilities and a growing body of evidence indicating the potential for the preservation of archaeological materials in a submerged context is making the archaeological investigation of submerged landscapes more vital (Bailey and Flemming 2008:2155). Integral to the investigation of submerged landscapes is the analysis of the geomorphology of palaeo-landscapes (Bailey and Flemming 2008:2157; Benjamin 2010:258; O'Leary et al. 2020:1; Veth et al. 2019:16; Ward et al. 2103:216).

There is little regional data that can be utilised for a comparative analysis with the CBC assemblage. Apart from the research produced by the DHSC, there have been no peer-reviewed studies targeting the archaeological record of Cape Bruguieres Island or North Gidley Island (though images of some engravings from these islands have been published in Donaldson 2009 and Mulvaney 2015). Further to this, even though artefact scatters are the second most common site type in Murujuga, there are no detailed analyses of the lithic assemblages present in this region (Bird and Hallam 2006:13). As such, this study conducted landscape surveys in the area encompassing the CBC to gather data on the integrated onshore and offshore archaeological record of Cape Bruguieres and North Gidley Islands to determine if these materials are related. The landscape data can then be reintegrated into the DHSC survey methodology to determine the potential for further submerged archaeological material to be preserved in the study area that can be targeted with future archaeological study.

This study aims to:

1. Identify archaeological features in the Cape Bruguieres landscape that indicate what resources were utilised by past Aboriginal communities;
2. Gather contextual evidence for the interpretation of the Cape Bruguieres Channel assemblage;
3. Identify lithic resources from which the Cape Bruguieres Channel assemblage may have been sourced;
4. Identify archaeological features that provide chronological information for when past Aboriginal communities were active in the Cape Bruguieres Channel landscape; and
5. Identify locations for future submerged landscape investigation.

To achieve this, pedestrian and drone surveys were conducted at locations in the Cape Bruguieres Channel landscape that correlated with landscape modelling developed by the DHSC (Veth et al. 2019:16–21).

2 Literature review

2.1 Murujuga Sea Country

Murujuga Sea Country is located on the North West Shelf in the Western Pilbara, North Western Australia. It comprises an archipelago of 42 islands extending into the Indian Ocean encompassing an area of 1,456km², with a combined landmass of 300 km². The Burrup Peninsula, an island now joined to the mainland by manmade solar salt fields, is the largest of the islands with an area of 118km² (Mulvaney 2018:3). Large, jumbled piles of Neoarchean igneous rocks dominate the landscape; the result of over 2.75 billion years of erosion (Donaldson 2009:504; Mulvaney 2018:7). The islands can be broadly classified by their geological base into three groups. The first group comprises 2.75 billion-year-old Neoarchean rocks, primarily consisting of gabbro and granophyre, overlying an older Archaean granite, dolerite intrusive base (Mulvaney 2018:7). The dominant rock type is a fine-grained igneous ‘Gidley Granophyre’. Over time, the closely jointed igneous rocks have fractured to form a distinctive landscape of angular block massifs, disaggregated blocks and angular cobbles (Mulvaney 2018:7). This process has formed large, imposing concentrations of weathered angular boulders, separated by steep narrow ravines. The second group form the islands in the west of the archipelago. This group comprises younger basaltic and other igneous formations, including those of the Fortescue group. These formations, though still rugged, form gentler and shallower sloped groupings. The third group comprises Pleistocene limestones. These tend to dominate the outer islands including Legendre and Delambre Islands (Mulvaney 2018:7). Smaller accumulations of this limestone can be found on other islands including North Gidley Island and Cape Bruguieres Island.

2.2 Climate

The Pilbara has a hot, dry climate characterised by limited rainfall (Zone B: Arid or dry in the Koppen system). Murujuga has a cooler, more humid climate than the inland Pilbara, due to its proximity to the Indian Ocean. It has two main seasons: *Muthu* (cold time) from April to October and *Garrbarn* (hot time) from November to March (Murujuga Cultural Management Plan 2016:104). The coolest month is July with temperatures ranging from 13–26°C. There is some rain from May to July from winter storms however the most significant rainfall is from December to April. This comes in the form of thunderstorms, squalls and cyclones.

Murujuga's climate can cause heavy dewfalls compared to other parts of the Pilbara (Long, Mulvaney & Young 2016:8).Temperatures during the hot season average 26–36°C but can reach as high as 47°C (Murujuga Cultural Management Plan 2016, p. 105). Data collected at the nearby town of Karratha between 1972–2020 indicates average annual rainfall of 290mm (Bureau of Meteorology 2020). Studies conducted by the CSIRO (2015:15) indicate that rainfall is increasing in the Pilbara.

2.3 Geology and hydrology of Murujuga

The study area covers the islands bordering the Cape Bruguieres Channel, North Gidley Island and Cape Bruguieres Island (Figure 2.2). The mainland comprises a cratonic mountain-basin tectosome, with a creek and river system that drains into sedimentary plains. The coastal zone contains Holocene sedimentary deposits interspersed with outcrops of Pleistocene limestone and Precambrian rock beds (Figure 2.2) (Semeniuk 1993:237). Red, Pleistocene sedimentary deposits comprised of deltaic, colluvial, aeolian and alluvial deposits are present inland. Strike ridges of Precambrian rock accent the Dampier coast, causing the ria, archipelago, island dominated seascape of the study area, disrupting an otherwise monotonous Pilbara coastline (Semeniuk 1985:5).

The Dampier Archipelago has a wave-dominated coastline, impacted by long-period swell generated in the southern Indian Ocean (Silvester 1963 in Semeniuk 1993:238). Arriving primarily from the north and northwest, long-period swell is refracted by the local bathymetry, shoals, reefs and islands of the Dampier Archipelago (Figure 1.2). Swell waves, generated regionally by prevailing winds and cyclones, are also present in the archipelago. These two wave forms are the dominant landscape sculpting force resulting in boulder-shores, spits, and beaches (Semeniuk 1993:238). These forces have shaped the western peripheries of Cape Bruguieres and North Gidley Islands. Shores sheltered by major structures or gently sloping, shelved seafloors are more protected from wave action and tidal forces have a greater influence on the development of these landforms.

Embayments and inlets behind protective structures, found to the north and west of the study area, are tidal dominated environments (Semeniuk 1993:238). The study area is protected to the north by Legendre Island, to the west by Cape Bruguieres Island and to the south and east by North Gidley Island. The broader area is further sheltered by the northern extremity of Dolphin Island to the east and a string of small islands to the north east. This protected environment, influenced by tidal rather than wave dominated forces, has provided the conditions suitable for the preservation of archaeological materials in a submerged context.

North West Australia is subject to regular tropical cyclones. The islands surrounding CBC also afford it protection from long period swell and damaging winds, mitigating the destructive capacity of tropical cyclones (Figure 2.1). This was demonstrated by Benjamin et al. (2020:20) through the analysis of drone survey data collected before and after a Category 2 cyclone passed through the Dampier Archipelago in March 2019. Comparative analysis of the two data sets indicated that stone structures on the calcarenite terrace, contiguous with CBC, had not been impacted by swell surges or extreme winds. Wave-induced sediment resuspension increases significantly during cyclones, transporting sediment in a southwest direction along the Pilbara coast (Dufois 2017:10,242). Modelling produced by Marglashavili et al. (2006:19) indicate that the Burrup Peninsula interrupts this flow, acting as a sediment trap and reducing bottom shear velocity. They also purport that finer sediments are transported offshore during high turbidity events, but larger grain sediment is only transported locally. This raises two considerations for the identification and assessment of submerged landscapes in the Dampier Archipelago: 1) Artefacts identified in certain localised environments are likely to be in context due to the limited transportive capacity of bottom shear velocities; and 2) The accretionary nature of coastal sedimentary transport along the Pilbara coastline is likely to bury and preserve archaeological features below sediment traps.

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Figure 2.1 Bathymetry and geomorphology of seabed of Dampier Archipelago, from (Veth et al. 2019:17).

The terrace adjacent to the Cape Bruguieres Channel represents a local veneer of Holocene deposit cemented on the surface of a Pleistocene base (Semeniuk1993:247–250). This probably formed as a shore-parallel dune barrier as the ocean deposited mobile sands to the west of North Gidley Island. Dune barriers are accretionary systems that can form on Pleistocene limestone outcrops from the effects of tidal or freshwater creeks debouching into dune belts (Semeniuk 1993:246–247). Benjamin et al. (2020:10) interpret this landform as an ebb-tidal sand spit that formed during the Holocene highstand that never completely blocked the channel. This may have resulted from the east–west drainage of the channel, preventing the accumulation of an accretionary deposit across the western periphery of the channel mouth.

2.4 Marine transgression

During the LGM, the Dampier Archipelago was a low-lying mountain range with the coastline approximately 160km to the north west (Figure 2.3). The coastal hinterland separating the Dampier range from the coast comprised a gently seaward sloping sand plain interspersed with ephemeral waterways and rivers, estuaries, hillocks and knolls, mangrove forests, lithified dune and beach systems and rock outcrops (Benjamin et al. 2020:4; Semeniuk and Wurm 1987:35; Semeniuk 1993:237; Ward et al. 2013:218). The northward flowing waters of the Nickol and Maitland Rivers located to the east and west of the archipelago, flowed intermittently following heavy rainfalls (Ward et al. 2013:222). These rivers and ephemeral drainage systems formed a series of overlapping deltas that acted as accretionary systems. This landscape was slowly drowned following the LGM.

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Figure 2.2 Cross-section of sea floor geomorphology to the west of the study area, after Kojan 1994:22.

Marine transgression had a significant impact on the Pilbara landscape. Dates for the peak of the LGM are contested however it is recognised that by 18 kya the sea level had begun to rise (Benjamin 2020:4; McDonald, 2015:125; Yokoyama et al. 2001:295; Ward et al. 2013:223). Global warming during this period resulted in the continual melting of the polar ice sheets. By about 12 kya the coastline had encroached to within 30 km of its current location. Macrotidal regimes, summer monsoons and dune building began to impact the morphology of the region. The coastline would have become accessible to small mobile groups occupying the Dampier Ranges at this time (Ward et al. 2013:223). This is supported by evidence from Boodie Cave, on nearby Barrow Island, that marine molluscs were being transported distances of 20 km during the Terminal Pleistocene (Veth et al. 2017:26). There are geophysical records indicating that drowned Pleistocene dune systems, representing the coastline from this period, may have survived the continuing marine transgression (Ward et al. 2013:224).

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Figure 2.3 Marine transgression in Murujuga Sea Country, from (McDonald et al. 2018:269).

Terminal-Pleistocene transgression rates were rapid, and the coastline encroached on the outer reaches of the Dampier Ranges by about 10 kya (Ward et al. 2013:220). The valleys began to infill separating the high points of the Dampier range. By 8 kya Mermaid Strait had formed and by 7 kya Enderby and Rosemary Islands had separated from the mainland (Lewis et al. 2013:130). During this same period the ocean began to approach Cape Bruguieres Island. Tidal action would have become pronounced along ephemeral waterways in this region. Angel, Gidley, North Gidley and Cape Bruguieres Islands constituted a single landform at this stage. The water table would have risen during this period; potentially extending the time that potable water was available in the landscape, making this area more amenable to occupation in the decades prior to transgression (Hale 2014:6). By about 7 kya the ocean breached the Cape Bruguieres Channel. The sea level continued to rise reaching a high stand approximately 2m above current levels around 5 kya, then regressing to current levels by 2 kya (Benjamin et al. 2020:10).

2.5 Traditional Owners

Murujuga is the ancestral homeland of the Yaburara people. Murujuga refers to the shape of the skyline on the Burrup Peninsula and means ‘hipbone sticking out’ (Murujuga Cultural Management Plan 2016:22). The Yaburara were estimated to number between 500 and 600 at the time of European contact (Gara 2017, p. 4). William Dampier was the first recorded European to make landfall in Murujuga. He was an English buccaneer who arrived in the region in 1699. Though he did not make contact with the Yaburara, his journals claim he witnessed the smoke from their fires and other evidence of their activities (Murujuga Cultural Management Plan 2016, p. 60). The French explorer, Nicholas Baudin led a small exploration fleet through the archipelago in 1801 and 1802. He named the chain of islands the Dampier Archipelago, in honour of the quality of Dampier’s journals (Mulvaney 2013, p. 13). Foreign whalers began operating in the Archipelago early in the nineteenth century though it is difficult to determine exactly when they first arrived in the region as these operations were unofficial and rarely documented (Mulvaney 2015, p. 12). Early European explorers noticed that the Yaburara had a fondness for European foods as well as familiarity with certain English words. This has been attributed to contact with the whalers by King (1818), Gregory (1861) and Stow (1865) (in Mulvaney 2015:13). Further to this, several engravings within the archipelago dated to the 1840s have been attributed to the whalers (Paterson et al. 2019:222). There is little historical evidence of the Yaburara's lifeways as interaction between the Yaburara and early settlers was rarely documented. It is now difficult to determine whether the Yaburara were a small autonomous tribe, or a subgroup of the Ngarluma tribe, who inhabited the coastal plains between the Sherlock and Maitland Rivers (Gara 2017:3; Mulvaney 2013:23). Ethnographic information documented from the neighbouring Ngarluma and Yindjibarndi groups maintains relevance for how the Yaburara perceived and interacted with their landscape.

A key component of the regional cosmology of the Pilbara are the Marrga. The Marrga are ancestral creator beings who arose near Murujuga and created all the features of the land as they travelled through the country and endowed it with the Law (Palmer 1977, p. 230). Yindjibarndi elder, Yilbie Warrie (in McDonald & Veth 2011, p. 44) describes Murujuga as 'where the Law came up out of the sea and travelled inland'. The following story explains the origin of Murujuga Sea Country:

> It was the Marrga and Minkala/Mangunyba (Skygod) that named and shaped the country, then all the birds and the animals, and finally the Ngardangali (Aboriginal people) came from Marrga themselves. In other places they call this the 'dreaming', but here we call it Ngurra Nyunjunggamu—'when the world was soft' (Juluwarlu Aboriginal Corporation 1993:2).

This story highlights the significant cultural value of the Murujuga landscape, both terrestrial and submerged, for Indigenous groups throughout northern Australia.

Early accounts of the Yaburara describe them as of proud bearing and fine physique (Mulvaney 2013:21). They were commonly observed with adornments of pearl shell at the waist and shoulder and in bands in their hair. Settlers also describe them wearing hair belts, rats-tails and pellets of spinifex gum in their hair (Curr 1886:297). The Yaburara were a maritime people who constructed watercraft to facilitate travel through the Archipelago. Historical accounts of early explorers describe the Yaburara using log rafts to travel between the islands (Gregory & Gregory 1884:55; King 1827:31). Canoes and rafts were made using a range of materials. Mangrove poles and boughs made from the foliage of the Kurrajong tree were utilised for the construction of rafts due to their buoyancy (Vinnicombe 1987b, p. 3). During Palmer's (1975, p. 154) research in the region in the 1970s, an informant told him that the 'old people' would visit the outer islands periodically on canoes made from cork trees (*Erythrina vespertilio*). Single logs were usually employed for shorter trips, while rafts of several logs lashed together were made for trips to the outer islands.

Boughs were used for the construction of shelters and for hunting. Stow (1881, p. 65) noted the presence of windbreaks made from bushes when he came across a Yaburara camping ground while surveying the dunes of Burrup Island. Spinifex grass was also bound together to form the roofs and walls of shelters, known locally as *yatha*. The sides were doused with water to help keep the inside of the shelters cool (Murujuga Cultural Management Plan 2016:123). Bough fences were employed for hunting and fishing (McCarthy 1961:123). Spinifex boughs were placed in shallow water and were used to push fish up onto banks and sandy shores (Murujuga Cultural Management Plan 2016:122). Bough fences, along with net traps, were placed around small water holes and were used to trap kangaroos (Withnell 1901:9). Nets were an integral part of the Yaburara toolkit, and they were extremely proficient in their construction and use (Durlacher 2013:54; Gregory 1884:58–75).

A broad range of subsistence resources were available to the Yaburara in Murujuga. Early explorers observed that marine resources were favoured by the occurrence of discarded turtle and fish bones near old fireplaces throughout the archipelago (King 1827:32; Stow 1881:66). Vinnicombe (1987:5) informs that spears for fishing and hunting turtles were made from hard woods sharpened to a point. Turtle shells were utilised for carrying and bathing babies and for cooking (Murujuga Cultural Management Plan 2016:130). In 1865, when Stow's party made landfall on a beach on Dolphin Island, they made contact with a small group of Yaburara. Stow exchanged tobacco and knives with the group for cooked fish. The Yaburara also showed Stow's party where to find fresh water in the rocks near the summit of the hills (Stow 1865:187). The Yaburara targeted terrestrial species including raptors, wildfowl, lizards and macropods with snares (Withnell 1901:20). A range of berries, roots, seeds, yams and vegetable leaves were also targeted as food sources (Curr 1886:297). Excess meat was cured and stored, and surplus seeds were stored in bark parcels. On the coast, mangroves were also targeted as a food source. The fruit of *Avicennia marina* were eaten but they were toxic if not processed. One method of detoxification was to leave the fruit buried in the mangrove mud for an extended period. Goannas and kangaroos were once targeted as subsistence resources however this is no longer permitted in Murujuga (Murujuga Cultural Management Plan 2016, pp. 132–136).

The limited availability of water in the arid Pilbara climate made permanent settlement of Murujuga difficult. There are no permanently flowing rivers or creeks in the archipelago. The region is characterised by ephemeral waterways which replenish waterholes and soaks during the wet season (Vinnicombe 1987a:2). This restricted population numbers and meant that much of the archipelago was not habitable during the dry season (Vinnicombe 1987b:5). Stokes, (1846:ch. 2.5) noted that the Ngardangali on Depuch Island were attracted to reservoirs of water in the rocks following rain. Some water sources are much harder to identify. During fieldwork in the 1920s Hall, (in Palmer 1975:154) witnessed Ngarluma men collecting fresh water from springs at the base of sandy beaches at low tide. Historically, Ngardangali were observed using vessels to store and transport water. These include coolamons, baler shells (Withnell 1901:23) and kangaroo skins (Nobbs 2000:43). This would have extended the Yaburara's mobility range during the dry season. Large groups of people could gather in Murujuga for ceremonial, social or trade purposes but these gatherings would have been limited to times of the year when water was available in the landscape (Nobbs 2000:38). Mobility was likely more restricted prior to the LGM as the climate was drier during this period (McDonald et al. 2018:267).

Due to the impacts of European colonisation including disease, massacre, kidnapping, enforced slavery, imprisonment and displacement, the Yaburara did not survive as a cultural unit (Gara 2017:5). Exploration missions conducted by Gregory (1884:35) in 1861 and Stow (1881:26) in 1865 identified regions suitable for grazing and cropping in the Pilbara. Cossack was first settled in 1863, followed by Roebourne in 1865 (Gara 2017:5). Pastoralism and pearling quickly became established industries in the region in direct opposition to the continuation of the Yaburara's lifeways. When abundant pearl shell was discovered by Europeans in 1865, friendly relations with the Yaburara ended and they were forced into labour for 'rations' (Gara 2017:5). An Aboriginal elder from the Pilbara, Wendy Hubert (Murujuga Cultural Management Plan 2016:63) describes European settlement bluntly: 'They invaded us, took our people away for slave labour. They had guns and horses, remember that'. This situation further deteriorated, culminating in the Flying Foam Massacre. Over several weeks in 1868, a state-sanctioned campaign of murder was perpetrated against the Yaburara by two posses of 'special constables' drawn from the European settler population at Roebourne and Cossack. This resulted in the deaths of at least 60 Yaburara men, women and children. Any surviving Yaburara abandoned their ancestral lands in fear of further attacks (Gara 2017:1–16). Members of five Indigenous groups, the Ngarluma, Yindjibarndi, Mardudhunera, Wong-Goo-Tt-Oo and Yaburara now act as caretakers for Murujuga Sea Country (Murujuga Cultural Management Plan 2016:27).

2.6 Archaeological history

Archaeological works did not commence in the archipelago until the development of a port at Hearsons Cove in the 1960s. Ironically, these works were triggered after the preferred development location at Depuch Island, was removed from consideration due to the presence of high-density engraving sites (Mulvaney 2015:49; Mulvaney 2013, p. 27). Crawford's (1964:54) assessment of the engravings in the Dampier Archipelago as inferior to those of Depuch Island, which had undergone a detailed study by Ride and Neumann (1964), likely played a major part in this decision. The Dampier Archipelago was selected as the site for the port and the area has been subject to encroaching industrial development since. This has resulted in the loss and removal of rock art, the destruction of pristine habitat, extensive damage to the archaeological record and the destruction of places of cultural significance to Traditional Owners (Mulvaney 2015, p. 49).

The significance of Murujuga's rock art was initially recognised in the late 1960s. Robert Bednarik recorded some 600 petroglyphs throughout Murujuga between 1967 and 1970 however this was not publicised at the time (Vinnicombe 2002:5; Lorblanchet 2018:18). Several projects, primarily focused on rock art, were conducted in the archipelago during the 1970s. Enzo Virilli, a project engineer with Dampier Salt, spent the 1970s recording the engravings of the archipelago. He joined forces with the then registrar of Aboriginal sites at the Western Australian Museum, Warwick Dix, to draw wider attention to the significance of the rock art and the region more generally (Lorblanchet 2018:18). As development pressures increased, the Western Australian Museum sent staff to the region to conduct field surveys. Wright (1972:19) identified engravings of a striped mammal in the archipelago as part of a broader regional study to assess the possibility that the extinct thylacine may be represented in the rock art of the Pilbara. Palmer's (1975) ethnographic and linguistic studies provided valuable detail on the relationship of the engravings to creation stories.

Pat Vinnicombe (1987:8–9) conducted the first large-scale survey in 1980, prior to the construction of the North West Shelf Karratha Gas Plant. The project, covering an area of 12km^2, was primarily a record-and-salvage project, as blanket consent to destroy Aboriginal heritage had been granted by the 'responsible' government minister prior to the commencement of works (Lorblanchet 2018:18). A plethora of archaeological sites were recorded including engravings, stone structures, middens and stone tool manufacture sites. Vinnicombe (1987a:53) described Murujuga as a continuous archaeological landscape with 'considerable' research potential. This destruction of these sites highlights the structural frailty of Western Australian Aboriginal heritage protections, as the presence of globally significant Aboriginal heritage rarely curtails industrial development. Over 160 commercial development surveys have since been conducted in Murujuga, covering an area of 34 km^2. Distressingly, most of this data is not publicly available (Ward & Mulvaney 2018:18). This limits the ability of archaeologists to develop reliable landscape models for Murujuga.

By 2006, over 2,500 sites in Murujuga had been registered with the Department of Indigenous Affairs, with thousands more unrecorded sites identified. Densities of registered sites ranged from 17–76 sites per square kilometre. In well-surveyed rock art galleries, motif densities can be as high as 1,135 individual motifs per square kilometre. There are few areas where spatial data have been recorded at an adequate level, making comparative analysis challenging. As most of the archaeological research in Murujuga has been driven by industrial development, detailed information is primarily available for areas that have already been developed (Bird & Hallam 2006:5; Ward & Mulvaney 2018:18). The absence of a broad heritage inventory for Murujuga makes it impossible to develop a framework within which the individual, or site-level, elements of the landscape can be properly assessed. This problem was identified during the Dampier Archaeological Project (Vinnicombe 1987:56) and has yet to be adequately addressed. Vinnicombe (DAS 1984:13 in Bird & Hallam 2006:5) recognised that the density and continuity of cultural material was sufficient so as to describe Murujuga as a continuous archaeological landscape. No subsequent works have negated this contention and Murujuga should be recognised as a continuous cultural landscape and afforded the appropriate statutory protections. Bird and Hallam (2006:4) describe the situation succinctly: 'Effectively, the requirements of developers drive the destruction of cultural heritage, and archaeological investigation has been merely a prelude to that destruction'. More recently the University of Western Australia (UWA) has conducted a range of research projects which are broadening our understanding of how past Aboriginal communities interacted with the Murujuga landscape including the identification of stone structures interpreted as housing foundations on Rosemary Island (McDonald and Berry 2017:41) and Pleistocene occupation of a rock shelter dating to 24,320 cal BP (McDonald et al. 2018:282). Flinders University, in association with UWA, is leading the DHSC project to identify submerged landscapes in the archipelago, which is also increasing our understanding of the Murujuga landscape (Benjamin 2020:1). The Murujuga Cultural Landscape was placed on the tentative list for World Heritage listing in 2020 following a decade long process (McDonald and Veth 2011:3; UNESCO World Heritage Convention 2020).

The DHSC identified a range of archaeological features that form Murujuga's archaeological record while developing their landscape model. These include stone structures, grinding sites, middens, engraving sites and quarry sites (Veth 2019:9–16). Vinnicombe's (1987a; 1987b) noted that Murujuga is a palimpsest and it is often difficult to clearly identify boundaries between different sites. Further to this, multiple site types are regularly found in a single location. In the following section, stone structures, grinding sites, middens, engraving sites and quarry sites will be described as they are likely to be encountered as part of this study.

2.7 Stone structures

A diverse range of stone structures is present throughout Murujuga and they form a key aspect of the archaeological landscape. These include standing stones, thalu sites, stone pits, 'Burrup patches' and fish traps.

2.7.1 Standing stones

Standing stones are the most common type of stone structure present within Murujuga. They occur across all landscapes in the archipelago and have been identified wherever systematic survey has occurred (McDonald & Veth 2011:51). Standing stones are naturally formed columnar stones ranging in size from 36–222 cm and are found wedged between rocks in a vertical position (Vinnicombe 1987b:32). They are generally found on prominent ridges or other conspicuous locations and they are sourced from naturally occurring, local stone(Figure 2.4). They have been recorded as individual stones, in pairs and in large groupings

(Vinnicombe 1987a:69). There are examples of standing stones that have been engraved or positioned in association with engravings (Vinnicombe 1987b:32). Standing stones have been interpreted as landscape markers (Elkin 1933:283) or physical manifestations of ancestral spirits (Gould 1968:101).

Figure 2.4 Standing stone, North Gidley Island, view west, J. Leach.

2.7.2 Thalus

Some standing stones, known as thalus, are ritual structures used in the practice of 'increase ceremonies'. (Vinnicombe 1987a:69; Wangka Maya Aboriginal Language Centre 2008:35). Withnell (1901:6) noted that thalu sites were hallowed places and were geospatial cosmological markers that required visitation to perform specific ritual praxis, related to the seasonal regeneration of animals, plants, people and other favourable conditions. These sites represent and concentrate spiritual forces that are already present within the landscape (Reynolds 1989:8; Edmunds 1998:192; Zarandona 2020:64). Thalus can be natural or man-made and are generally represented by a standing stone, a pile of stones, a boulder arrangement (McDonald & Veth 2011:45) or a stone pit (Piddington 1932:395). Thalu sites are located at a place where the resource they represent is generally plentiful (Piddington 1932:379). Rituals performed at these sites often involve hammering the ceremonial object with round stones or clubs (McCarthy 1961:146) or impersonating the actions of the subject being willed (Clement 1903:6). All material paraphernalia utilised for the procurement of a resource, are integral elements of these ceremonies (Clement 1903:6), and practitioners often adorn themselves with clays and ochres for these rituals (Withnell 1901:6). The extensive geographic network of thalu sites present within Murujuga indicate a spatially co-ordinated pattern of landscape modification and attest to the outstanding cultural significance of this landscape to the Ngardangali (McDonald & Veth 2011:46). McDonald and Veth (2013:75) purport that standing stones became more prevalent in the last millennium and that they may be a component of a ritual repertoire that was previously represented by the production of engravings.

2.7.3 Stone pits and Burrup patches

Stone pits are one of the most prolific, and enigmatic, occurrences in the Dampier Archipelago. While some may have ritual associations, they have broadly been interpreted as hunting hides (Vinnicombe 1987a:69; Sheppard 2013:64). Though it is difficult to determine if they are natural or constructed features, Chappell (1985 in Vinnicombe 1987a:33) contends that it is unlikely that these pits result from tree-root action or other geological processes. It is probable that the stone pits were made by removing stone from a central depression which was then walled up on the downslope margin (Vinnicombe 1987b:33).

Though many of these stone pits are interpreted as hunting hides, the purpose of some of these features is less conclusive. Some of these features are too large and flat to be effectively utilised as hunting hides (Veth et al. 2019:10). Vinnicombe (1987b:23) defines them as ‘Burrup patches’ and describes them as ‘flat clear areas, like platforms, among the boulder slopes where floors of small compacted angular stones standout as significantly different from the tumbled array of boulders around them’. They are often demarcated by portable stones (10–15kg) with discoloured surfaces lacking desert patina, in stark contrast to the larger boulders present, suggesting a high probability for human modification (Vinnicombe 1987b:34). Burrup patches can measure up to 10 m in diameter and are commonly identified along drainage channels and gullies (Vinnicombe 1987b:33). Some patches have been recorded containing alluvial soils and moisture that foster the growth of edible tuber and root species that are endemic to the Kimberley and not found in other parts of the Pilbara (Vinnicombe 1987a:69; Vinnicombe 1987b:33). Other Burrup patches incorporate elevated rows of small boulders around their peripheral margins. McDonald and Berry (2017:9) have interpreted a small grouping of Burrup patches with this feature on Rosemary Island as the foundations of habitation structures.

2.7.4 *Fish traps*

Several intertidal areas throughout Murujuga contain stone walls that have been interpreted as tidal fish traps. Tidal fish traps are stone barriers that are constructed across shallow inlets, that trap fish when the tide recedes (Basedow 2012:88). The Bardi, an Aboriginal group from the Kimberley, identify stone wall fish traps as their most efficient method of trapping marine resources (Kreij et al. 2018:149). Vinnicombe (1987a:70) initially identified fragmented tidal fish traps in the archipelago in the 1980s. As of 2011 there were four recorded fish traps identified within Murujuga (McDonald & Veth 2011:20). It is likely that there are more yet to be identified. Ward et al. (2013:218) recorded anecdotal evidence from Traditional Owners that submerged fish traps are present along drowned waterways throughout the archipelago. Emma Beckett (2020 in press) is currently completing her doctoral research on stone structures in the region and has identified several new stone features that have been interpreted as fish traps.

2.8 Grinding patches

Grinding patches are stones that exhibit smooth or polished surfaces resulting from the grinding of seeds or other materials (Mulvaney 2013:29). The seeds of *Triodia epactia* and *Triodia wiseana* spinifex (Murujuga Cultural Management Plan 2016:123) as well as the seeds of mangrove and acacia species (McCarthy 1961:123) were utilised by the Ngardangali to produce damper in the Pilbara. Grinding patches are normally found proximal to food or water sources or in correlation with major occupation loci (Berry 2018:100; McDonald & Veth 2009:52; Bird & Hallam 2006:15; Vinnicombe 1987a:70; Vinnicombe 1987b:31). They are generally oval-shaped and range from 10–40 cm in length (Vinnicombe 1987b:31). In areas where bedrock is absent, grind stones, which are portable grinding tools, are used for grinding activities. Grind stones are large, flat pieces of stone, commonly made from granophyre or sandstone. They will generally exhibit one smoothed working surface, which is stored face down for protection (Fullagar et al. 2017:175). Seed grinding is commonly perceived as gendered within Aboriginal communities and is generally conducted by women (Webb 2007:115). In 2006 there were 170 recorded grinding patches in the Dampier archipelago (Bird & Hallam 2006:19). The number of grinding patches likely far exceeds this number as McDonald and Berry (2017:30) identified 140 grinding patches at a single site: the Wadjuru Pool site on Rosemary Island. Several grinding patches have been identified with incisions or pitting indicating that their working surfaces have been rejuvenated for continued utility (Bird & Hallam 2006:15; Vinnicombe 2002:13; Vinnicombe 1987a:70). Some have been identified with desert varnish overlaying the grinding surface indicating a great antiquity for the utilisation of seed-grinding technology in Murujuga (Bird & Hallam 2006:15; Vinnicombe 2002:13).

2.9 Middens

Shell midden sites have been identified along the coastal margins of Murujuga. Shell middens are accumulations of shell refuse representing past marine resource exploitation. They can also contain the bones of terrestrial animals, lithics, crustaceans and the remains of hearths (Bird & Hallam 2006:13). They are representative of the strong relationship that the Yaburara had with the sea (Department of Conservation and Land Management 2005:50). Middens can manifest as deflated surface accumulations of shell lenses of varying thickness in dunes or watercut gullies; small concentrations of shell in rock piles; or as large ‘mound middens’ (Bird & Hallam 2006:13–14). All of these midden types have been identified in Murujuga. Several large mound middens of ‘particular importance’ have been identified in Murujuga including George’s Valley, Nickol River, Anadara Mound Midden, Skew Valley, Magic Midden and West Intercourse Island (McDonald & Veth 2011:52). Massive mound middens, up to five metres in height and over 300 m in length (McDonald et al. 2018:267), have been identified on West Intercourse Island contiguous with an historic pearling camp (Bradshaw 1995:37–38). Little is known about this midden as archaeological excavation has yet to be conducted at this site (McDonald et al. 2018:267).

Middens have been recorded at the mouths of waterways and along the coast on the mainland and are prevalent along the coast as far the Kimberley. Middens began to appear in the archaeological record about 7000 kya (Mulvaney 2011:45) however many earlier middens in Murujuga were likely destroyed due to the deleterious impacts of marine transgression (Veth 1995:743). Clune and Harrison (2009:74) identified several mound middens along Nickol Bay, on the eastern periphery of the Burrup Peninsula. These middens were dominated by *Anadara granosa* and date to 4250±60 BP. Clune and Harrison (2009:70) interpret these middens as relating to seasonal periods of sedentism and ceremonial gatherings. McDonald and Veth (2009:52) purport that the large mound middens at Skew Valley and West Intercourse Island provide clear correlation between the exploitation of marine resources and the production of rock art. Lorblanchet (1992:46) takes this further, characterising a shift in the art of Murujuga as the sea level began to stabilise. He defines this difference as the ‘art of the kangaroo hunters’ and the ‘art of the shellfish gatherers’. McDonald et al. (2018:267) purport that the exploitation of mangrove shellfish species declined approximately 4 kya and rocky shore and sandy beach shellfish species became more prevalent.

2.10 Engravings

Murujuga is known as the ‘storybook’ of the Pilbara due to its vast gallery of engravings (McDonald & Veth 2011:44). It is estimated that there are over one million engravings present in Murujuga (McDonald 2015:132). The traditional owners indicate that the engravings were laid down by the Marrga as a physical manifestation of the Law (Murujuga Cultural Management Plan 2016:34). The Gnarluma have songs and mythology associated with the rock art (Vinnicombe 2002:13). They were used for education, initiation and ritual purposes and likely had a role as a mnemonic device (McDonald & Veth 2011:41–46; Vinnicombe 1987b:6). Vinnicombe (1987b:6) suggests that the retouch, tracing or repetition of engravings or motifs may have played a role in ceremony. Some early settlers to the region witnessed the production of engravings. Clement (1903:9) describes the process:

> This carving is done with a stone axe (kaidu or gamma). The design is drawn with chalk or charcoal on the rock, and by repeatedly hammering along the lines, it is cut deeply into the rock.

At present, dating methods have not been developed that can provide absolute dates for the production of petroglyphs. Methods that have proven successful in other rock art regions of Australia, including the dating of mineral accretions and oxalate crusts (Dorn 2001:170), have not been applied in Murujuga as amenable conditions have not been encountered in the region (Mulvaney 2011:32). Attempts have been made to date the ‘desert patina’ that is present on Pilbara geology, but results have so far been inconclusive. One engraving at Skew Valley, uncovered during an excavation of a midden was dated to 3,800 ka, however it is believed to be much older (Hallam and Bird 2006:18). McDonald (2015:128) and Mulvaney (2015:326) have developed typological chronologies for Murujuga’s rock art based on engraving style and subject, engraving technique, climatic events, archaeological data and contrast state. ‘Archaic faces’ and elaborate geometric and anthropomorphic images have been designated as the oldest engraving type due to the heavy repatination they exhibit and are estimated to date between 47–22 ka (McDonald 2015:128; Mulvaney 2015:290). Of key interest is the transition from terrestrial faunal images to marine faunal images during the Holocene period relating to marine transgression.

2.11 Quarry sites and artefact scatters

The archaeological record of Murujuga is characterised by open-air quarrying sites and artefact scatters (Benjamin et al. 2020:5). Locally available materials including granophyre and gabbro dominate artefact assemblages. The quality of these materials varies from fine-grained to porphyritic. Small quantities of exotic lithic materials have been recorded from contiguous mainland sources (Bird and Hallam 2006:13). Materials identified include chert, chalcedony and quartz, however these materials are much less prevalent and tend to date to the pre-Holocene period (McDonald et al. 2018:275). Negative flake scars on boulders provide evidence of quarrying activity in Murujuga with finer grained materials targeted. Quarries can also be identified by extraction pits and associated reduction debris (Veth et al. 2019:18): they are generally determined as workshop sites and can contain high-density accumulations of discarded materials. Even though artefact scatters are the second most common site type in Murujuga, few studies have focused on this area (Bird and Hallam 2006:13). An intertidal artefact scatter was recently identified on Dolphin Island confirming that conditions suitable for the preservation of submerged archaeological features in Murujuga are not isolated (Dortch et al. 2019:2).

2.12 Landscape archaeology

While surveying Bezout Island, 15 km east of the Burrup Peninsula JL Stokes (1840:2.6) noted in his diary ‘a more dreary country can scarcely be seen, yet it still maintains its inhabitants’. A similar attitude was expressed by Charles Frome in 1842 while surveying the Lake Frome Plains: ‘[I] can speak with almost as much confidence of its absolute sterility as if I had actually ridden over it’(Auhl and Marfleet 1972 In Nobbs 2000:22). These impressions are at odds with an observation Kimber (1976:145) repeatedly made during his anthropological career ‘I have yet to hear an Aboriginal describe his tribal land, no matter how barren it might look to an outsider, as anything but ‘properly good’. These divergent views indicate that landscapes, as conceptual entities, are subjective and bound by the realms of human perception, experience and contextualisation (Knapp and Ashmore 1999:1). A key challenge with landscape analyses is reconciling processualist views, that designate the landscape as a canvas for archaeological enterprise, and post-processualist views, that perceive interactions with landscape as dictated by symbology and imbued with meaning (Ingold 1993:153; Knapp and Ashmore 1999:7). The divergent descriptions of landscape by English explorers and the Ngardangali indicate that an objective interpretation of landscape is problematic.

Landscape has become a key conceptual tool in a diverse range of fields including literature, resource management and archaeology (Bradley and Kearney 2018:290) but it struggles to thoroughly articulate the nested relationships that define peoples' interactions with the space that they inhabit. The Cartesian perception of landscape, often employed in archaeological analysis, has little correlation to Indigenous ways of knowing Country. The use of ethnographic analogy or phenomenology to recognise perceptions of landscape shaped by human experience is denounced as being dependent on circular reasoning and allegorical interpretations of data (Knapp and Ashmore 1999:5). While this is something to remain cognizant of, archaeologists must also remain mindful that the term 'landscape' is a construct of modern European Society and its use as an interpretive tool is as much a sign of modern scholarship as it is of the past societies that we study (Lemaire 1996:6). The definition of landscape is malleable as it lies along a nature-culture continuum (Tilley 1994:37). The ways in which a society perceives their landscape can have a significant bearing on how it is presented and organised (Derks 1997:126). 'Hidden behind the observable world lies the imaginary one, referring to a permanent cosmological order of ancestors, spirits and gods' (Derks 1997:127). There are many different ways of knowing the places within our environment and the places within it that contain social value (Knapp and Ashmore 1999:6). Landscape as a conceptual tool is highly effective but, like any tool, it is only useful when applied to the task for which it has been created. If we conflate our modern perception of landscape, with those of the past communities that we study, the efficacy of this tool dissipates.

Here, Yanyuwa woman Dinah Norman a-Marngawi, (in Bradley and Kearney 2018:292) describes her relationship to Sea Country:

> Our songs and ceremony are also in the sea, they are running through the sea, both along the bottom of the sea and they also rise and travel on the surface of the sea. White people think the sea is empty that it has no law, but the law and the ceremony is there in the saltwater, in the

> fish, in the sea birds, the dugong and the turtle, it is there and we knowledgeable people are holding it.

This relationship with Sea Country directly influences how the Yanyuwa interact with and perceive their landscape, yet this relationship is rarely considered by archaeologists undertaking landscape analyses. To begin to engage with Indigenous ways of knowing we must go beyond our conceptual restraints of landscape as geology or ecology and examine the unquantifiable 'imaginal' phenomena of the Indigenous Ancestral realm, commonly known as the 'Dreamtime' or 'Dreaming' (Bradley and Kearney 2018:291). The Dreamtime is 'an Aboriginal English word used to describe the religion or spirituality of Aboriginal Australians. It is a philosophy, a cosmology, a worldview and a way of life that explains how the world was created and our relationship to each other' (Andrews 2010:2). It is also inextricably linked with landscape, or Country. Bird Rose explains (2000:119): 'Country is the nexus of individuals, social groups, Dreamings, nourishing relationships, birth and death, and conversely an individual is a nexus of countries''. Time, which is not linear in Indigenous Lore, is also entwined with the Dreaming 'that which is Dreaming does not die, does not get washed out, but has the potential to exist forever' (Bird Rose 2000:204). Further to this, Indigenous connection to Country extends beyond the shoreline and below the ocean's waters. The mapping of landscapes is considered a 'whitefella's' way of knowing, which does not give consideration to Indigenous ways of knowing (Bradley and Kearney 2018:289). While archaeologists cannot replicate the stories represented in these ancient landscapes, we can start to conceptualise how they can be incorporated into our studies. If we are to attempt a transcultural rendering of Country, first we need to recognise our own cultural biases and challenge the Western academic tradition of the objective premise (Bradley and Kearney 2018:291). That time and landscape are indivisibly linked and they 'are essential topical points of contact between archaeology and anthropology' is a potential starting point to explore these ideas (Ingold 1993:152). Knowledge does not need to be a binary between science and culture: we can enliven landscapes with the movement of their inhabitants experiments in living and ensure our perceptions of what it is to be human are woven into the contours of their surfaces. Though this type of analysis is beyond the scope of this project, it has informed the author's thinking during this project.

A critical, theoretical and analytical element of landscape archaeology is the generation of landscape models. As with any form of modelling, landscape models are dependent on the collection and collation of quality data tailored towards a viable analytical or theoretical goal.

Technological advances over the last two decades have made a broad range of data collection tools, such as satellite imagery, LiDAR and drone imagery available to archaeologists that can be collated utilising software to create geographic information systems (GIS) (Parcak 2009, p. 26). The use of GIS reflects theory rather than generates it and alludes to the theoretical proclivities of the practitioner (Hu 2011:83). Gillings (2012:601–602) suggests that during the 1990s landscape archaeologists had fallen into a comfortable pattern of conducting 'distanced approaches such as mapping' and that GIS practitioners should 'begin to develop and explore their own unique theoretical frameworks'. The use of these technologies was commonly critiqued as technological determinism and that the use of GIS was a merely a 'set of methodologies looking for a problem' (Gillings 2012:604). Increasingly, the confluence of better remote sensing techniques and spatial software are highlighting the increasing viability of utilising Artificial Intelligence (AI) for the detection of archaeological features. With effective recording and modelling of known archaeological features, AI can be trained to identify reflection, shape or object-based signatures (Casana 2020:593). The primary limitations to this methodology are that it can only identify known archaeological features in specific regions and that these features must be recorded in sufficient detail to train the AI. At present these methods still produce false positives while overlooking known sites and cannot outperform trained archaeologists (Casana 2020:594). These technologies are continually improving and the key to their success is the collection of high-quality data to be used in conjunction with landscape models. These methods can also be applied to the identification of submerged archaeological landscapes.

2.13 Submerged landscape archaeology

The field of submerged landscape archaeology has undergone a florescence over the past decade and is now at the vanguard of research into two of archaeologies most pressing questions: how did past cultures respond to climate change? and, how did prehistoric hominins migrate between continents (Bailey 2011:311; Benjamin 2010:255; Flemming 2014:viii)? A growing body of evidence indicates that submerged landscape archaeology is not only integral to developing sound hypotheses in relation to these questions, but conclusions drawn solely from terrestrial archaeological data are based on incomplete data (Bailey & Flemming 2008, p. 2157). The potential for the continental shelves to preserve significant archaeological features has been recognised for over half a century (Flatman & Evans 2014:2) however, little research has been conducted within Australian waters. This is despite evidence for the preservation of cultural materials from submerged landscapes in the Middle East (Galili et al. 2018, pp. 34–40), Europe (Fischer 1993, pp. 372–380) and the Americas (Faught 2004, pp. 276–279).

Submerged landscape archaeology involves the identification, recording and analysis of landscapes inhabited by past hominins that were drowned before the sea level stabilised at its current level. Until the early 2000s, the majority of texts on underwater archaeology primarily focused on shipwreck and nautical archaeology (Benjamin 2010:254). Over the last decade there has been a concerted shift towards developing methodologies for the targeted investigation of submerged landscape sites on the continental shelf (see Bailey and Flemming 2008; Bailey et al. 2017; Benjamin et al. 2011; Bicho et al. 2011; Evans et al. 2014; Ford 2011). A universal methodology for the identification and investigation of submerged landscapes has been lacking due to the complexity, scope and variation in submerged environments and the high costs associated with their investigation. While these factors make the application of a universal methodology challenging (Benjamin 2010:254), the discipline has drawn on techniques developed in both terrestrial and maritime archaeology (Gusick and Faught 2011:29) and is rapidly evolving towards standardised, stepwise procedures for the identification of submerged sites.

Historically, the broader archaeological community was reluctant to accept that in-situ submerged sites containing reliable archaeological data could have survived marine transgression (Fischer 1993:371). Submerged landscape archaeology was a discipline relegated to the theoretical shadows, occasionally resurfacing when submerged artefacts, opportunistically recovered through dredging and fishing, offered tantalising glimpses of a drowned world. The most renowned accidental find was a deer-antler harpoon recovered by trawlers off the British coast in 1931. The harpoon was recovered from the Leman and Ower sand shoal in a lump of peat. It was determined to be of the Maglemose culture and was the first confirmation that humans once occupied the now submerged landscape of Doggerland (Evans 1932:218). The name Doggerland was given to the submerged landscape between Britain, Holland and Denmark, in reference to a study that identified a submerged Neolithic forest in this area of the same name (Coles 1998:47). Following excavations at the Mesolithic settlement site of Star Carr in Yorkshire, Britain, Clark (in Coles 1998:48) determined that a previously unknown culture had been active in this region. This contention was supported by the analysis of palaeo-environmental data and the antler harpoon retrieved from a submerged context in Doggerland.

Artefacts recovered through dredging, fishing and oceanic processes confirmed that artefacts can survive marine transgression and that they yield valuable archaeological data not encountered on terrestrial sites (Fischer 1993:371), however it was not until the early 1980s that artefacts were identified in situ (Gusick and Faught 2011:29).

Systematic investigations were conducted in Ertebølle, Denmark that assessed factors such as sea level history and the potential for site preservation. The survey recovered a wealth of artefacts including textiles and elaborately decorated wooden objects from the Maglemose culture (Fischer 1993:372). The artefacts recovered from these submerged contexts were unique and bore no resemblance to artefacts known from terrestrial sites (Fischer 1993:372). In 1983 the Danish government enacted legislation for the protection of submerged landscapes and developed a program to identify submerged sites (Fischer 1993:373).

The resources required to investigate all areas potentially harbouring sites was unrealistic, so a predictive model was developed to identify a 'reasonable amount' of the most valuable sites. The model was developed from archaeological data from Karabaek and Roskilde Fjords and ethnohistorical data gathered from interviews with local fisherman (Fischer 1993:373). This determined that standing fishing structures, made of woven fences and stick baskets, were utilised from the Mesolithic period until the nineteenth century and identified the types of locations where they were most likely to occur. Divers conducted investigations at depths of four, six and ten metres at a range of sites. The model proved successful and archaeological materials were identified at 80 per cent of surveyed sites. Sites that did not fit the model were also investigated. Archaeological materials were not identified at these sites, confirming that site distribution was not random. The surveys were completed with relatively simple equipment: a small boat, three scuba divers and a commercially available navigator with an accuracy of 30 m (Fischer 1993:372–375). The Danish model proved highly successful and still informs research methodologies in the present day (Benjamin 2010:257). From this work, Fischer (1993:371) determined three key benefits to the study of submerged archaeological landscapes:

1. Artefacts, particularly those made from organic materials, preserve well;

2. A wealth of environmental indicators associated with the artefacts are preserved; and
3. Adaptational strategies are markedly different to those identified at terrestrial sites.

Israel also has a long history of research of submerged sites. The first site to be investigated was the partially submerged settlement of Neve-Yam, which was uncovered by a storm in 1969. This led to the establishment of a research program focusing on the survey, excavation, research and salvage of submerged prehistoric settlements (Galili et al. 2018:34). The proceeding four decades of activity revealed 17 submerged prehistoric sites off Israel's Mediterranean coast dating as far back as the Palaeolithic. These well-preserved sites were primarily found in paleosols in between north–south aligned kurkar ridges, protected by mobile sands at depths between 0–12 m (Galili et al. 2018:39). The Israeli model shares many similarities with the Danish model but, like the Danish model, has evolved to reflect the nuances of the Israeli coastline. It is a general purpose, multi-disciplinary, investigatory model aimed at detecting sites for the purpose of mapping, monitoring, rescuing, researching and managing prospective sites. A key development in the Israeli model was a focus on severe weather events. Targeted diver surveys following storm events were conducted to record changes to submerged landscapes and identify the exposure of archaeological features. Pedestrian surveys were also incorporated into the model to identify archaeological features and opportunistic finds exposed along dynamic coastlines (Galili et al. 2018:42–48).

While both the Danish and Israeli Models have proven highly effective at identifying submerged landscapes, they have both been tailored to the specific landscapes in which they were developed. Submarine landscapes vary dramatically by region, which must be a key consideration in the development of a universal model (Benjamin 2010:255). To address this issue, Benjamin (2010:258) devised a theoretical six-phase model for the identification and documentation of submerged landscapes based on the Danish model but also incorporating 'sea-level change, coastal geomorphology and coastal settlement patterns' as key considerations identified from experience in North America (Ruppe 1988 in Benjamin 2010:258). This model informed the methodology employed by the DHSC (Veth 2019:16–21).

2.13.1 Phase I—Regional familiarisation: archaeology, geography, geology, geomorphology, oceanography, and hydrology.

Submerged landscape archaeologists draw on a broad range of academic disciplines to successfully identify submerged sites. Factors such as sedimentation rates, rainfall, bedrock geology, wave direction and hill slope can all influence where sites are located and how they preserve. Landscapes targeted for intensive survey must exhibit features likely to contain archaeological materials as well as conditions conducive to site preservation (Gusick and Faught 2011:36). The preservation of submerged landscapes is heavily influenced by geological and geomorphological principles following transgression (Veth et al. 2019:3). Geomorphological considerations and the post-depositional impacts associated with marine transgression and marine and coastal processes should be conscious considerations at all stages of the research process, particularly during the development of models and during post-fieldwork analysis. Coastal topography, geological composition, tidal activity, rates and types of sedimentation, surge and sea currents are all key considerations (Benjamin 2004:259). An understanding of local sea level models is also important for submerged landscape archaeology. Sea level rise is not uniform and can be impacted by tectonic, eustatic and isostatic influences (Gusick and Faught 2011:34) and variation in coastal morphology (Benjamin 2010:259).

Integral to Benjamin's (2010:255) model is the development of a binary predictive model based on diagnostic features of the palaeo-landscape to determine high-potential sites for targeted investigation. Some archaeologists have challenged the incorporation of predictive modelling into a survey methodology. The primary concern is that it employs environmental determinism (Kammermans 2004:274), creates a self-fulfilling survey strategy (Whitley 2004:316) and it cannot provide any useful archaeological data (Price in Benjamin 2010:266). Identifying submerged archaeological sites is exceedingly difficult. This is primarily due to the vast scale of survey areas and the challenges associated with working in an underwater environment (Gusick and Faught 2011:38). The historical paucity of submerged landscape sites is directly related to these challenges (Gusick and Faught 2011:27). Randomised survey strategies are not appropriate in an underwater context as 'repeated failures may threaten the availability of future funding' (Erlandson and Fitzpatrick 2006:14). Underwater archaeology can be expensive and time consuming, therefore well-developed models that identify high probability targets increase productivity and efficiency

(Gusick and Faught 2011:37). Even models developed with small data sets are better than making no attempt due to fear of a flawed analysis. The only way to improve modelling is to identify more sites (Hale and Garrison 2017:169). While the limitations of predictive modelling are relevant, at present there are no viable alternatives for the efficient identification of submerged archaeological landscapes.

The DHSC identified four landforms that were assessed as containing the highest site densities (Veth et al. 2019:11):

1. Coastal and interior valleys with semi-permanent water;
2. Flat coastal pavements and outcrops flanking mangroves and sandy bays;
3. Dunes and sand bodies flanking embayments; and
4. Granophyre and basalt substrates and especially finer grained outcrops.

The DHSC determined six of the most frequent and visible terrestrial archaeological sites that could survive inundation and be identifiable in a submerged context (Veth et al. 2019:18):

1. Midden and artefacts within cemented dunes and beach rock deposits and around calcium carbonate encrusted waterholes on identified palaeo-creek lines;
2. Quarry outcrops, extraction pits and associated reduction debris;
3. Circular and curvilinear stone structures on pavements with associated middens;
4. Standing stones on platforms and in boulder piles;
5. Lag deposits of artefacts on hardpan outer island landscape features and in the intertidal zone along protected waterways of the inner islands; and
6. Small overhangs and shelters with preserved deposits.

2.13.2 Phase II—Ethnographic component: cultural parallels, historical research, and modern interviews.

Ethnohistorical data is useful for gaining an understanding of the types of resources that were targeted locally and the methods employed in their procurement. While ethnohistorical data can provide valuable insights, caution must be exercised when applying ethnographic analogy as significant ecological and climatic changes have occurred since the LGM (Hale and Garrison 2017:167). Interviews with local divers and fishermen are useful as they can reveal unpublished information such as chance finds and local histories (Benjamin 2010:260). Interviews with local fisherman were integral to the development of the successful modelling used to identify submerged sites in Denmark (Fischer 1993:374). No formal interviews were conducted as part of the DHSC however the Murujuga Aboriginal Corporation Council of Elders was regularly engaged in consultation during the project.

2.13.3 Phase III—Map, chart and aerial imagery analysis, and location plotting.

Analysis of navigation and nautical charts, bathymetric maps and satellite imagery are assessed to visualise the palaeo-environment and determine prospective sites for further analysis. High-resolution bathymetric data is useful for identifying features in a submerged landscape, such as rock outcrops, steep slopes and shell middens that could have been key landscape features to prehistoric communities, but may not be visible in lower resolution data (Guscik and Faught 2011:31).

An airborne LiDAR survey was completed over Murujuga Sea Country to develop high resolution onshore and near shore digital elevation models (DEM) and photomosaics. Riegl topographic and topo-bathymetric systems were used resulting in point clouds with a density range of 10–20 points/m^2. The resulting imagery enables the seamless integration of terrestrial, intertidal and seabed morphology to water depths of 12 m (Benjamin et al. 2020:6).

2.13.4 Phase IV—Observation of potential survey locations, physically and with sonar.

Once prospective sites have been determined they should be physically observed. This gives the team an opportunity to verify the determinations from the modelling. Features that are not apparent during desktop studies may become obvious while in the field. This includes issues related to the validity of the prospective site or potential safety concerns, such as strong tidal currents or poor visibility, which can only be assessed in the field. Remotely operated vehicles (ROV) used in conjunction with sidescan sonar can confirm the location of high-potential sites without the need to send divers into the water (Gusick and Faught 2011:41). While sonar and other remote sensing techniques are valuable tools that can inform the development of a safe and efficient dive plan, they should not be considered a substitute for diver survey (Benjamin 2010:260).

Once the DHSC determined high-potential sites they were investigated by boat. The project focused on near-shore environments as it facilitates more efficient and productive field work by increasing bottom times for diver surveys, simplifying technical diving requirements, increasing mobility and flexibility, increasing the probability that identified submerged sites will be proximal with terrestrial sites and reducing travel times between sites. Areas of the seabed targeted for more detailed investigation were surveyed with an EdgeTech 4125 sidescan sonar system. Where necessary, the sidescan imagery was enhanced with multibeam bathymetric data from Australian Marine Services and EGS Survey (Benjamin et al. 2020:6).

2.13.5 Phase V—Marking of theoretical site with GPS and diving to investigate.

Once a site has been confirmed for diver survey its location is marked with a sonar-integrated GPS. This records location and depth information that can be incorporated into future submerged landscape models (Benjamin 2010:261). Even in the absence of archaeological material, this data can be utilised to refine models to improve the efficiency of future research. It must be stressed that familiarisation with regional archaeological materials, settlement patterns and practices is essential prior to the commencement of diver investigations. The physical and mental stress of working in a submerged environment, visibility issues and limited communication are added challenges for the practice of archaeology underwater (Muckelroy 1978:24–32). Underwater archaeologists need to be able to identify archaeological materials independently as second chances are rarely afforded.

Sites flagged for diver survey by the DHSC were investigated by two- or four-person dive teams of archaeologists with specialised underwater archaeology training. Entry points were marked with the navigation system of the diver support vessel, while dive lines were marked with 100 m lead weights attached to shot weights with attached marker buoys. One member of the dive team towed a surface marker buoy with an attached eTrex GPS unit to determine the position of finds and diagnostic features on the ocean floor. Cameras utilised for the documentation of submarine features were calibrated with the GPS unit to catalogue find locations (Benjamin 2020:7).

2.13.6 Phase VI—Post-fieldwork analysis, interpretation and dissemination.

Post-fieldwork analysis, interpretation and dissemination for submerged landscape archaeology is conducted in a similar fashion to other archaeological fields. For the practice of submerged landscape archaeology to develop it is integral that findings are published. Benjamin (2010:262) articulates the need for the dissemination of findings succinctly: 'This is standard practice in archaeology and is no exception here'. It has been argued that submerged landscape archaeology does not produce data that is directly comparable to data produced from terrestrial sites. Although current models may be useful for the identification of submerged sites, it does not produce systematic survey and recovery of archaeological features comparable with terrestrial archaeological practices. While it is important to remain conscious of the fact that current sea levels played no part in the social organisation of prehistoric communities, it has had a significant impact on the post-depositional processes that have impacted these sites. Attempting to apply common methodological approaches in terrestrial and submarine settings is fundamentally and irreconcilably flawed. A keyway to address this issue is to ensure the 'reporting of material, regardless of age, from underwater, inter-tidal and onshore fieldwork in a cooperative effort' (Benjamin 2010:265).

2.14 Submerged landscape archaeology in Australia

A range of research projects have tried to identify submerged archaeological landscapes in Australia however evidence has proven elusive. In 1982, Flemming (1982:150–153) conducted systematic diving surveys on the Cootamundra Shoals in North Western Australia targeting beach ridges, cliffs and submerged reefs at depths of 30 m+. The Cootamundra Shoals are a karstic valley system located between Australia and East Timor, a potential route for the first human migration into Australia. No potential archaeological material was identified during these surveys. Dortch and Godfrey (1990:3–8) recovered stone artefacts from the bed of Lake Jasper, south of Perth in Western Australia. These were recovered both from the shoreline during low lake levels and from a later diving survey when the lake had returned to normal levels. Though this indicates that artefactual material can be identified and retrieved from an underwater context, this lake was several kilometres inland from the ocean and cannot be considered an analogue for a marine context. Dortch (1991:1; Dortch and Dortch 2019:15) also attempted to identify sites on the nearby Rottnest Island but had no success. This research did indicate that extant and former freshwater swamps are likely to contain archaeological materials and should be a focus for future research. In the early 2000s Dortch (2002:38) conducted systematic diving surveys in the Dampier Archipelago to identify submerged petroglyphs and other archaeological features. Seven sites at a depth range of 10–20 m were targeted during these surveys yet no archaeological materials were identified. Coroneos et al. (2007 in Nutley 2014:266) investigated submerged rock shelters at South West Arm at Port Hacking in NSW and concluded that it was ‘highly probable’ that they were utilised by past Aboriginal communities, however they did not identify any supporting archaeological evidence. Though none of these projects were able to confirm the preservation of archaeological materials in a marine context, elements of their survey methodologies would all be incorporated in the DHSC project.

3 Method

To achieve the aims of this study, a four-stage methodology was employed, drawing on the methodology developed by the DHSC for the identification of submerged archaeological landscapes. These stages are:

1. Analyse aerial imagery to identify landforms that correlate with the DHSC landscape models.
2. Conduct targeted pedestrian surveys to identify and record relevant archaeological features.
3. Conduct drone missions to collect high-resolution aerial imagery of relevant landscape features.
4. Process and analyse aerial imagery.

3.1 Analysis of aerial imagery

The DHSC conducted extensive aerial surveys over Murujuga Sea Country in 2017 and 2018 to acquire high-resolution data to identify terrestrial and submerged landscape features. An HK36TTC-ECO Dimona motorglider with wing-mounted bathymetric and topographic LiDAR sensors and a Canon 5D Mk4 was deployed to collect this data in 2017 and 2018. This study utilised the RGB imagery collected with a Canon 5D Mk4 fitted with an EF 24 mm lens synchronised with a Q680i-S (Benjamin 2020:6). Orthomosaics were created with DxO Optics Professional with a pixel size of 15 cm (Hacker 2019:13). The orthomosaic covering the Cape Bruguieres Channel was assessed to identify landforms consistent with the DHSCs landscape modelling identified in Veth et al. (2019:11).

3.2 Pedestrian surveys

Due to the nature of working around a dive schedule in a marine context the ability to conduct pedestrian surveys was subject to time constraints dictated by the tides, weather and light. Where possible, coastal fringes were surveyed from the boat to identify archaeological features. The primary consideration of the survey was to be flexible and to be able to move quickly. As drop-off and pick-up points were also directed by coastal topography and tides there was usually little notice to disembark before heading into the field. For this reason, a minimal field-kit consisting of a notebook, a camera, a photographic scale and a Mavic 2 Pro with three batteries was all that was taken into the field. A handheld GPS unit was considered to collect spatial data in the field but as the camera had internal GPS, it was deemed redundant.

If a significant archaeological feature was identified it was photographed with a scale (where possible) and a description was noted. In instances where an archaeological feature could not be captured in a single image, multiple images were taken to attain full coverage. These images were processed during post-field analysis to create orthomosaics with Metashape. If several significant features were identified the landform was flagged for an aerial survey. Aerial imagery was collected to characterise landform, help visualise the distribution of archaeological features, better understand site formation processes (Veth et al. 2019:15) and attempt to identify further archaeological features during post-field analysis. As the purpose of the pedestrian surveys was to acquire data that would inform on the submerged landscapes, archaeological features that correlate with the DHSC's landscape modelling were targeted during the pedestrian surveys including quarry sites, artefact scatters, middens, standing stones, grinding patches and engravings (Veth et al. 2019:11). In the absence of absolute dating methods for the archaeological data encountered during this study, McDonald and Mulvaney's engraving chronologies have been used as a proxy to indicate broad time scales when Ngardangali were active in the study area. Due to the ubiquity of engraving sites in Murujuga Sea Country, engravings of terrestrial and marine faunal species were targeted, as they are representative of the transition in engraving depictions relating to marine transgression as purported by McDonald (2015:128) and Mulvaney (2015:290) (Figure 3.1). Engraving sites along coastal margins were also targeted. A secondary aim of the surveys was to identify potential locations of ephemeral water sources.

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Figure 3.1 Murujuga art phases, Source McDonald 2015:129, (images from McDonald and Veth 2006 and Mulvaney 2011 and 2013).

Six targeted pedestrian surveys were completed as part of this study (Figure 3.2). Two pedestrian surveys on North Gidley Island concentrated on landforms that were identified during the aerial imagery analysis (pedestrian survey 1 and 2). Two pedestrian surveys concentrated on intertidal archaeological features that were identified by Benjamin and O'Leary during the November 2018 field season (pedestrian survey 1 and 5). Two pedestrian surveys were prompted during boat surveys of the coastline near CBC, one on southwest Cape Bruguieres Island and one on Collier Rocks (pedestrian survey 4 and 6).

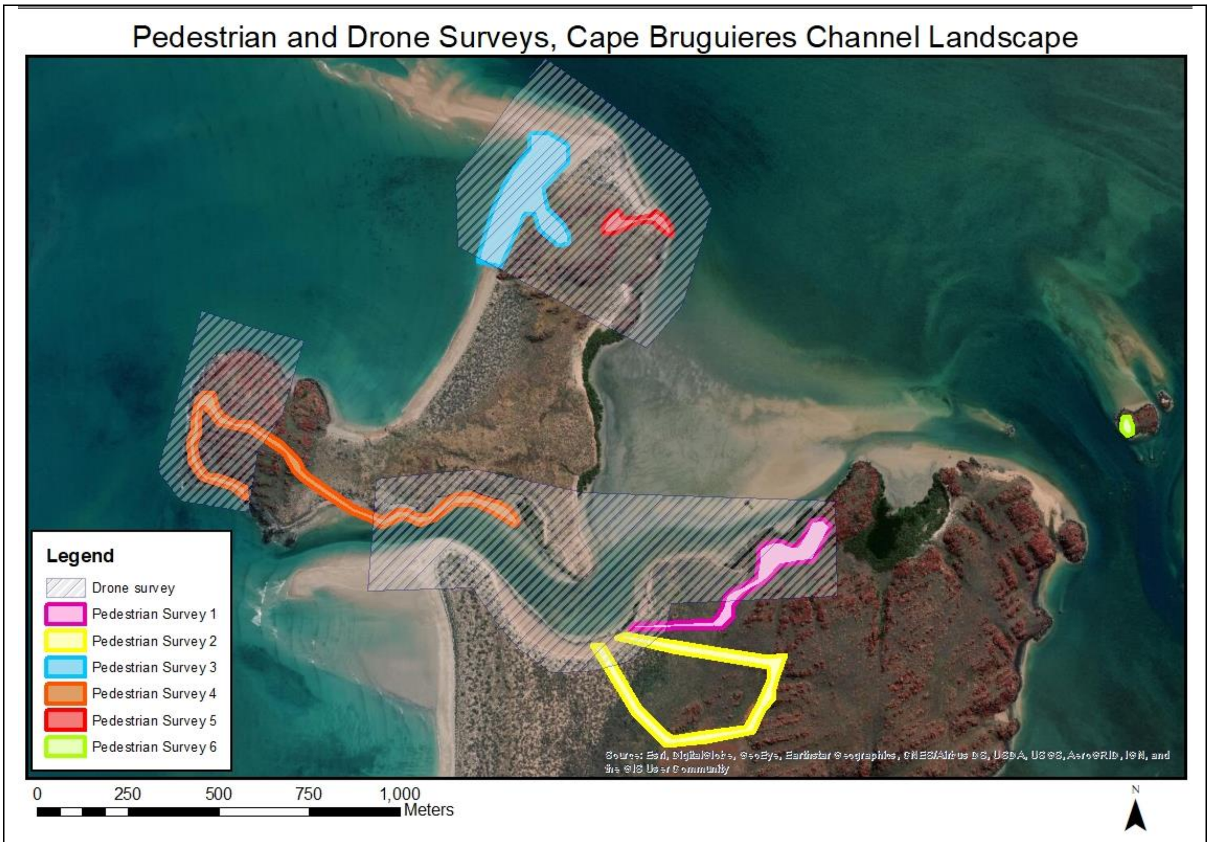

Figure 3.2 Pedestrian and drone surveys, Cape Bruguieres Island and North Gidley Island.

3.3 Drone missions

Two drones were used for the collection of aerial imagery in the field. The DJI Mavic 2 Pro (M2P) and the DJI Phantom 4 Pro (P4P) (Figure 3.3). The M2P was utilised for drone missions programmed during pedestrian surveys while the P4P was utilised for planned aerial surveys.

3.3.1 Mavic 2 Pro

Aerial imagery was collected during pedestrian surveys with a M2P. This drone was selected for its compact pack-down size, high quality one-inch 20Mp Hasselblad sensor, extended flight time and reliability. The entire M2P flymore kit can fit inside a backpack and weighs less than 2kg. The only limitation of the M2P, when compared to the P4P, is its rolling shutter. This can create distortion on the edge of images, which can reduce the quality of photomosaics and models when processing data. Increasing front overlap while programming flights can minimise the impact of this issue. The P4P was considered for use in the field as it has a mechanical shutter, which would eliminate this issue. However, the P4P is much bulkier and when stored in a road case weighs in excess of 15 kg. This is cumbersome and dangerous to transport by foot over rough terrain. The M2P was utilised for two drone missions as part of this study (mission 2 and 3).

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Figure 3.3 Mavic 2 Pro (left) and Phantom 4 Pro (right).

3.3.2 Phantom 4 Pro

Planned drone surveys were conducted with a P4P. The P4P has a 20Mp sensor with a mechanical shutter, suitable for mapping applications. It weighs approximately 500 gm more than the M2P, improving its flight stability.

3.3.3 Flight programming

Drone Deploy was used to program all drone missions in the field. Drone Deploy was selected for its user-friendly interface, full control over all mission parameters and its ability for offline use. The majority of these features are available with a free account. A paid account enables the processing of data and creation of orthomosaics, 3D models and digital elevation models (DEM) with an internet connection. This feature was not utilised as part of this study. This application was equally useful for planned and unplanned missions. Drone missions can be pre-programmed ahead of time and saved to minimise deployment times while in the field. The programs interface is user-friendly also enabling rapid programming for unplanned missions in the field. The highest resolution data was collected subject to three constraining factors: the area to be surveyed, the most appropriate altitude to fly the mission and the time available to complete the mission (generally subject to battery life).

Orthomosaics were created with Agisoft Metashape 1.6.2. All orthomosaics were completed with the highest possible settings. Workflows followed standard procedure: align photos, build dense cloud, build mesh, decimate mesh, build texture, build DEM and build orthomosaic. Orthomosaics and DEMs were exported to Arcmap 10.8 for analysis and map generation. The orthomosaics were cross-referenced with photos of archaeological features in the field. The locations of archaeological features were plotted in Arcmap using the location data from photos. Features that could be identified from the aerial imagery were marked. The orthomosaics were also analysed to search for archaeological features that weren't identified in the field.

3.3.4 Drone Mission 1—Cape Bruguieres Channel

The purpose of this survey was to collect imagery of the CBC during the lowest astronomical tide of the year to determine if the identified lithic assemblage was subtidal (Figure 3.4). The P4P was used for this mission to acquire the highest quality data possible.

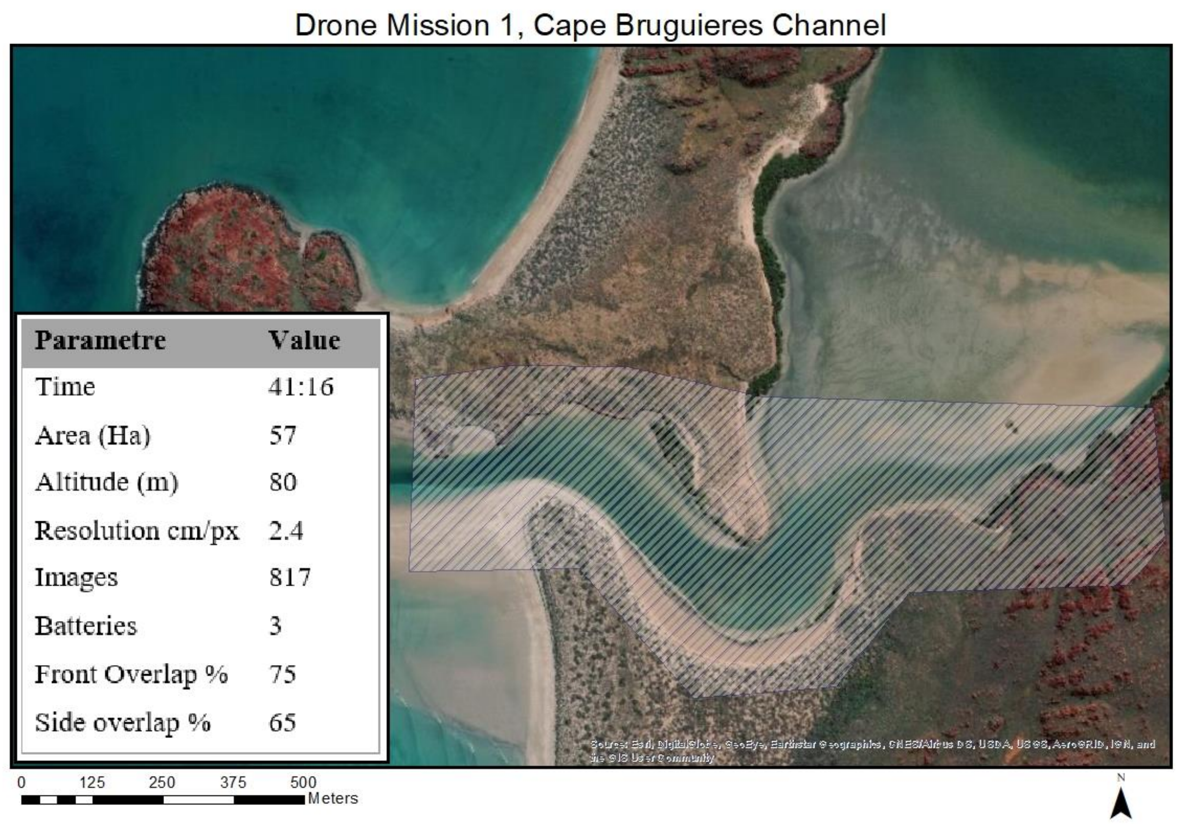


Figure 3.4 Drone mission 1, Cape Bruguieres Channel.

3.3.5 Drone Mission 2—Northwest Cape Bruguieres Island

A drone mission was programmed in the field to incorporate the intertidal artefact scatter and the western slope and summit of the granophyre outcrop on northwest Cape Bruguieres Island (Figure 3.5). The M2P was utilised for this mission as it was conducted during a pedestrian survey.

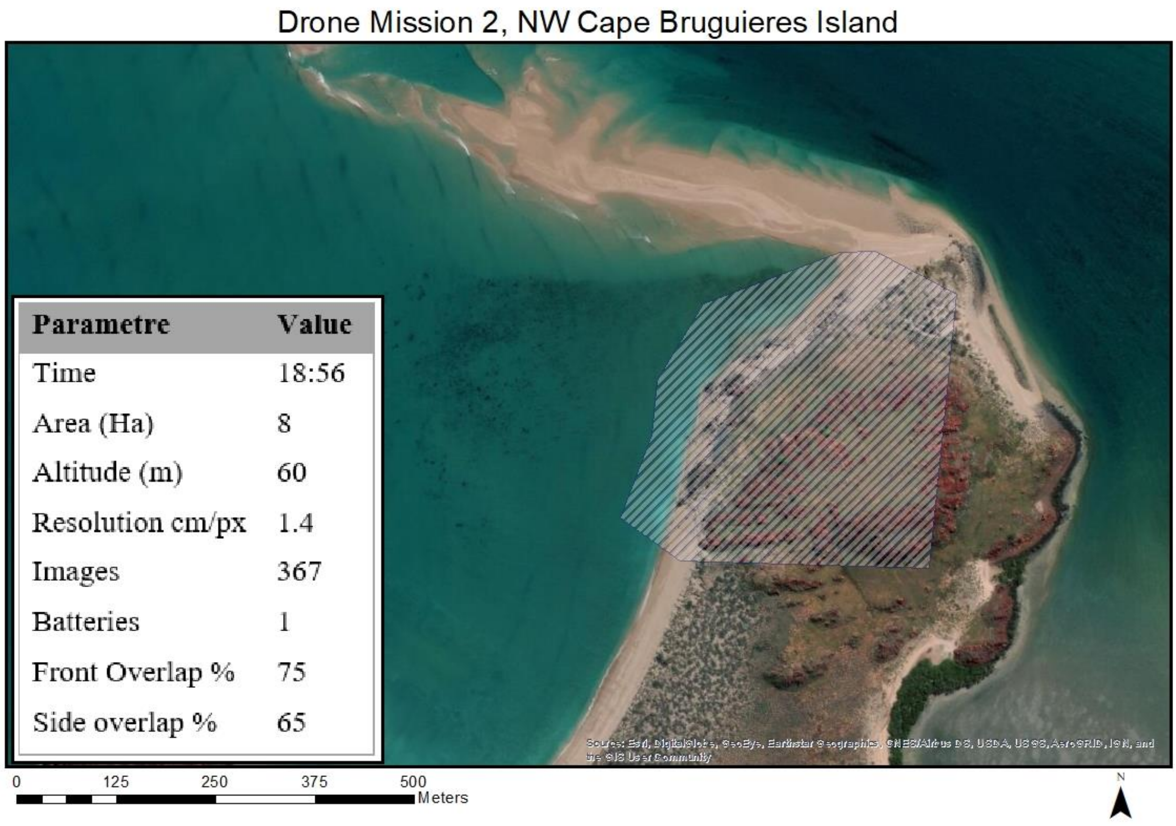


Figure 3.5 Drone mission 2, northwest Cape Bruguieres Island.

3.3.6 Drone Mission 3—Southwest Bruguieres Island

A drone mission was programmed to incorporate the majority of the outcropping granophyre as archaeological features were identified throughout this area (Figure 3.6). The M2P was utilised for this mission as it was conducted during a pedestrian survey.

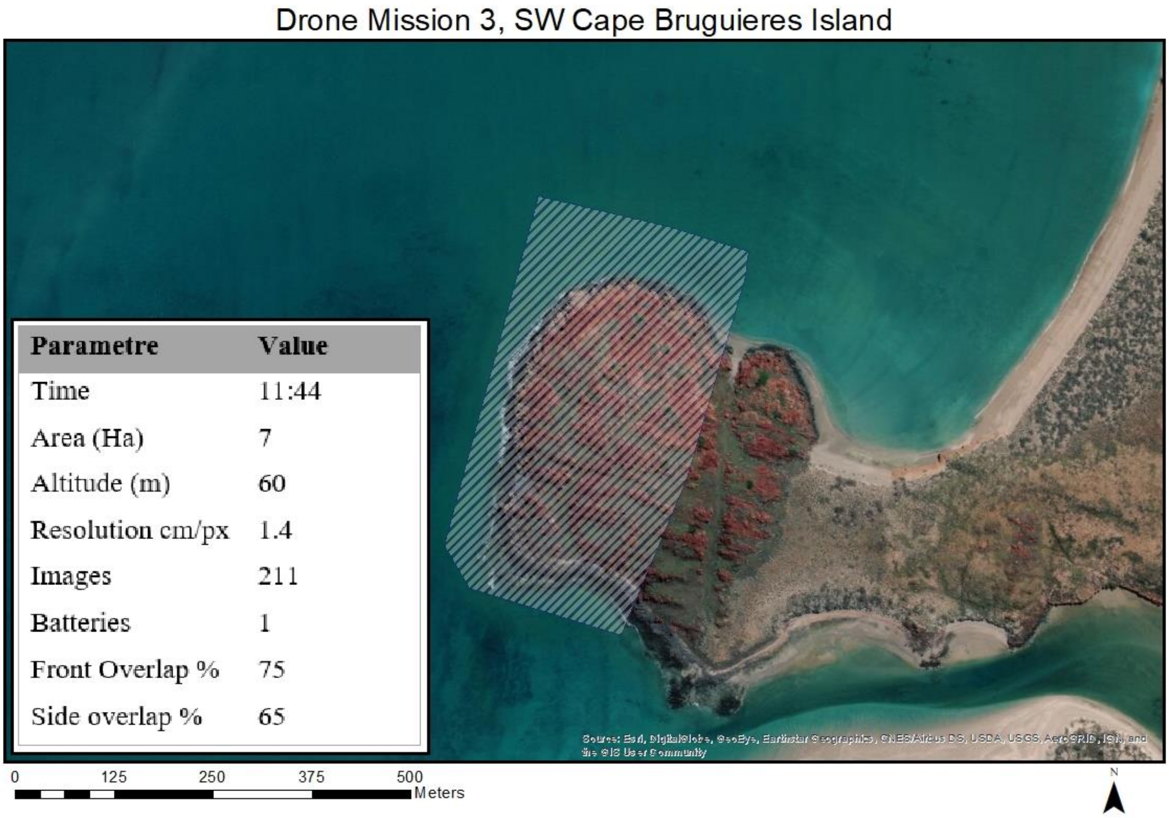
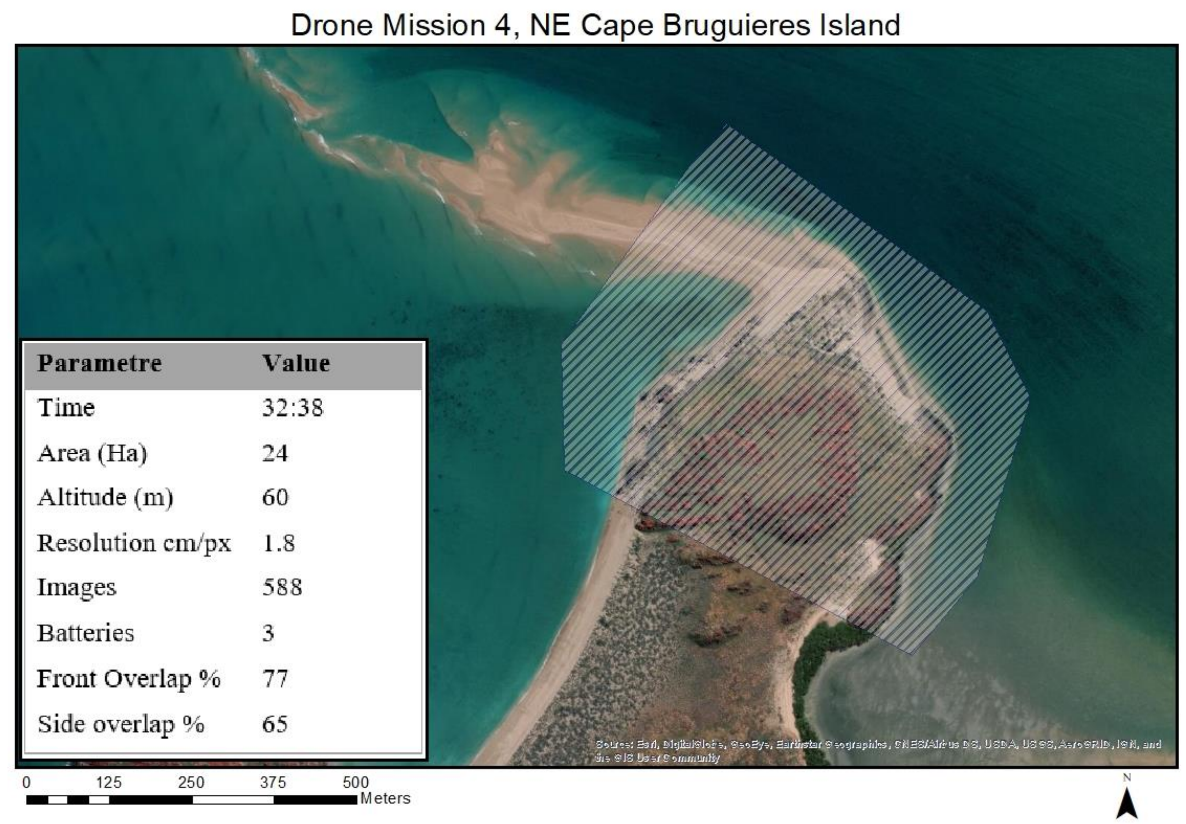


Figure 3.6 Drone mission 3, southwest Cape Bruguieres Island.

3.3.7 Drone Mission 4—North Bruguieres Island

A drone mission was pre-programmed to collect data over a larger area of northwest Cape Bruguieres Island with the P4P. Following identification of an intertidal quarry site during a pedestrian survey, the mission was re-programmed in the field to include the northeast of the island as well (Figure 3.7).



Parametre	Value
Time	32:38
Area (Ha)	24
Altitude (m)	60
Resolution cm/px	1.8
Images	588
Batteries	3
Front Overlap %	77
Side overlap %	65

Figure 3.7 Drone mission 4, North Cape Bruguieres Island.

3.4 Processing of aerial imagery

All data collected during the drone missions were processed with Agisoft Metashape 1.6.2. Workflows followed standard procedure: align photos, build dense cloud, build mesh, decimate mesh, build texture, build DEM and build orthomosaic. The highest accuracy settings were utilised to create point clouds and were aggressively filtered. Orthomosaics were completed with the highest possible settings. Orthomosaics and DEMs were exported to Arcmap 10.8 for analysis and map generation. The orthomosaics were cross-referenced with photos of archaeological features in the field. The locations of archaeological features were correlated with findings from the pedestrian surveys utilising the location data from photos. Features that could be identified from the aerial imagery were marked. The orthomosaics were also analysed to search for archaeological features that were not identified in the field.

4 Results

4.1 North Gidley Island

Two pedestrian surveys were conducted on North Gidley Island with the intention of investigating a potential ephemeral waterway and the contiguous granophyre rock outcrops. The ephemeral waterway was located approximately halfway between a clay pan to the south and the CBC to the north (Figure 4.1). It was confirmed as a drainage channel however no water was present. A heavily repatinated engraving of a figure with a headdress and a boomerang in each hand was identified on a granophyre outcrop adjacent to the waterway. An image is not included as the reproduction of anthropomorphic figures is restricted (Murujuga Cultural Management Plan 2016:252–256).

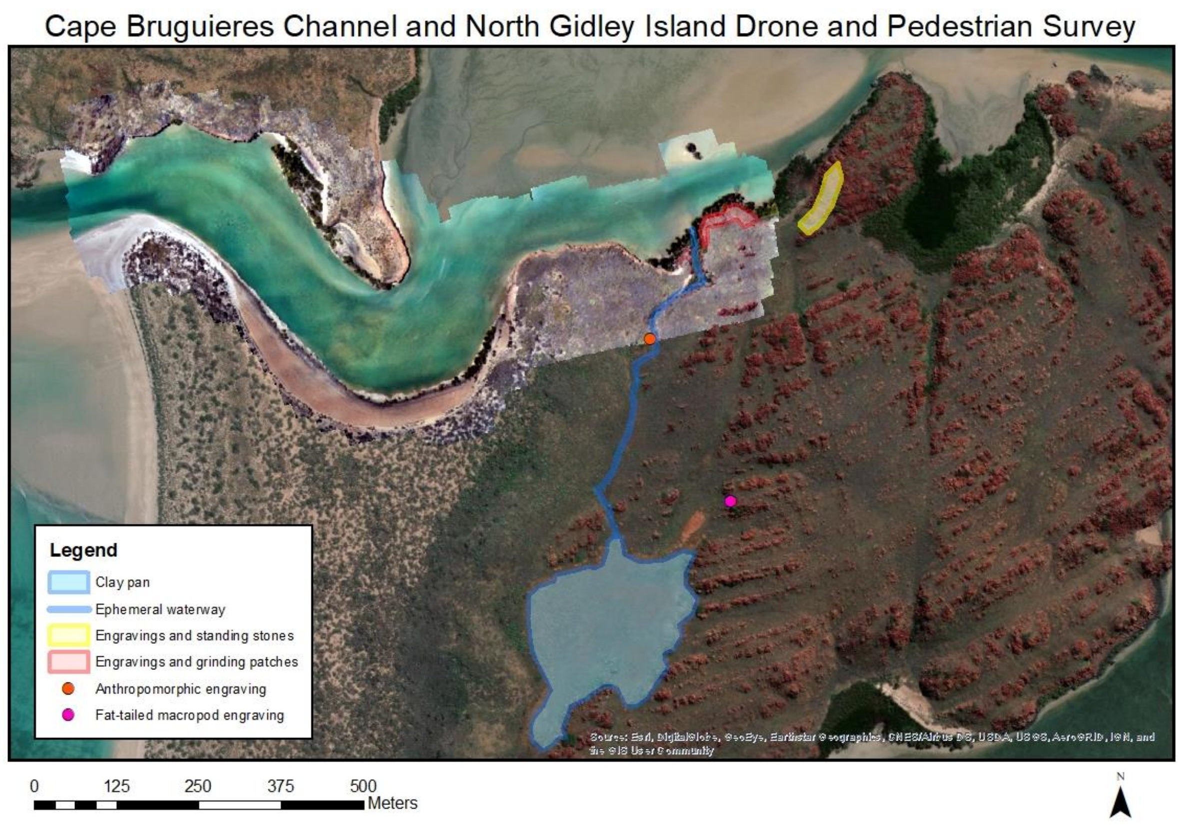


Figure 4.1 CBC and North Gidley Island drone and pedestrian survey.

The last 80 m of the ephemeral waterway contains mangroves bordered by outcropping granophyre. Engravings are present depicting zoomorphic, anthropomorphic, spooromorphic and geometric figures. Heavily worn grinding patches were identified on horizontal granophyre surfaces, some in association with engravings. Further engraving panels were recorded however they cannot be reproduced due to their proximity to anthropomorphic figures. This would be classified as a medium assemblage (6–20 motifs) and a single site as all archaeological features identified were separated by distances less than 25 m (McDonald 2015:7). This would likely move into a higher category if saturation recording was completed at this site.

A large granophyre slope, approximately 35 m in height is located 100 m east of the mouth of the ephemeral waterway. Engravings are present across the rocky slope. Four standing stones were identified along this rocky slope. The largest standing stone, approximately 100 cm in height, is located at the top of the slope. Another standing stone, located in a small infilled stone depression, is in close proximity to a stone exhibiting a small semi-circular bruised engraving.

4.2 Northwest Cape Bruguieres Island

During the November 2018 field season, Benjamin and O'Leary identified an intertidal quarry site on northwest Cape Bruguieres Island. This site was relocated and subjected to further pedestrian survey during the September 2019 field season (Figure 4.2). Pedestrian surveys were conducted on a low, but rising tide. 32 artefacts were recorded in the intertidal zone. Workings from primary boulder material, small flakes and core stones as well as quarried bedrock were identified in the intertidal zone. The dynamic nature of the site's geomorphology resulting from mobile sands became apparent while in the field. A sand spit had formed off the northern tip of Cape Bruguieres Island that was not present in the reviewed satellite imagery. Highly degraded engravings were identified in close proximity to the intertidal zone. These appeared to be undergoing a destructive process due to their proximity to the ocean.

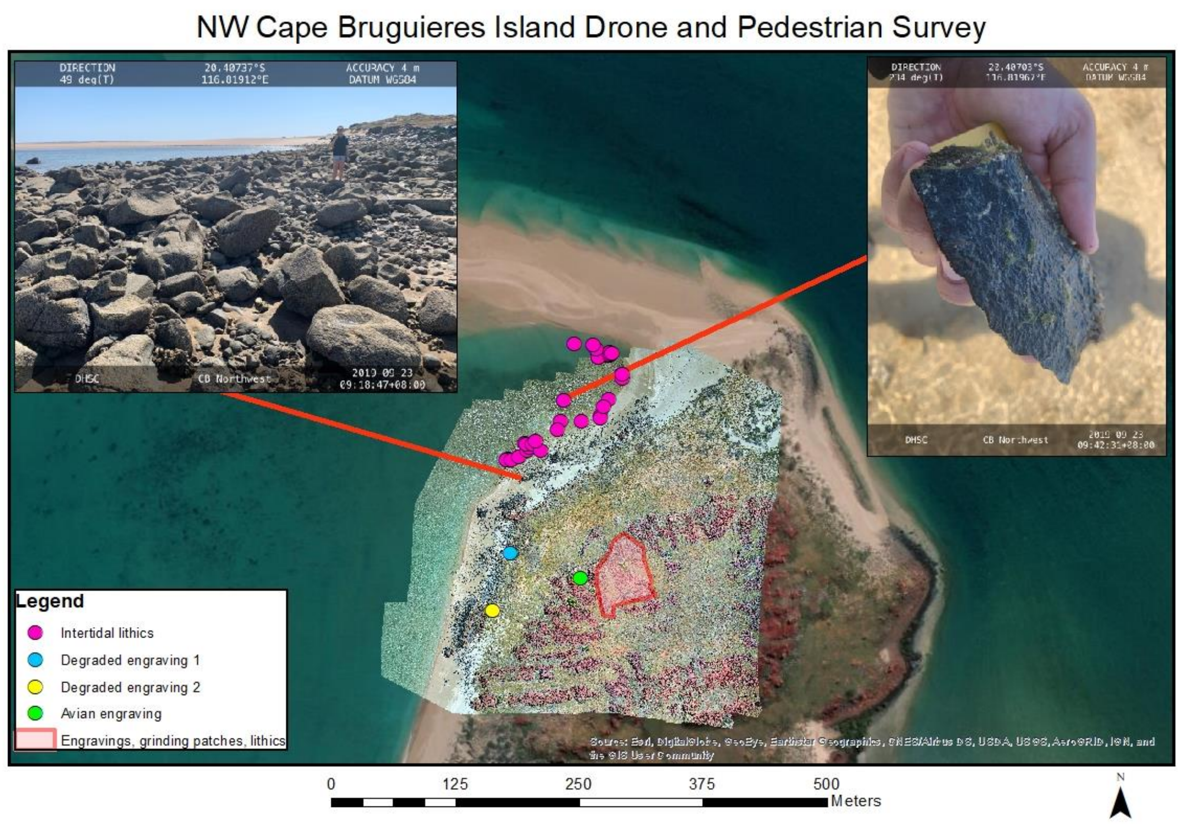


Figure 4.2 Northwest Cape Bruguieres Island drone and pedestrian survey.

High concentrations of worked granophyre are also present along the contiguous granophyre rock slopes. Flakes, single-platform cores and multi-platform cores were identified in this area. The flaked material does not exhibit any desert patina and is grey in colour. Sporadic engraved images are present throughout this area. There is extensive archaeological material on the high ground of the rock slopes. High-density engraving galleries, quarry sites, artefact scatters and grinding patches were all identified in this area.

4.3 Southwest Cape Bruguieres Island

A targeted survey of southwest Cape Bruguieres Island was conducted to investigate a potential quarrying site identified from the boat (Figure 4.3). Due to swell conditions it was not possible to land in close proximity to the quarrying site and it could not be relocated during the survey. Sporadic, isolated engravings are present along the intertidal zone. A cluster of grinding patches was identified in close proximity to three lenticular engravings.

Engraving density increases further upslope, away from the intertidal area. Turtles feature heavily in the engraving assemblage. Styles and production techniques are varied.

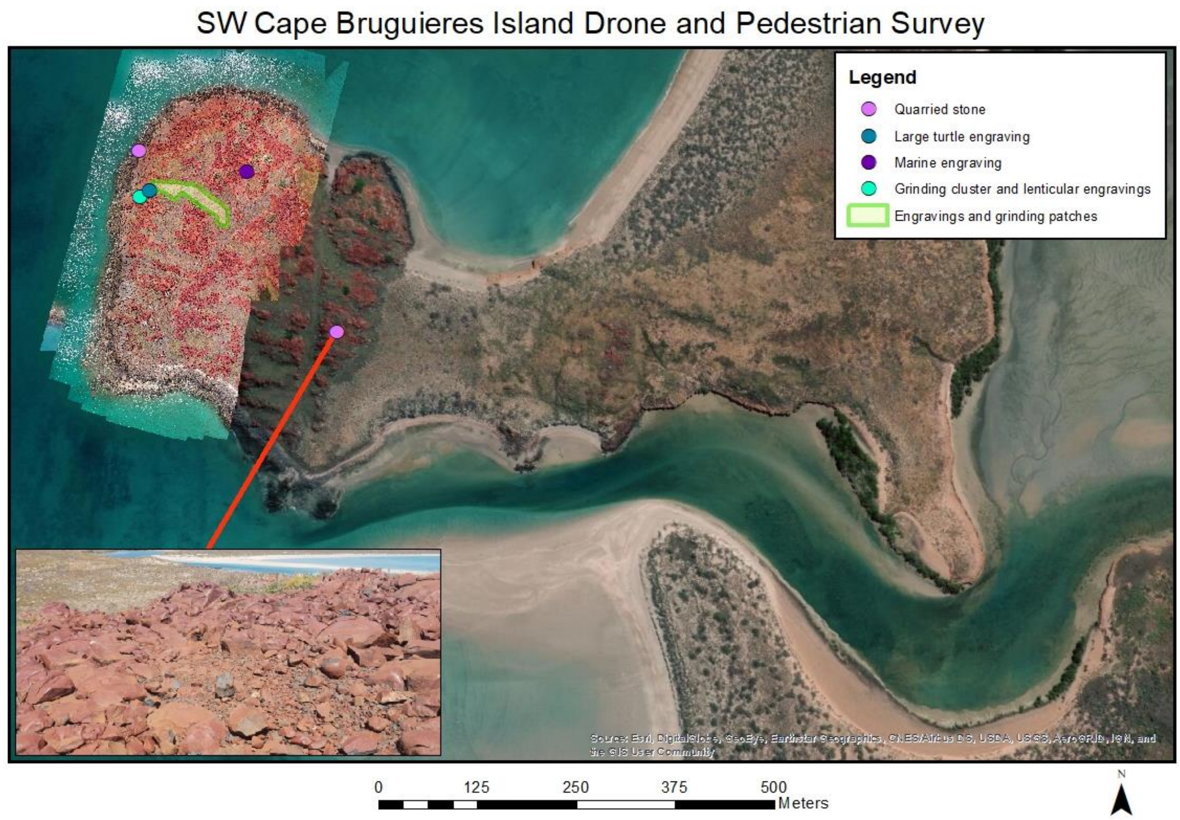


Figure 4.3 Southwest Cape Bruguieres Island drone and pedestrian survey.

Burrup patches were identified along the summit of the granophyre rock outcrop. Large areas appear to be infilled with small stones. Some of this material exhibited evidence of flaking however it is unclear if the concentrations of small stones resulted from natural or cultural processes. High densities of engravings were identified along the summit wherever outcropping granophyre was encountered. A concentration of flaked stone with evidence of quarrying was identified on the eastern periphery of the surveyed area.

4.4 Northeast Cape Bruguieres Island

During the November 2018 field season, Benjamin and O'Leary identified an extensive beach rock exposure on north east Cape Bruguieres Island (Figure 4.4). The initial interpretation is that this beach rock formed during the mid-Holocene highstand and will be an ideal site for acquiring minimum dates for the cemented artefactual material. The southern extremity of the beach rock and adjacent granophyre outcrop was subjected to a pedestrian survey.

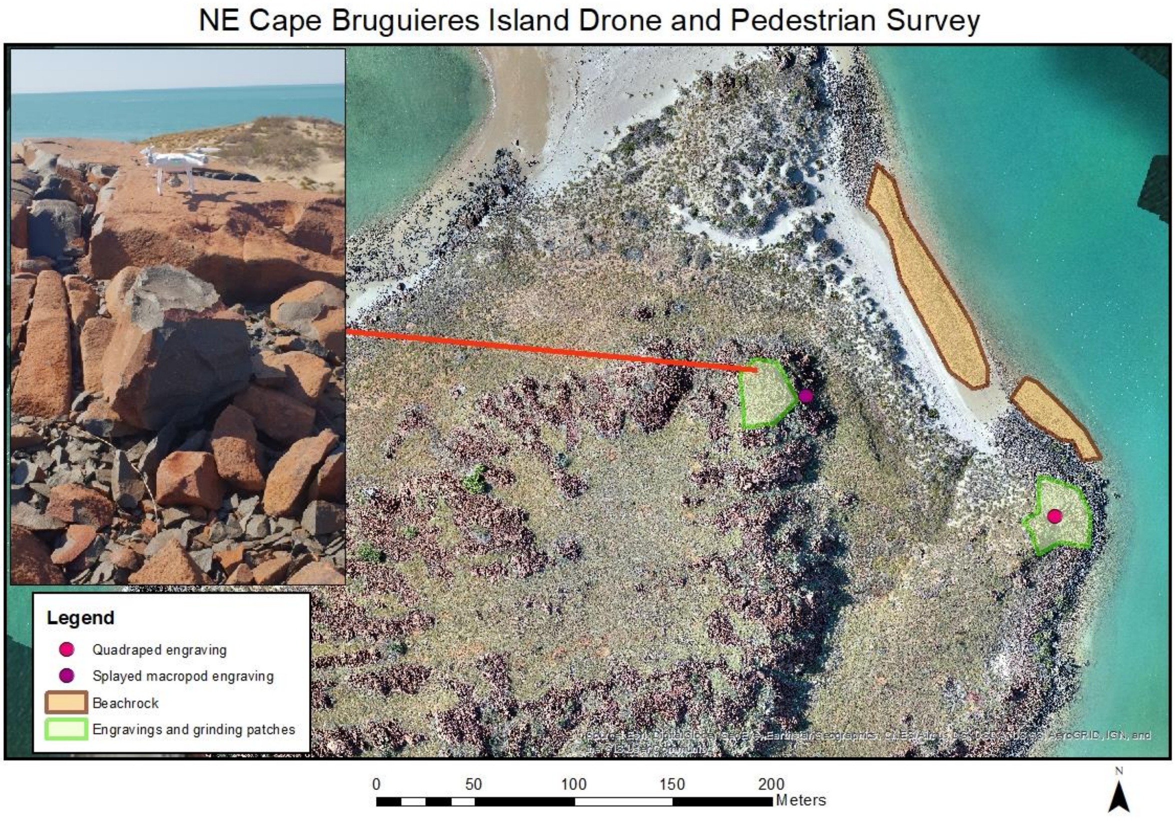


Figure 4.4 Northeast Cape Bruguieres Island drone and pedestrian survey.

Evidence of quarrying was identified in multiple locations along the granophyre outcrop in the intertidal zone. Much of the surveyed intertidal zone consists of aeolianite containing embedded granophyre flakes. Diagnostic features are clearly visible on these flakes. The worked stone presented varying rates of ware and smoothing, likely from wave action and contact with mobile sands. A broad range of granophyre artefacts are also present that are not embedded.

Evidence of quarrying continues along the rock outcrop, beyond the intertidal zone. Further up the slope engravings are present. Anthropomorphic, zoomorphic, and geometric figures were identified. One pecked engraving depicts a terrestrial quadruped which was interpreted as either a macropod or a thylacine. Grinding patches are present on this outcrop. Worked stone flakes are present in the interstices of angular boulders and open exposures. Degraded shell and lithic material are present in the sand upslope (west) of the rock outcrop. Restricted ground visibility due to thick spinifex hummocks made it difficult to determine if this area could be classified as a midden.

A large granophyre outcrop is located to the west of the beach rock, separated by low sand dunes. There is extensive archaeological material on the high ground of the rock slopes. High density engraving galleries, quarry sites, artefact scatters and grinding patches were all identified in this area.

4.5 Collier Rocks

A brief survey was conducted on Collier Rocks as an engraving was observed on a rock face while travelling to CBC. Due to its proximity to the study area and its unusual location, a brief survey was conducted on the western side of the outcrop. Collier Rocks is a small rock outcrop surrounded by water, approximately one hectare in size, located 800 m northeast of CBC (Figure 4.5). This location had not been identified for investigation as part of the landscape modelling.

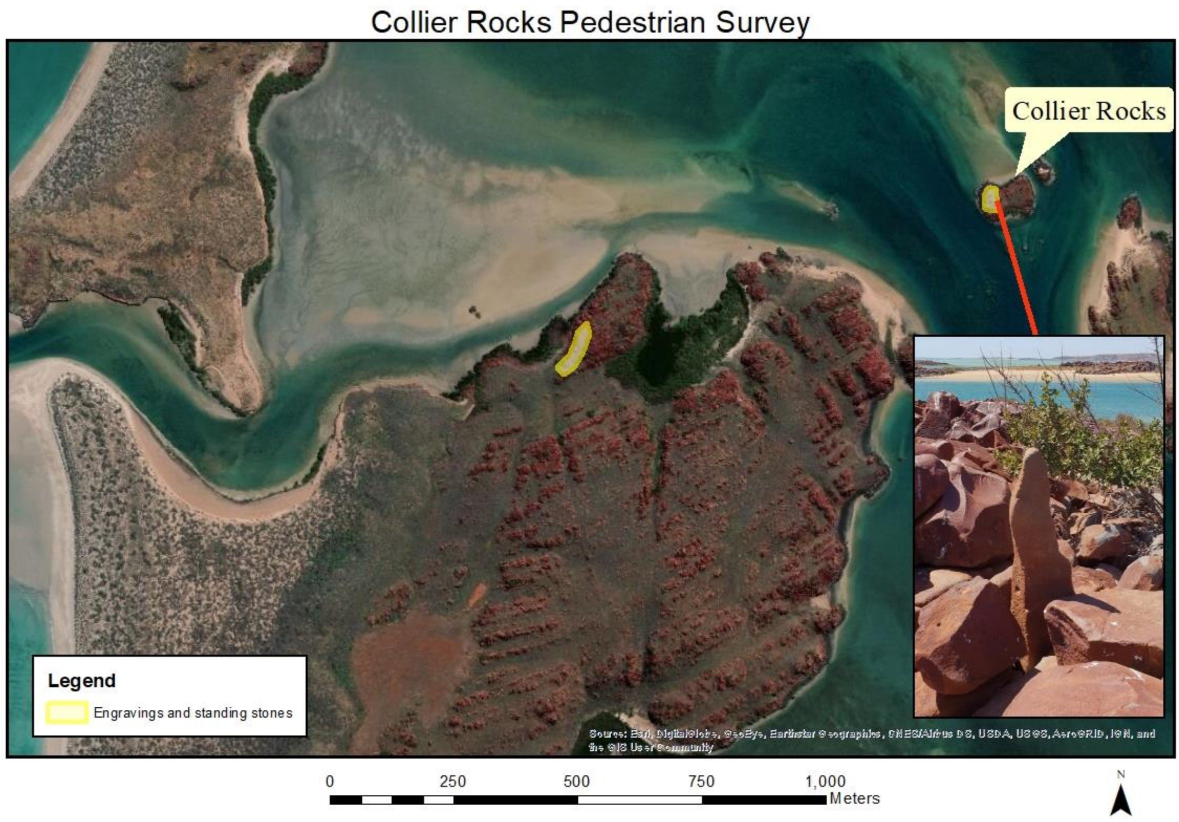


Figure 4.5 Collier Rocks pedestrian survey.

The surveyed area of Collier Rocks had a surprisingly high density of engravings. Anthropomorphic, zoomorphic and geometric figures were all identified at this site. Marine species featured heavily in the engravings. A standing stone was present at the summit of the rock outcrop. It is approximately one metre in height and is wedged between several large rocks. Engravings are present in the immediate vicinity of this standing stone. A Burrup patch was also identified at this site. Over 21 motifs were recorded on Collier Rocks making this a large assemblage (McDonald 2015:7).

4.6 Grinding patches

Evidence of grinding activities was observed at four surveyed locations (Figure 4.6). Multiple grinding patches were identified at southwest Cape Bruguieres Island, northwest Cape Bruguieres Island, northeast Cape Bruguieres Island and at the mouth of the ephemeral waterway on North Gidley Island.

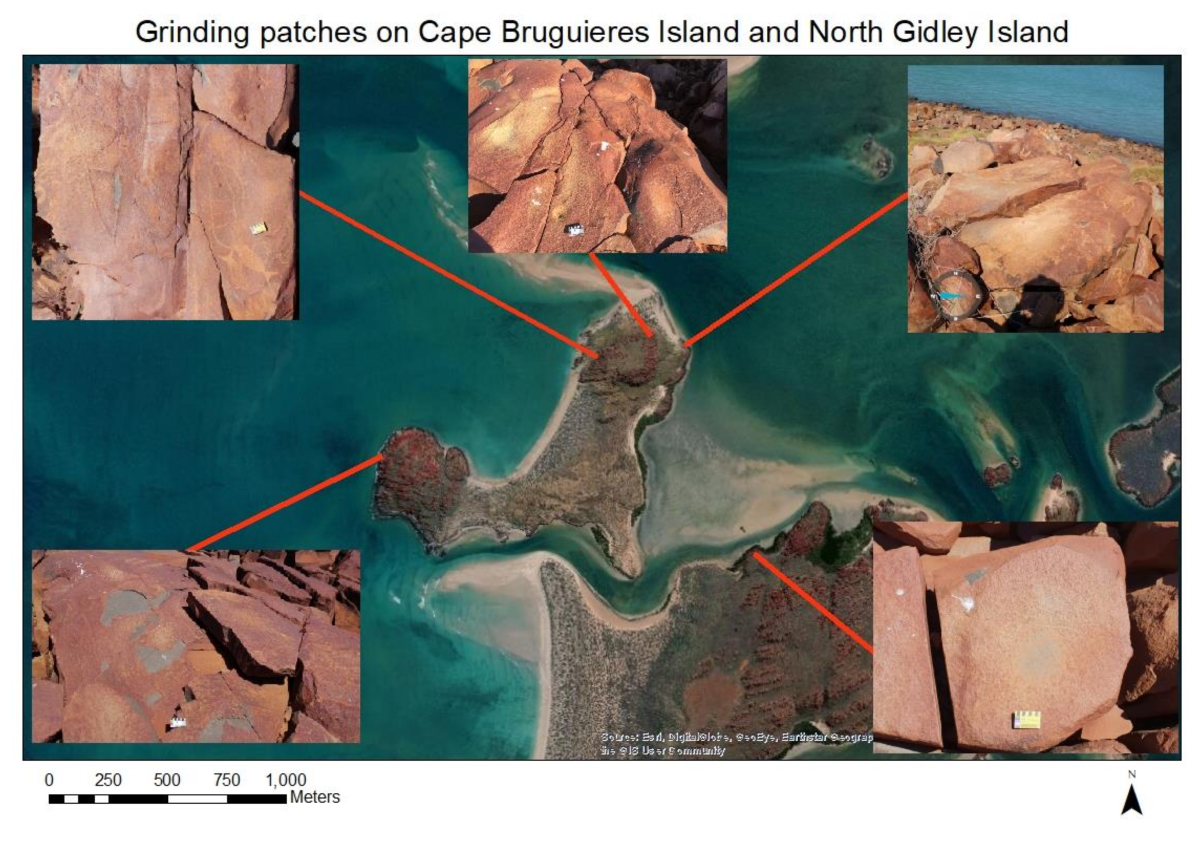


Figure 4.6 Grinding patch on Cape Bruguieres Island and North Gidley Island.

4.7 Quarrying

Quarried stone and associated artefact scatters were identified at three surveyed locations; northwest Cape Bruguieres Island, northeast Cape Bruguieres Island and southwest Cape Bruguieres Island (Figure 4.7).

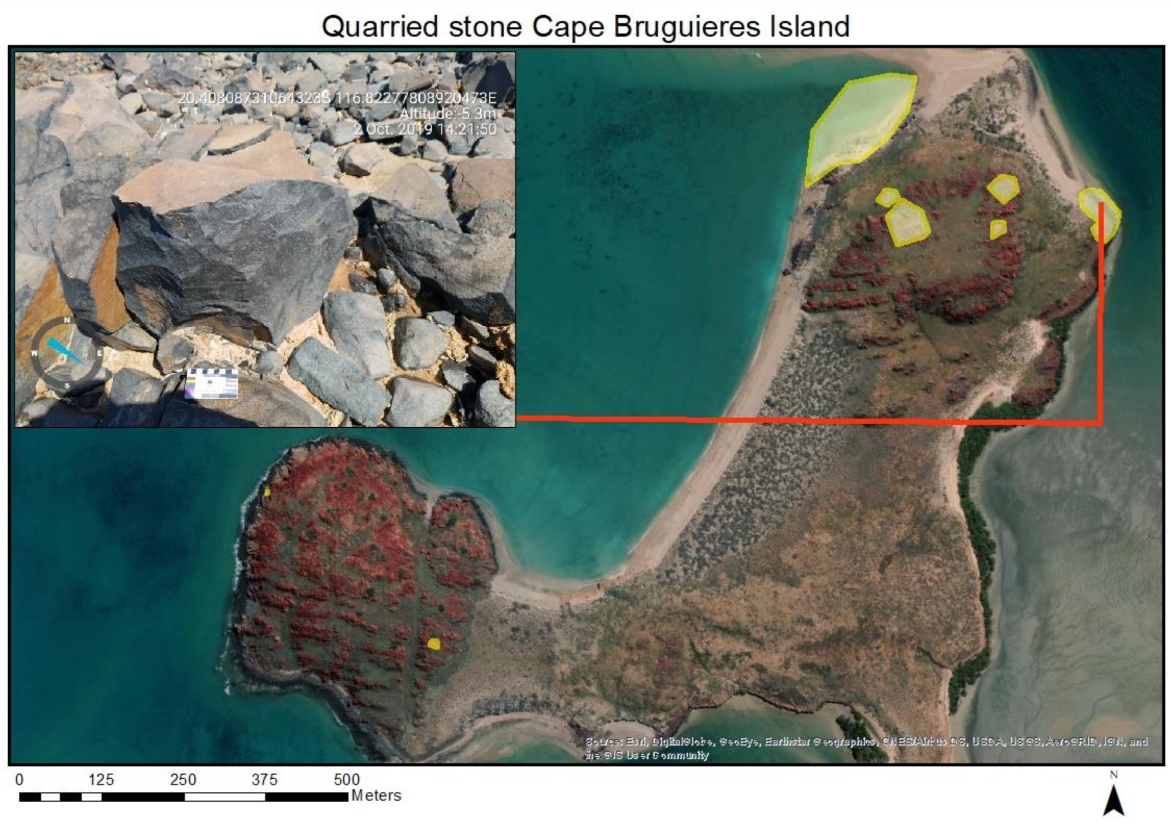


Figure 4.7 Quarried stone, Cape Bruguieres Island.

4.8 Engravings

4.8.1 Engravings of terrestrial species

Engravings of terrestrial species were encountered at three locations during the pedestrian surveys: North Gidley Island, northeast and northwest Cape Bruguieres Island (Figure 4.8).

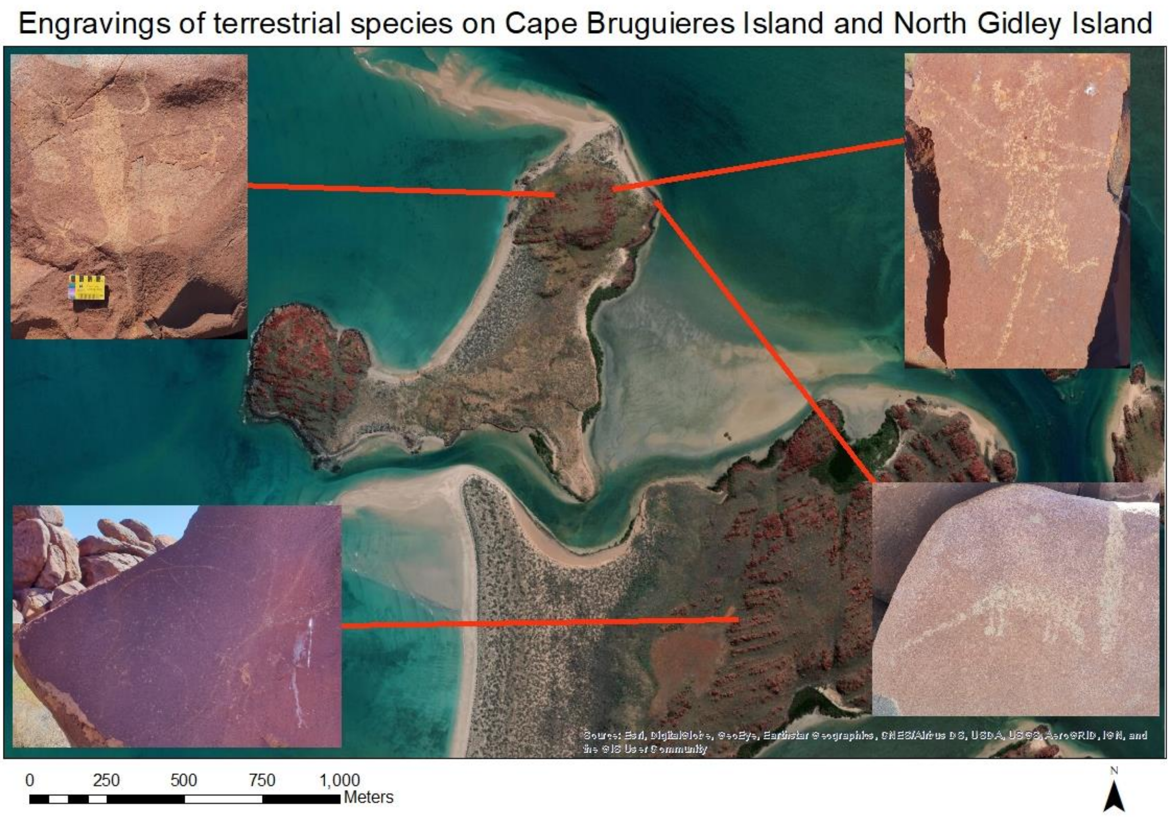


Figure 4.8 Engravings of terrestrial species.

4.8.2 Engravings of marine species

Marine species dominate the engraving galleries of North Gidley Island, Cape Bruguieres Island and Collier Rocks. Engravings of turtles were recorded at all surveyed coastal granophyre sites (Figure 4.9).

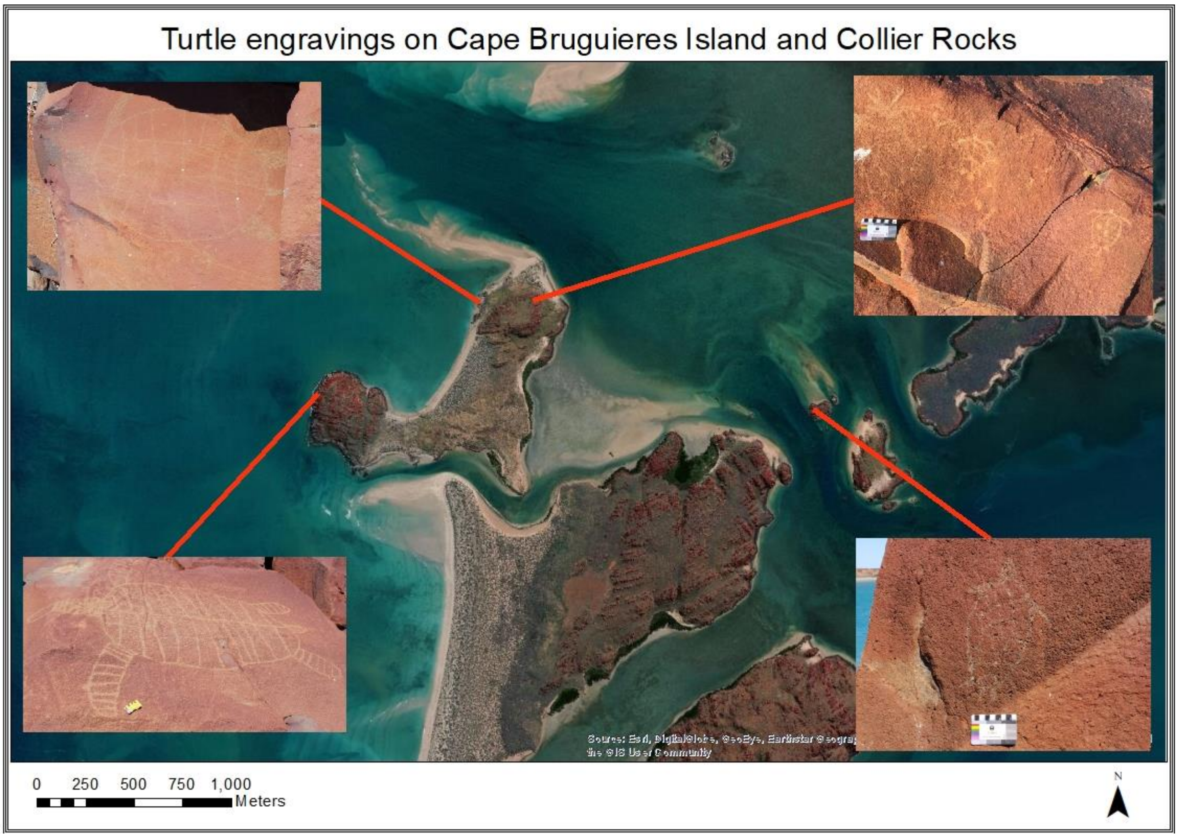


Figure 4.9 Turtle engravings, Cape Bruguieres Island and Collier Rocks.

Engravings of a triangular ‘approximation’ that recur consistently throughout Murujuga, particularly in coastal areas, have been interpreted as depicting dugong tails (Mulvaney 2015:127; Vinnicombe 2002:20). Several dugong tail engravings were recorded throughout the study area as well as an engraving of a complete dugong on southwest Cape Bruguieres Island (Figure 4.10).

Figure 4.10 Dugong and dugong tail engravings, Cape Bruguieres Island and Collier Rocks.

4.9 Drone surveys

All drone missions were completed successfully with no incidents in the field. The aerial imagery data sets enabled the production of high-resolution photomosaics, far exceeding the resolution of other available imagery. Initial analysis of the drone data revealed three important findings: archaeological features photographed in the field could be relocated in the aerial imagery; previously unidentified archaeological features could be identified in the drone imagery; and changes in landscape could be identified between different data sets.

4.9.1 Confirmed archaeological features

Several archaeological features identified in the field were visible in the photomosaics created from the drone data. These include a cluster of grinding patches identified on southwest Cape Bruguieres Island (Figure 4.11), a group of engravings associated with a grinding patch on northeast Cape Bruguieres Island and a quarry site on northeast Cape Bruguieres Island (Figure 4.13).

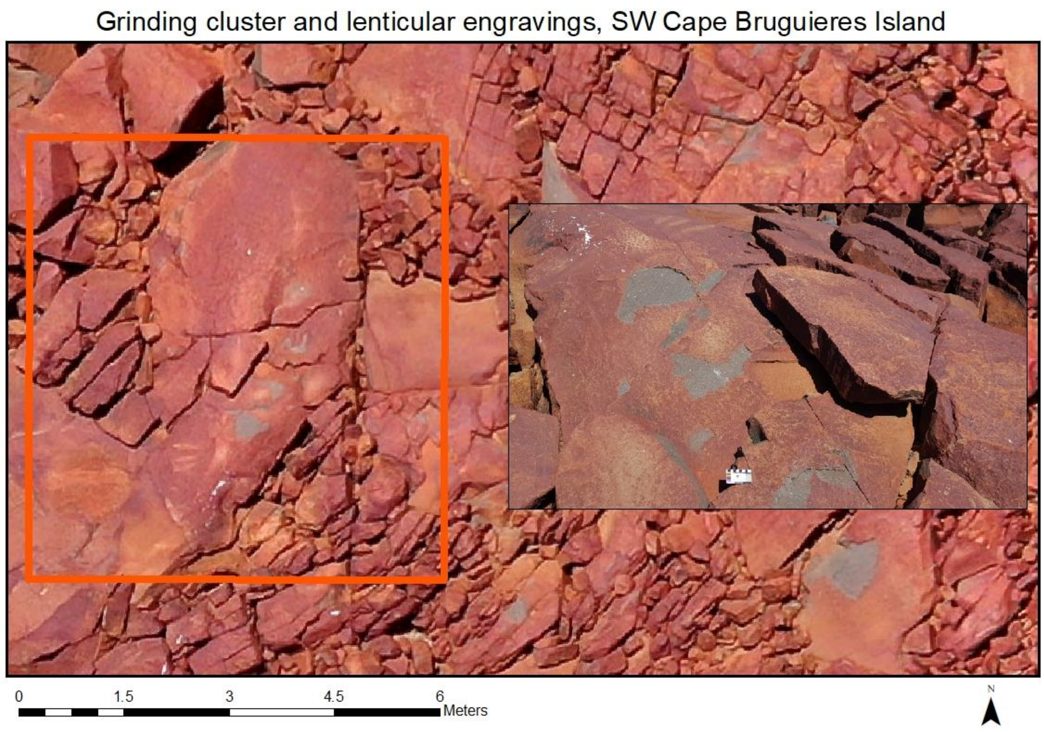


Figure 4.11 Grinding cluster and engravings, southwest Cape Bruguieres Island, inset view southwest.

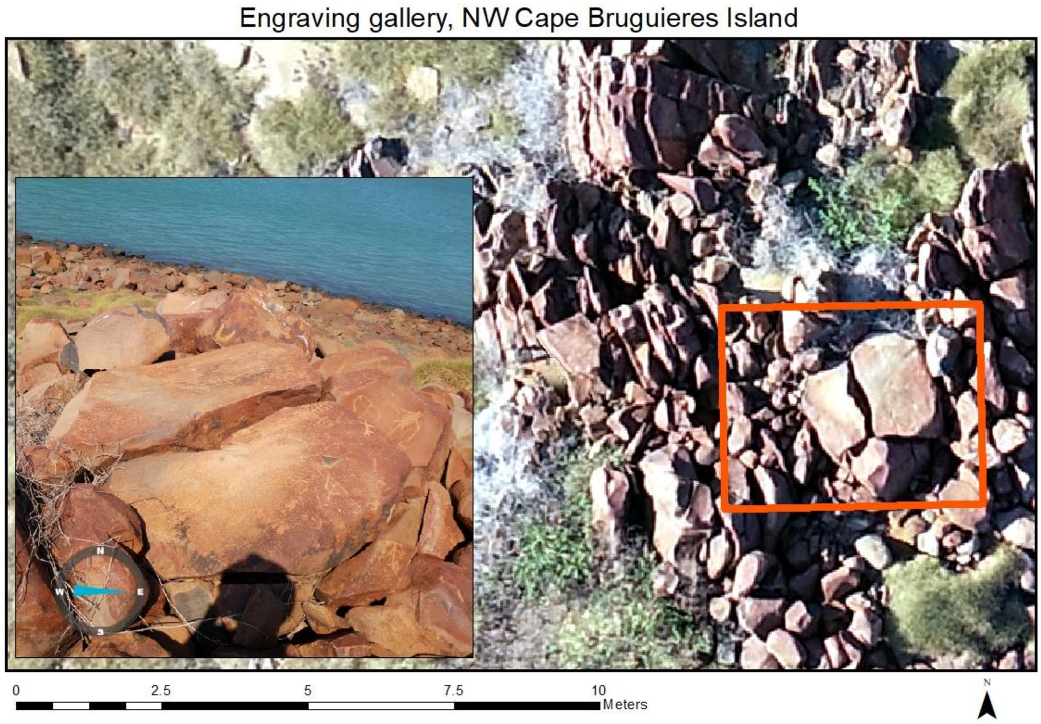


Figure 4.12 Engraving gallery, northeast Cape Bruguieres Island, inset view northeast.

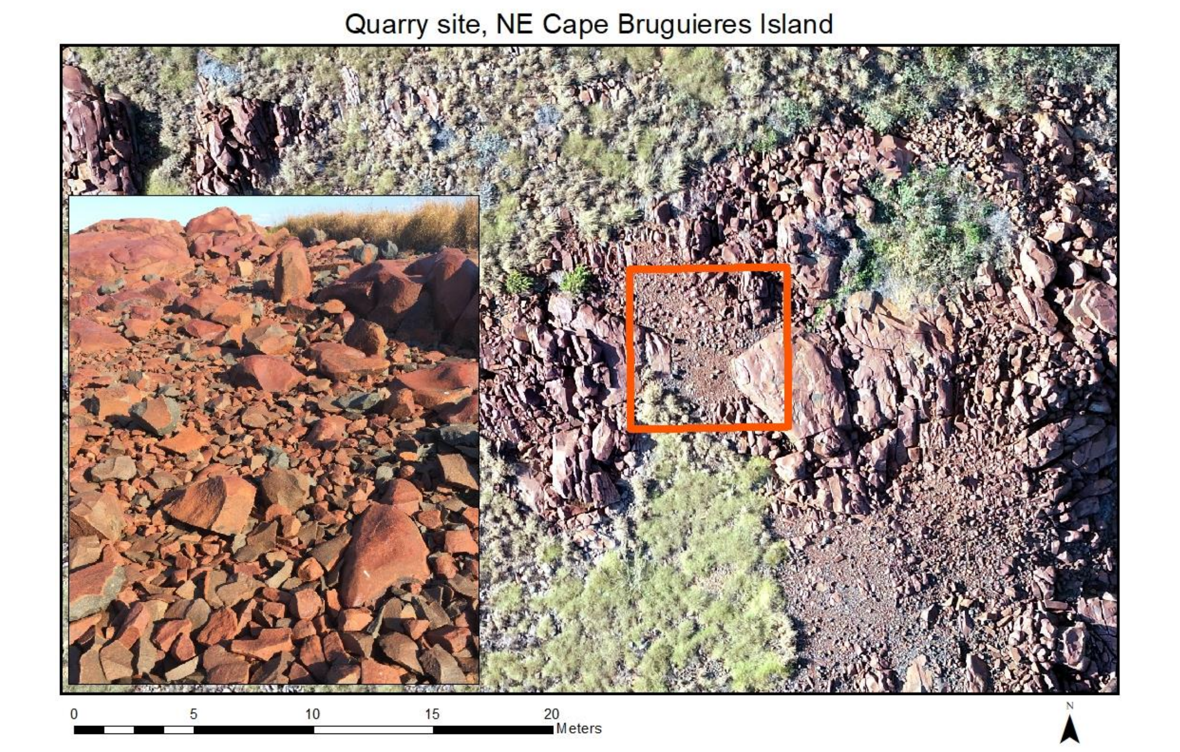


Figure 4.13 Quarry site, northeast Cape Bruguieres Island, inset view east.

A potential quarrying site that was identified and photographed from the boat was also relocated in the drone imagery (Figure 4.14). This quarrying site could not be located during a pedestrian survey. Unfortunately, the resolution of the photomosaic is not sufficient to determine if this is a quarry site.

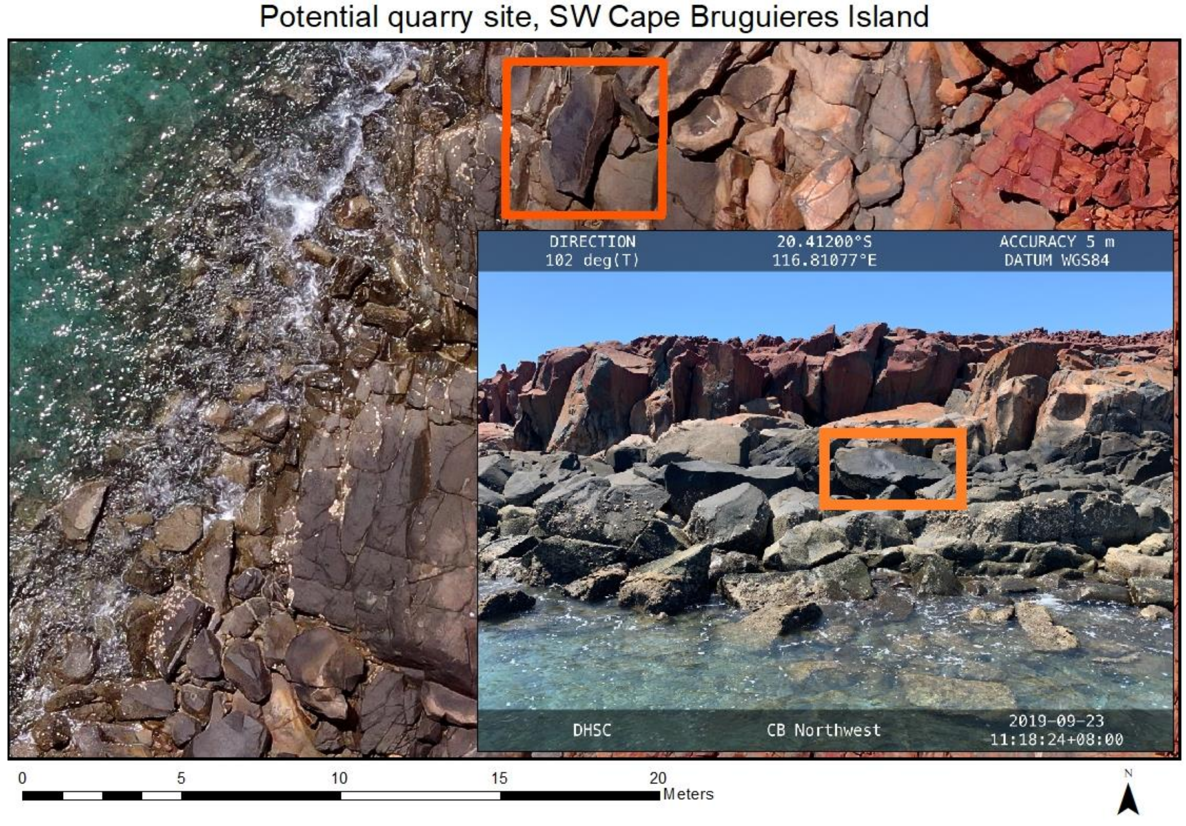


Figure 4.14 Potential quarry site, southwest Cape Bruguieres Island.

4.9.2 Remotely identified archaeological features

Three previously unidentified engravings were identified during the analysis of the photomosaics created with the drone imagery: an avian engraving on northwest Cape Bruguieres Island (Figure 4.15); and two marine engravings on southwest Cape Bruguieres Island (Figure 4.16).

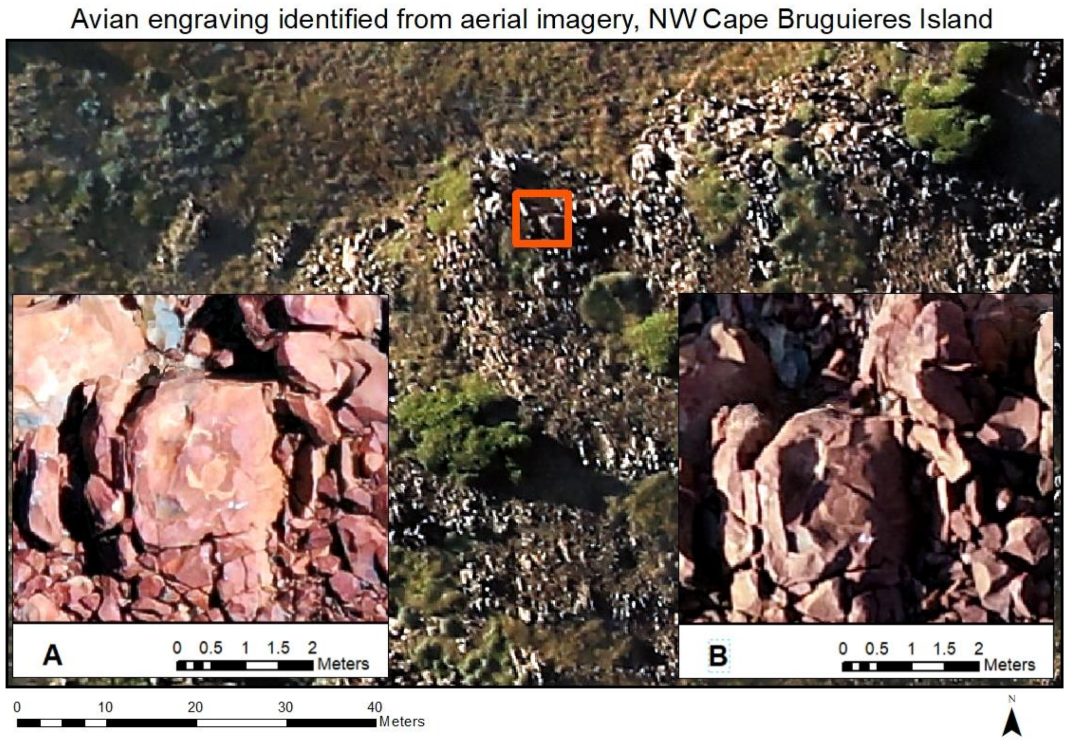


Figure 4.15 Avian engraving NW Cape Bruguieres Island, A) Mavic 2 Pro Drone mission 2, B) Phantom 4 Pro Drone mission 4, Base map (Hacker 2018).

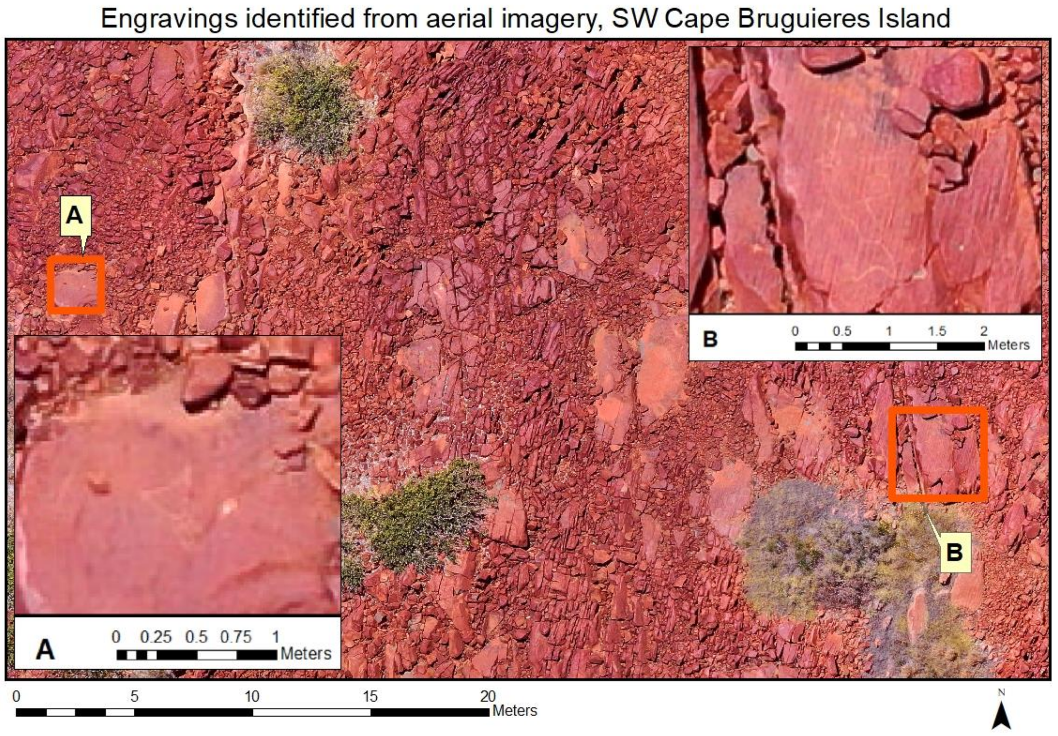


Figure 4.16 Marine engravings, SW Cape Bruguieres Island, Base map (Leach 2020).

4.9.3 Changing landforms

A comparative analysis of the drone imagery with satellite imagery and the RGB data collected during the motorglider survey in 2018 indicates the constantly changing morphology of Cape Bruguieres Island from mobile sands (Figure 4.17).

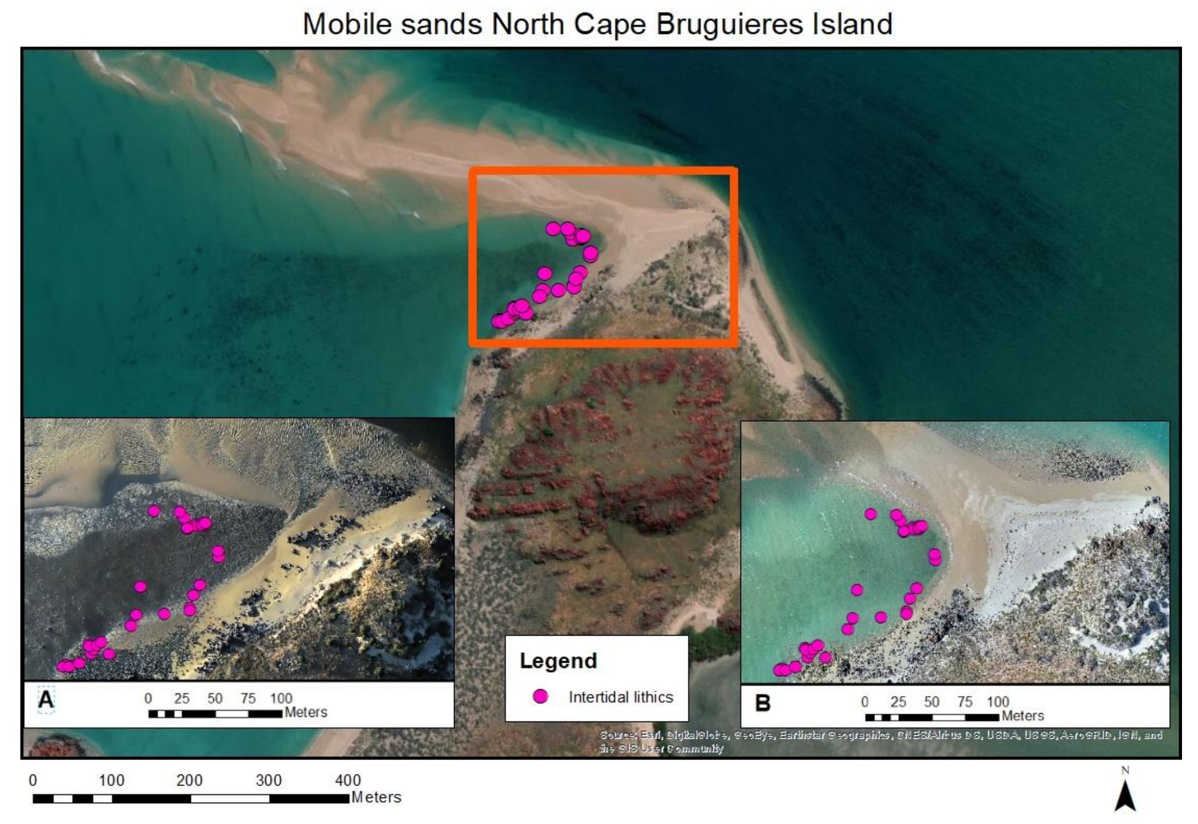


Figure 4.17 Mobile sands, north Cape Bruguieres Island. A) RGB data collected during motorglider survey 2018 (Hacker), B) RGB data collected during drone survey 2019 (Leach).

5 Discussion

5.1 Past subsistence resources

The pedestrian and drone surveys conducted as part of this study revealed that a range of subsistence resources were available to Ngardangali in the Cape Bruguieres Channel landscape. Semi-permanent water sources, grinding patches, quarry sites and engraved depictions of terrestrial and marine species all inform on how past Aboriginal communities interacted with this landscape.

5.1.1 Semi-permanent water sources

A recurring observation throughout archaeological studies conducted in Murujuga, is that archaeological features, particularly high-density engraving sites, are concentrated around water sources (Bednarik 2007:236; McDonald and Veth 2009:56; McDonald 2015:132; Mulvaney 2010:120; Mulvaney 2011b:22; Veth et al. 2019:2; Vinnicombe 1987a:2). Erlandson (2001:293) notes that ‘curiously’, fresh water is our most important aquatic resource, yet it is seldom discussed. Murujuga has an arid climate with no permanently flowing waterways, therefore rock holes and other ephemeral water sources such as gnamma holes were integral for the survival of Ngardangali in this landscape (Bindon 1997:174). An ephemeral waterway was identified on North Gidley Island that acts as a drainage channel for a large clay pan in the centre of North Gidley Island. Water would pool on the clay pan following heavy rain and overflow into this waterway (Figure 5.1). Engravings and grinding patches on granophyre rock outcrops contiguous with this waterway indicate that the Ngardangali were aware of the seasonal availability of water at this site and targeted it as a water source (Bednarik 2007:236; McDonald 2015:132; Vinnicombe 1987a:32; Vinnicombe 1987b:32). Analysis of the topographic and bathymetric LiDAR data indicate that this stream would have debouched into the Cape Bruguieres channel approximately 250m east of where the CBC assemblage was identified. The bathymetric LiDAR DEM shows that the channel has a higher elevation at the east of the channel than it does to the west (Figure 5.2).

Figure 5.1 Ephemeral waterway, North Gidley Island.

During the MLWS, when the tidal waters did not overtop the eastern extremity of the channel, it was observed that the water drained from east–west and that water pooled in depressions in the relict Pleistocene aeolianite. Though mobile sands are present in the channel, these are shallow and rest on the aeolianite floor and do not appear to impede or redirect this flow (Benjamin 2020:9). This suggests that prior to marine transgression, fresh water would have drained into CBC following heavy rains and that it would have pooled in locations proximal to the CBC assemblage. McDonald and Veth (2009:56) purport that artefact scatters are commonly found adjacent to ephemeral water sources. Further to this, the claypan was likely targeted following heavy rains as they provided a temporary water source, encouraged the growth of grass species and attracted game. This is supported by the presence of lithics on the clay pan and the engraving of a fat-tailed macropod on an adjacent rock outcrop (Anderson 1999:1621; Barber and Jackson 2011:34; Bindon1997:174).

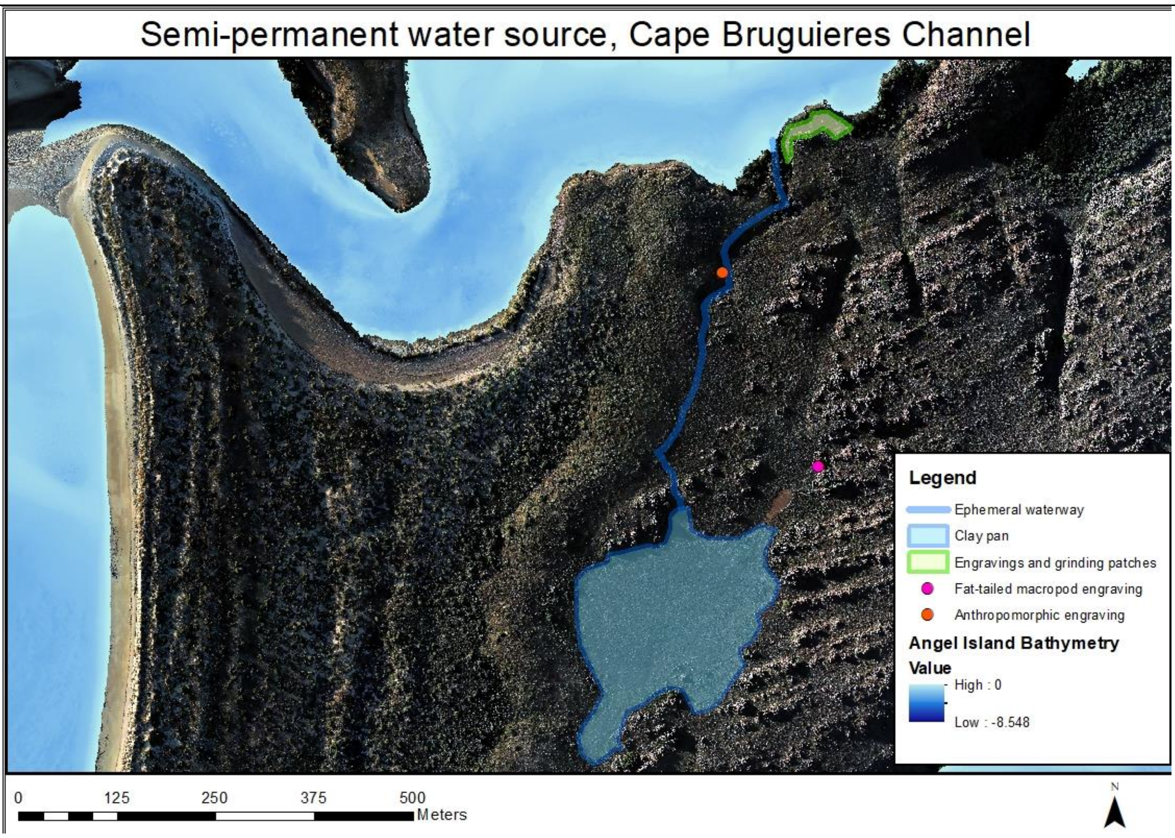


Figure 5.2 Ephemeral waterway, Cape Bruguieres Channel, RGB photomosaic and bathymetric LiDAR DEM (Hacker 2018).

5.1.2 Grinding patches

Grinding patches were identified on Cape Bruguieres Island and North Gidley island at all locations where granophyre exposures were investigated. The presence of grinding patches indicates that seed resources were exploited and processed in this environment by the Ngardangali. *Triodia epactia* and *Triodia wiseana*, have been identified on Cape Bruguieres Island and North Gidley Island. These species were targeted for their seeds (Murujuga Cultural Management Plan 2016:122–123). Several of these grinding patches are in close proximity to engravings, including at North Gidley Island and Cape Bruguieres Island (Figure 5.3). This suggests that the use of this environment was not solely restricted to resource exploitation and that significant meaning was associated with this landscape. Many of the grinding patches exhibit highly polished surfaces and heavy alteration of the stone surface. The presence of intensively used grinding patches at multiple locations suggests this was a productive landscape for seed resources and likely represents an extensive occupation period.

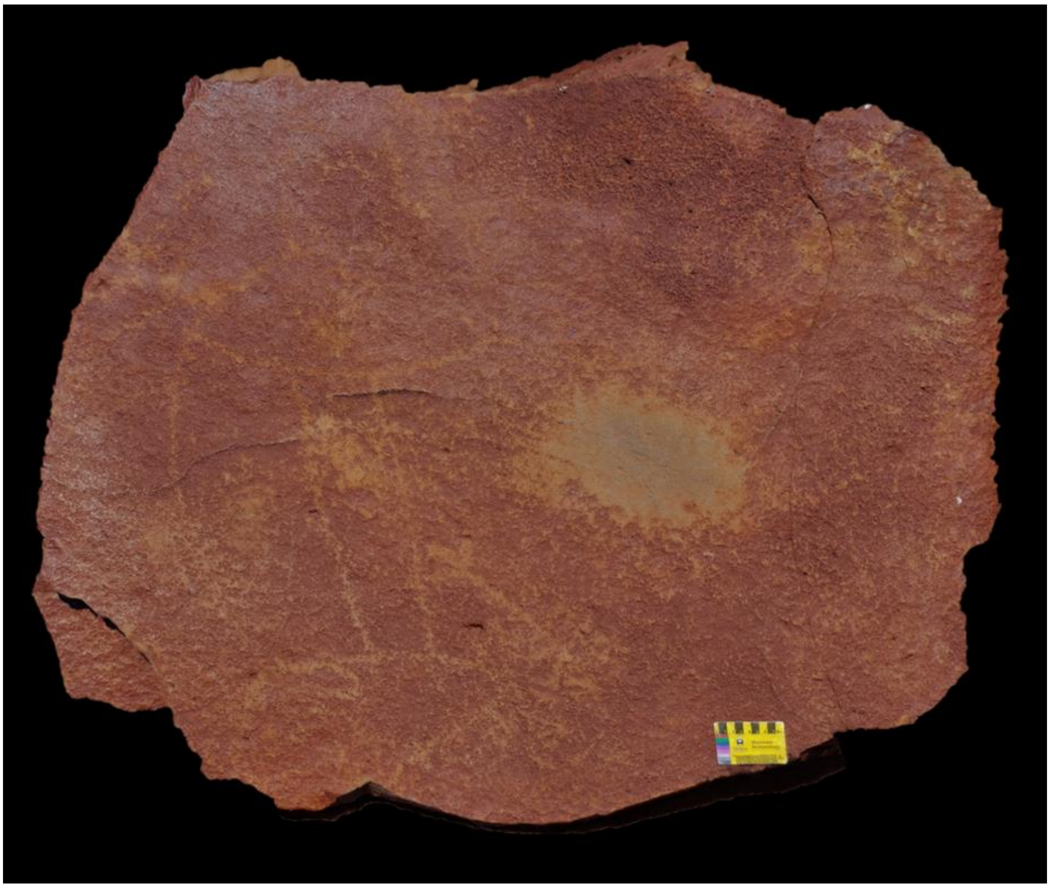


Figure 5.3 Grinding patch contiguous with turtle engraving, mouth of ephemeral waterway on North Gidley Island, orthomosaic created in Metashape, J. Leach.

5.1.3 Quarrying and artefact scatters

Evidence of quarrying is extensive on Cape Bruguieres Island indicating that the stone from this site was highly valued. The pedestrian survey conducted as part of this study recorded 32 examples of worked stone in the intertidal zone on NW Cape Bruguieres Island (Figure 5.4).

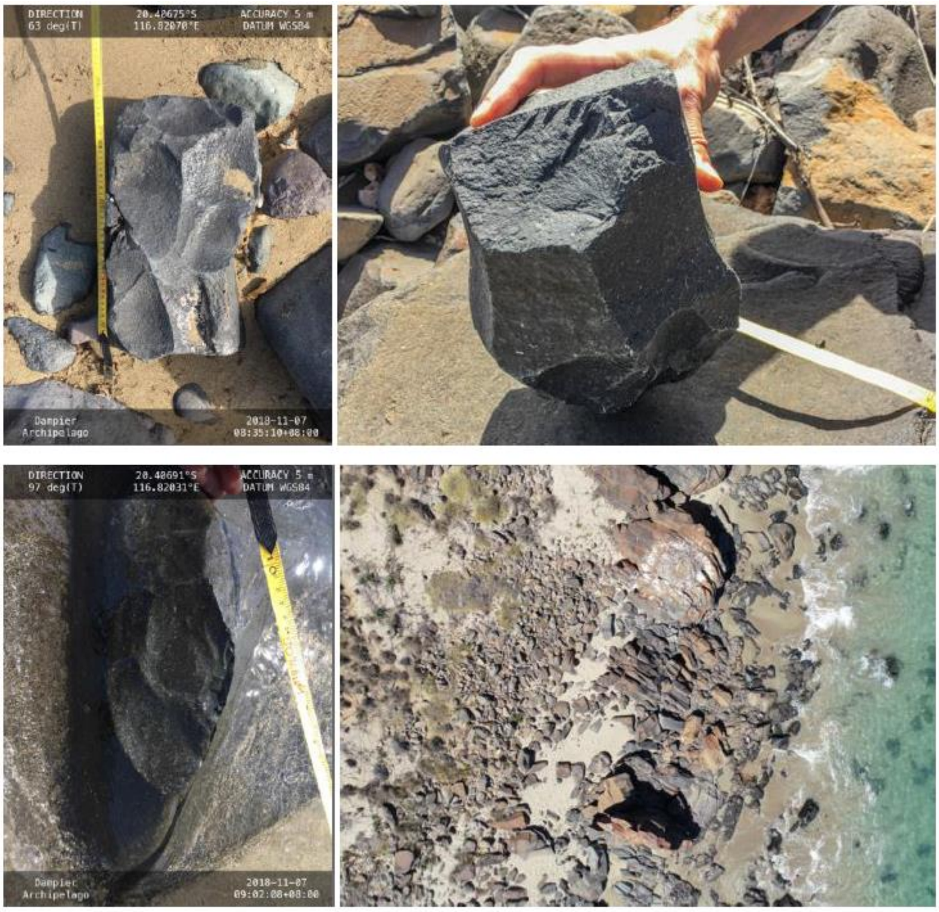


Figure 5.4 Worked stone, intertidal quarry site NW Cape Bruguieres Island, Benjamin and O'Leary 2018.

Extensive quarrying was also documented along the adjacent granophyre outcrop slope and summit. The north east of Cape Bruguieres Island exhibits further quarrying and lithic materials extending into the intertidal zone and potentially beyond. Single platform cores, multi-platform cores, flakes and debitage are present throughout the intertidal zone. These lithics were identified within a boulder field, interspersed with mobile sands and cemented aeolianite. Artefacts were identified embedded in aeolianite in this area. It is unclear whether this is a Holocene or Pleistocene deposit. Analysis of the bathymetric LiDAR data suggests that parts of this assemblage are at a similar elevation to the CBC assemblage however this cannot be confirmed as no elevation data was collected in the field. There is high potential to acquire direct dates for the production of lithics in this area. Further to this, the evidence for quarrying may continue into a submarine context. Review of the drone imagery appears to indicate the presence of exposed granophyre below the MLWS.

Very high-density artefact scatters were identified on the summit of the granophyre outcrop on north Cape Bruguieres Island. Flaked stone infills interstices and large areas between exposed bedrock. Large multi-platform cores were also identified (Figure 5.5). The sheer scale of this site suggests that quarrying was intensive in this area. Tens of thousands of flakes appear to be present in some deposits. Some direct evidence of quarrying was identified however this was in no way commensurate to the amount of flaked material that was identified. Some of these deposits are visible in the aerial imagery (Figure 5.6). Although individual artefacts cannot be discerned, there is an obvious colour difference between flaked material (grey) and unflaked material (reddy-orange).

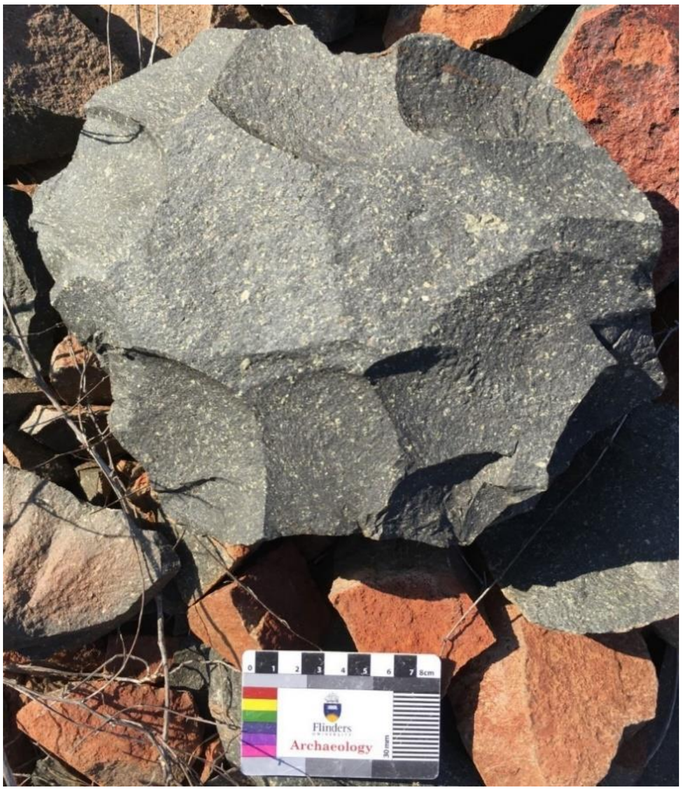


Figure 5.5 Large multi-platform core, North Cape Bruguieres Island summit, view north, J. Leach.

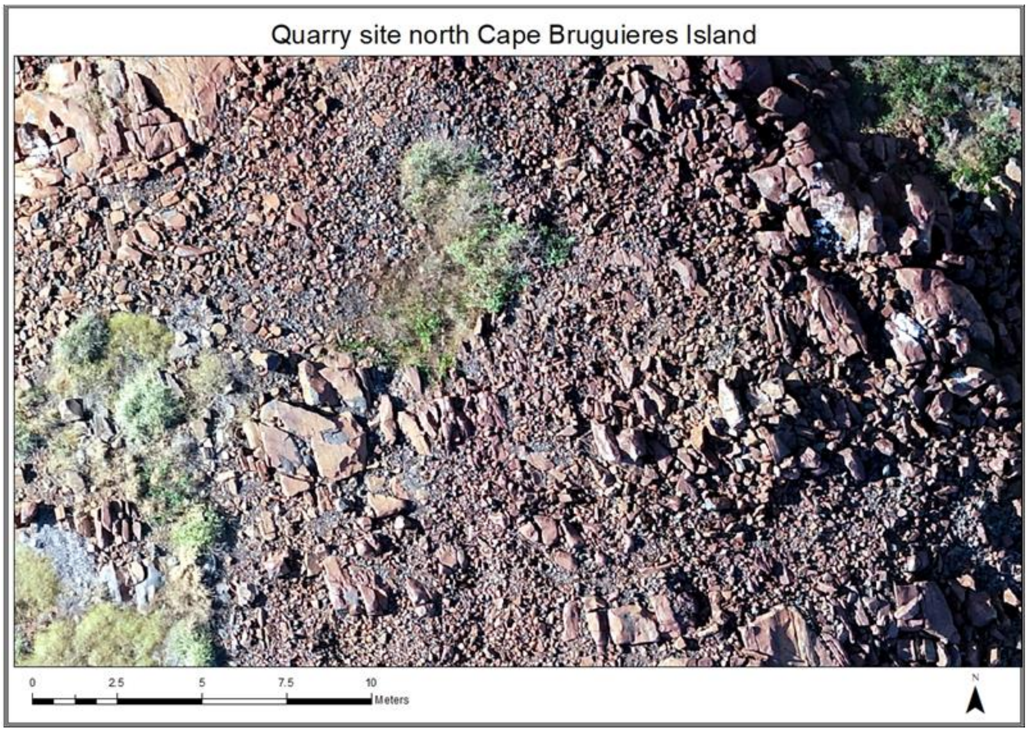


Figure 5.6 Quarry site, North Cape Bruguieres Island, orthomosaic created in Metashape, map created in Arcmap 10.8, J. Leach.

The eastern periphery of the granophyre outcrop on southwest Cape Bruguieres Island also contained evidence of extensive quarrying. The site identified contained small granophyre boulders exhibiting evidence of quarrying on multiple platforms (Figure 5.7). Discarded lithics and debitage are dense in this area.

Figure 5.7 Quarrying and artefact scatter, SW Cape Bruguieres Island – Cape Bruguieres Channel, view east, J Leach.

The scale of quarrying on Cape Bruguieres Island is immense. As noted by Vinnicombe (1987a; 1987b), Murujuga is a palimpsest and it is difficult to clearly define boundaries between sites. It is not possible to determine if the onshore and intertidal lithic materials are related but it is clear that these stone resources were targeted by the Ngardangali prior to sea level stabilisation at current levels. A review of archaeological sites in Murujuga identified quarry sites and reduction areas as a rare site type, accounting for just 2.5 percent of sites in the archipelago (Veth et al. 2019:10). The presence of these quarrying and reduction sites in association with engravings and grinding patches, extending into the intertidal zones reinforces the contention that the archaeological record of Cape Bruguieres Island is a unique site of high significance (Vinnicombe 1987a:62). Cape Bruguieres Island has high potential to reveal how Ngardangali adapted to marine transgression through the identification and analysis of submerged and terrestrial sites.

5.1.4 Engravings

Engravings of faunal species were recorded during the pedestrian surveys as a chronological proxy for the presence of the Ngardangali in the Cape Bruguieres Channel landscape, in the absence of absolute dates. The depiction of terrestrial species is considered an indicator that the Ngardangali were present in the landscape prior to marine transgression, and the depiction of marine species, particularly turtles and dugongs, is considered an indicator that the Ngardangali were present in the landscape during and following marine transgression.

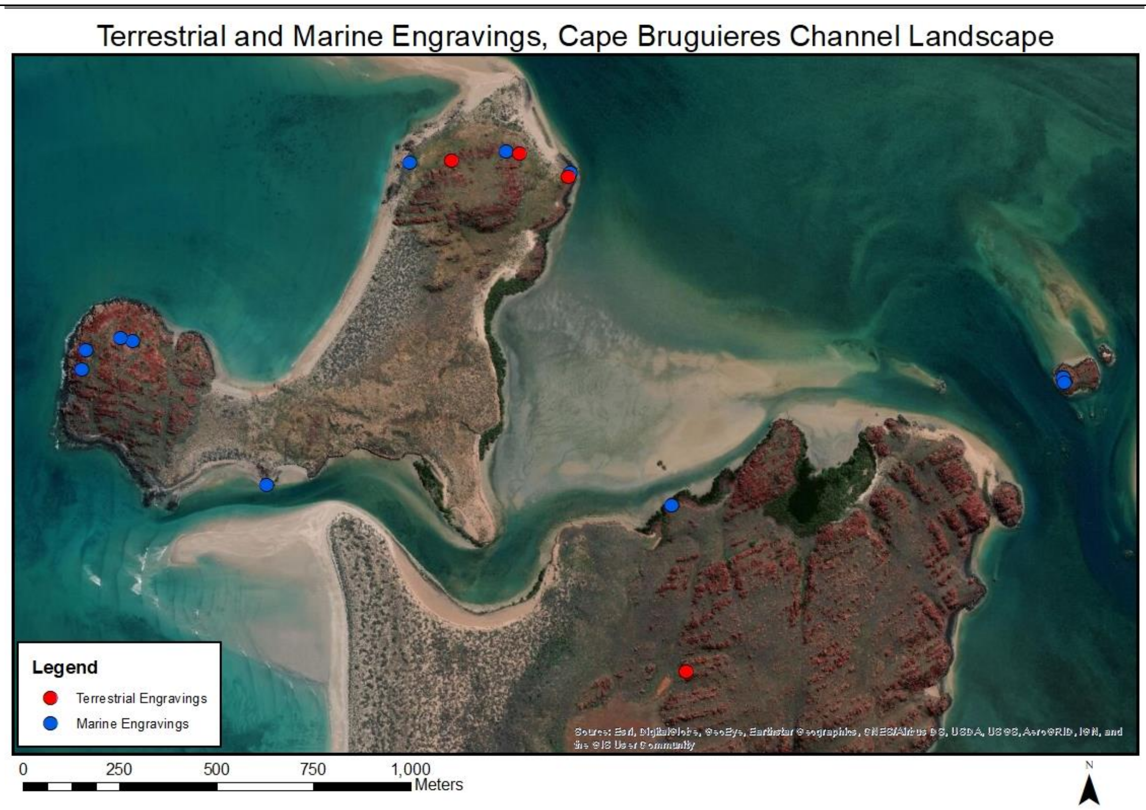


Figure 5.8 Terrestrial and Marine Engravings, Cape Bruguieres Channel Landscape.

Five terrestrial engravings were recorded as part of this study. Species depicted in the engravings include macropods, lizards and a quadruped. Lizards and macropods were targeted as subsistence resources (Withnell 1901:20). An engraving of a macropod on North Gidley Island has been interpreted as a fat-tailed macropod (Figure 5.9). Identifying features of the fat-tailed macropod include pointed ears and snout, enlarged cloacal protuberance, short forearms and a proportionately wide tail (Mulvaney 2015:236). This design is quite rare with only one other example recorded on granophyre in the Archipelago (Mulvaney 2015:243). Mulvaney (2009:40–41; 2015:244) concludes that production of these engravings ceased in the early Holocene, with examples of lower contrast state dating to the Pleistocene. The location of this engraving, in what would have been open plains and rocky slopes during the terminal Pleistocene, corresponds with the environmental range of this species. This supports the contention the Ngardangali were present in this landscape prior to marine transgression (Benjamin et al. 2020:11).

Figure 5.9 Fat-tailed macropod, North Gidley Island, view south, J. Leach.

Representations of marine species are ubiquitous in the engraving galleries of the CBC landscape. Two species that are heavily represented are turtles and dugongs suggesting that these species' became targeted subsistence resources as the sea level encroached. Engravings of turtles are present on the two closest granophyre outcrops to the CBC assemblage (Figure 5.10). This suggests that turtles were hunted in the channel as the ocean would not have reached these rock outcrops until the channel was inundated. Engraving styles, techniques and sizes differ greatly throughout the study area suggesting that turtles were of significance to the Ngardangali for a prolonged period. Mulvaney purports that turtles became the dominant faunal representation in the engraving galleries once the archipelago formed and the waters began to warm, becoming habitable for turtles and dugongs (Mulvaney 2015: 324).

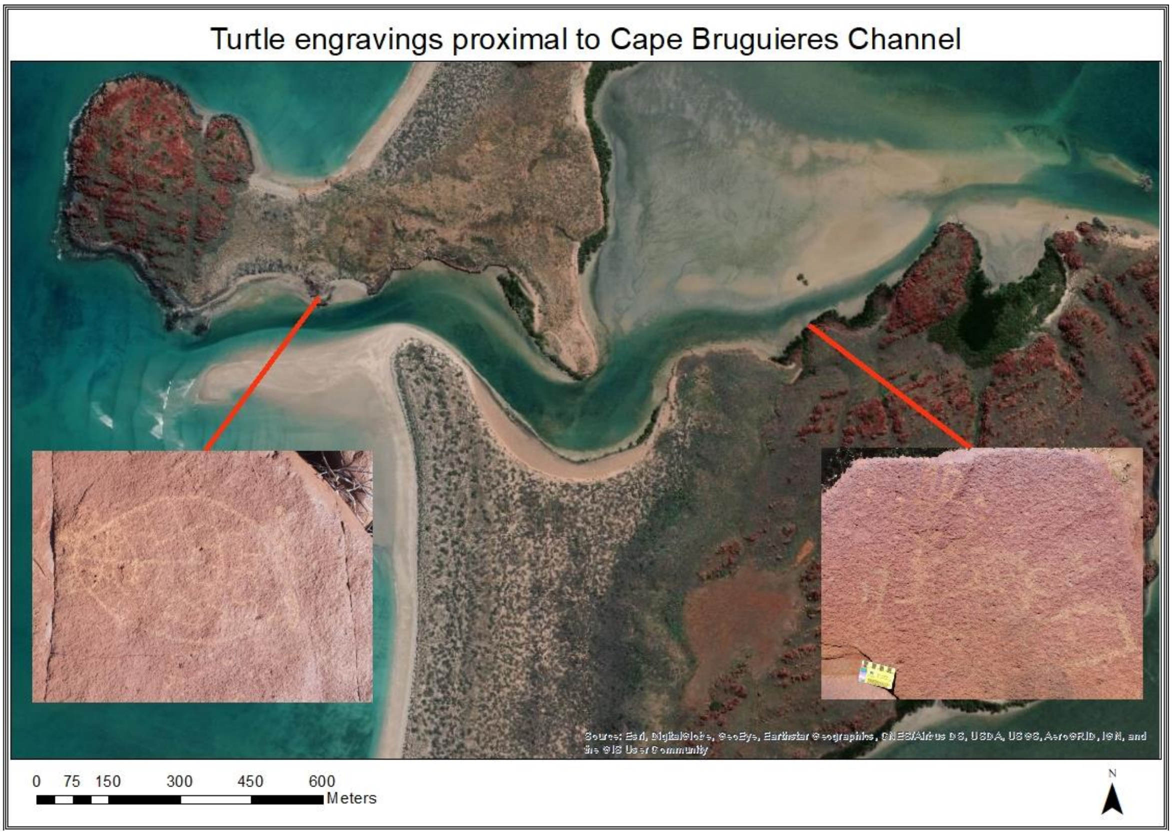


Figure 5.10 Turtle engravings, Cape Bruguieres Channel.

Dugongs are also consistently represented in the rock art of the study area. Dugongs are most prolific in Murujuga during the summer when sea grass is abundant. They were a prized food source and the Yaburara were known to hunt them with nets and wooden spears (Durlacher 2013:61; Mulvaney 2011:33). Several dugong tail engravings were recorded throughout the study area as well as an engraving of a complete dugong on southwest Cape Bruguieres Island (Figure 5.11). The complete dugong engraving resembles an engraving recorded by McDonald (2015:129) of a scene depicting a dugong being hunted with a net. Subsistence resources, such as dugongs, represent high risk targets but the economic payoffs of successful hunts are substantial and therefore lucrative (Kelly 1995). Boats and other high investment technology are usually required to acquire these resources. Once the sea level had stabilised at its current level the Cape Bruguieres Channel could have been used as a choke point for the hunting of dugong or turtles. The Yaburara were known to be proficient with nets and to use them for the hunting of dugongs (Durlacher 2013:54; Gregory 1884:58–75). There are stone structures on the calcarenite terrace adjacent to the channel. Similar structures have been historically observed on the De Grey river that acted as fish increase sites (Read and Coppin 1999:18–19). Further investigation of the area contiguous with CBC should be conducted to determine if dugong and turtle were targeted at this site.

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Figure 5.11 A) Dugong engraving, southwest Cape Bruguieres Island, J. Leach; B) Rendering of an engraving depicting a dugong being hunted with a net, After McDonald 2015:129.

5.2 Preservation of submerged engravings

A key study area for submerged landscape archaeology in Murujuga Sea Country is to determine if engravings can survive inundation. Dortch (2002:37–42) conducted diver investigations at 12 locations in the archipelago at depths of 10–30 m in 2000. Seven of these dives targeted submerged granophyre slopes in search of submerged engravings. Dortch did not identify any submerged engraving sites, though he purports that the chances of identifying sites are high in areas where galleries occur on rocky slopes that continue below the water line. Dortch (2002:40) suggests that while biotic growth may inhibit the identification of submerged engraving sites, they are the only site category that is likely to survive the deleterious impacts of marine transgression and the extensive tidal range of the Dampier Archipelago. To investigate this hypothesis and identify potential sites for diver survey, granophyre rocky slopes contiguous with the intertidal zone were investigated. If engravings can be identified in the intertidal zone, it will provide diagnostic information that can be utilised for the identification of engravings in a submarine context. Field observations in the intertidal zone made it apparent that the desert varnish is negatively impacted by exposure to saltwater. The desert patina, present on rock surfaces throughout the Pilbara, is absent on rocks in the intertidal zone. Further to this, a spectrum of degradation of the desert patina in relation to proximity to the intertidal zone is clear (Figure 5.12). If the desert patina cannot survive inundation, then it is very unlikely that engravings can be identified in a submarine context, as few engravings penetrate deeper into the stone.

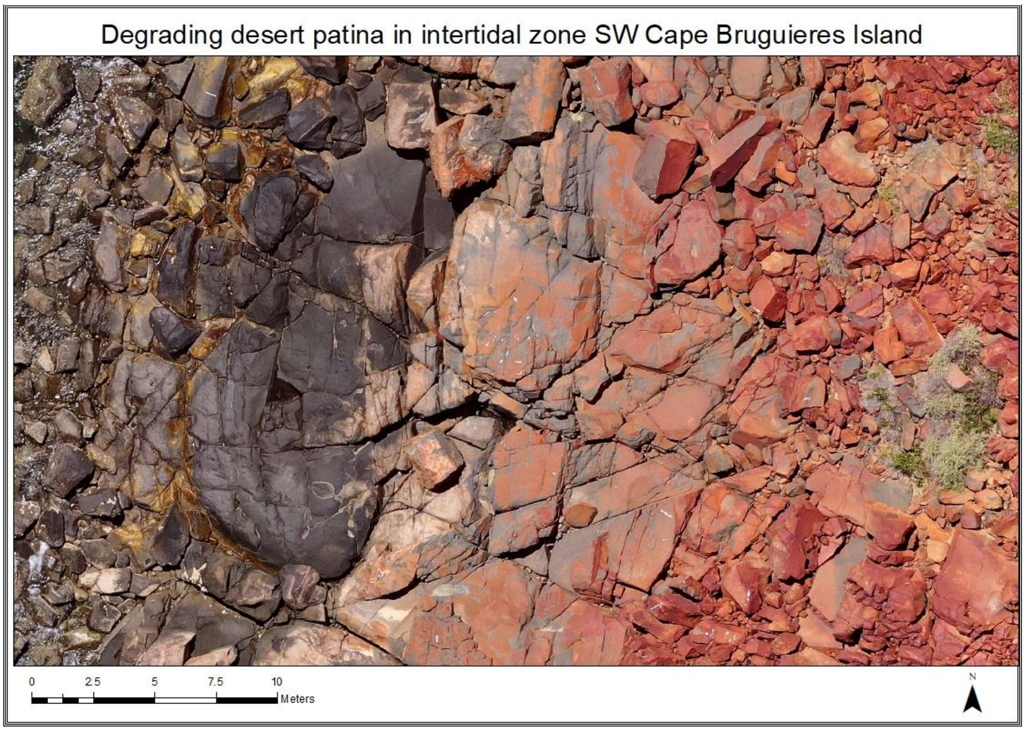

Figure 5.12 Degradation of desert patina in intertidal zone southwest Cape Bruguieres Island—note turtle engraving in bottom right hand corner of image, orthomosaic created in Metashape with Mavic 2 Pro imagery, map created in Arcmap 10.8, J. Leach.

Several engraving locations were identified on northwest Cape Bruguieres Island that appeared to be well advanced in the degradation process, so much so that it was difficult to determine the designs that were present. On northwest Cape Bruguieres Island two panels were recorded in the intertidal zone in an advanced stage of degradation (Figure 5.13).

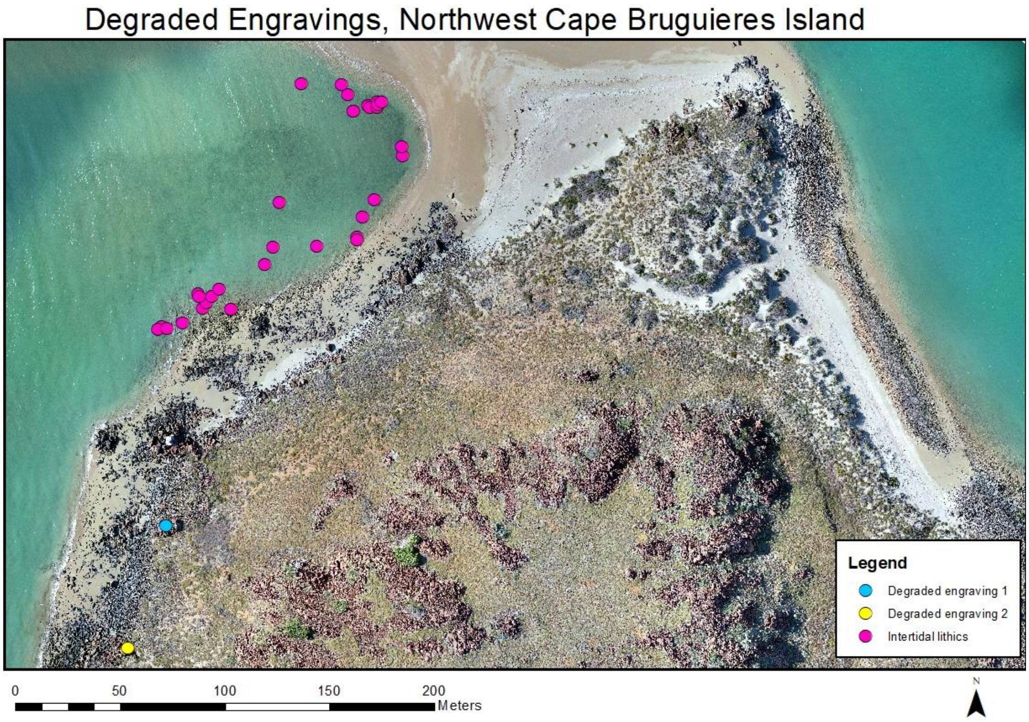

Figure 5.13 Degraded engravings, northwest Cape Bruguieres Island.

On degraded engraving A, a dugong tail is visible in association with geometric designs (Figure 5.14). Engravings are present on degraded engraving panel B but their contrast state is extremely low, making it difficult to determine individual designs (Figure 5.15). A fish can be seen in the top left of the panel and avian spooromorphs in the bottom left. These images can be allocated to the more recent phases 4 and 5. A characteristic of engravings from these phases is that they have high contrast states due to their more recent production. As marine zoomorphs are depicted on this panel, the low contrast state is more likely to be attributed to the degradation process relating from its proximity to the ocean than significant age. It is unclear whether this process of degradation results from erosion, water action or a chemical process. Mulvaney (2015:170–171) contends that sea spray has a detrimental impact on the preservation of the desert patina. Targeted research should be conducted in the intertidal zones where granophyre outcrops are present to determine if the desert patina can survive inundation. Areas with engravings that were inundated during the Holocene highstand, that were re-exposed following sea level stabilisation at current levels, would be the most cost-effective places to focus this study. A DGPS unit is required for this work as accurate elevation data is essential for this type of study. If it is determined that the engravings can survive marine inundation, the results of this work could potentially inform future targeted diver investigations.

Figure 5.14 Degraded engraving A, northwest Cape Bruguieres Island, view west, photomosaic created in Metashape, J. Leach.

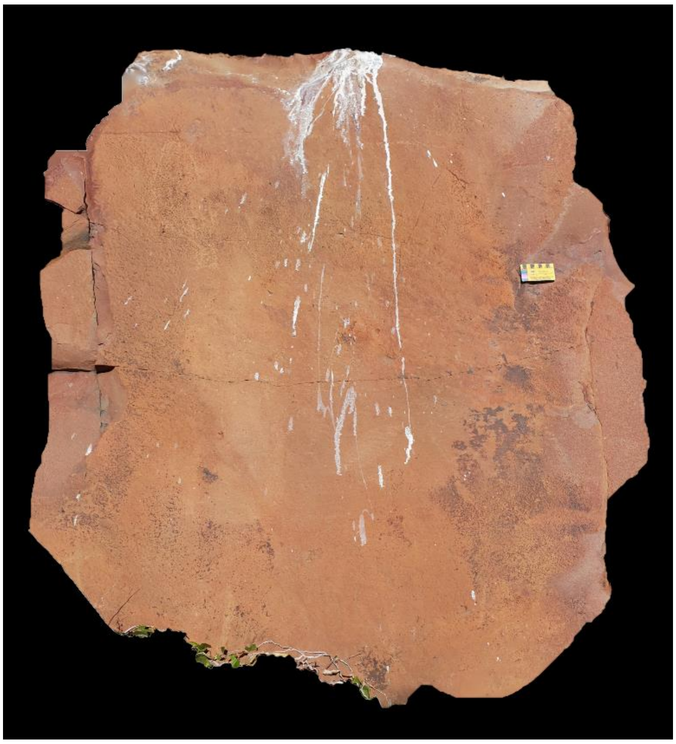

Figure 5.15 Degraded engraving B, northwest Cape Bruguieres Island, view west, photomosiac created in Metashape, J. Leach.

5.3 Future research

5.3.1 North Gidley Island and Collier Rocks

The sub-tidal area between North Gidley Island and Collier Rocks has been assessed as a potential site for diver investigation (Figure 5.16). Clues as to the presence of water, indicated by the presence of high-density engraving sites and standing stones in this area, correlate with the DHSC landscape modelling (Veth et al. 2019:18) and prompt further investigation.

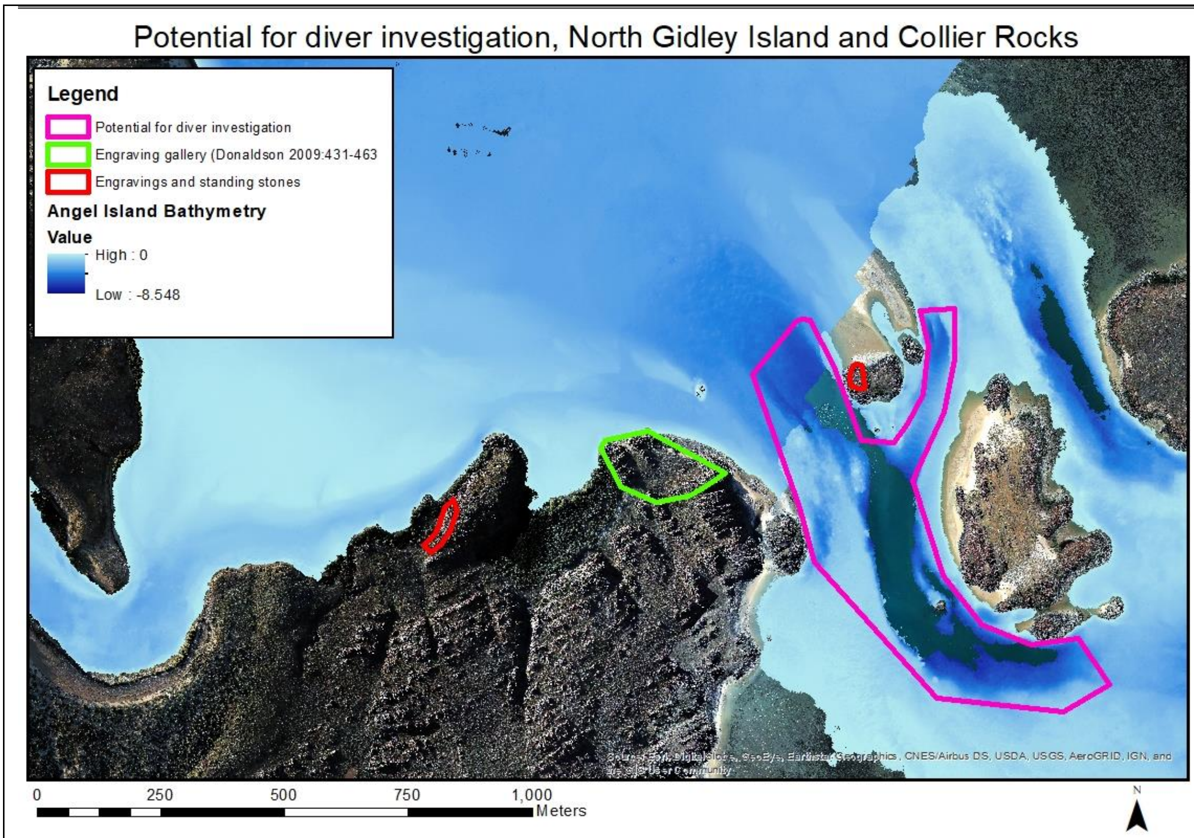

Figure 5.16 Potential for diver investigation, North Gidley Island and Collier Rocks, RGB photomosiac and bathymetric LiDAR imagery (Hacker 2018).

The presence of standing stones and high-density engraving sites on North Gidley Island and Collier Rocks makes the submerged landscape between these outcrops a potential site for diver investigation. This is further supported by the presence of an engraving of concentric circles on Collier Rocks (Figure 5.17). There are examples of concentric circles being used to represent water sources in the Flinders Ranges (Nobbs 2000:185) and the Western Desert

(McDonald & Veth 2013:67). In addition to this, a high-density engraving gallery is present on the adjacent granophyre outcrop on North Gidley Island (Donaldson 2009:431–463). The targeting of an underwater spring, colloquially known as a 'wonky hole', by the DHSC proved successful in locating a lithic in the Flying Foam Passage at a depth of 14 m (Benjamin et al. 2020:22). There is extensive evidence that places lithic materials in close proximity to water sources in Murujuga (Bednarik 2007:236; McDonald 2015:132; Vinnicombe 1987a:32; Vinnicombe 1987b:32). Review of the bathymetric LiDAR will help identify potential locations where water may have pooled which can inform future diver investigation.

Figure 5.17 Concentric circle engraving, Collier Rocks, view south, J. Leach.

5.3.2 North Cape Bruguieres Island

Cape Bruguieres Island is a high priority location for future diver investigation (Figure 5.18). The north of the island is of particular interest as it exhibits a broad range of archaeological features within or proximal to the intertidal zone including quarried stone, artefact scatters, artefacts embedded in aeolianite, engravings and grinding patches. Further to this, high density engraving galleries, quarrying sites, artefact scatters and grinding patches are present in the contiguous onshore record.

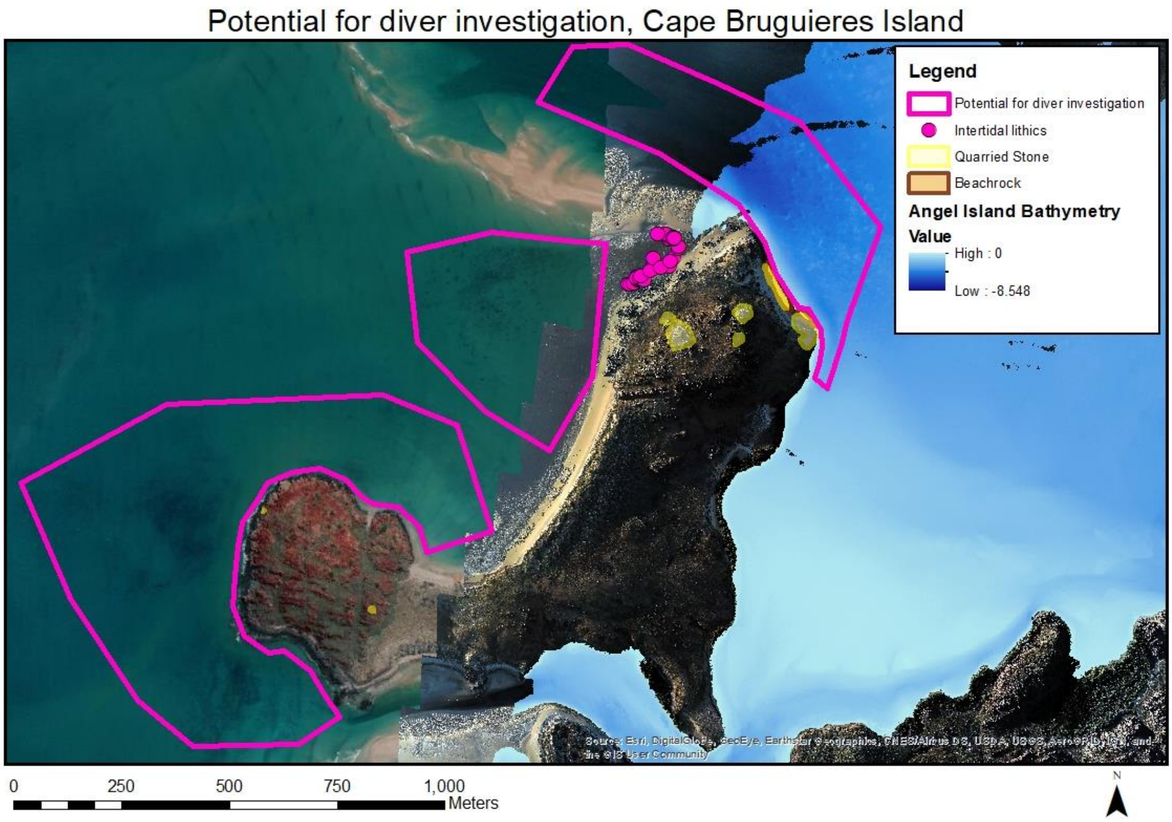

Figure 5.18 Potential for diver investigation, Cape Bruguieres Island.

Artefacts embedded in aeolianite will facilitate absolute dating of artefact assemblages (Figure 5.19). This will enable the comparative analyses of onshore and offshore artefact assemblages. Granophyre outcrops and aeolianite appear to persist beyond the intertidal zone off the northeast of the island correlating with the DHSCs landscape models for high potential sites (2019:16–21). The presence of engravings in the intertidal zone make this an ideal location for diver investigations to identify submerged engraving sites. The effects of salt water on engravings can also be studied in the intertidal zone on the northwest of the island. The presence of onshore and offshore quarrying sites and artefact assemblages means that high resolution 3D modelling could be conducted that could be used to train AI to identify sites in other parts of the archipelago.

Figure 5.19 Flaked materials embedded in aeolianite, northeast Cape Bruguieres Island, view west, J. leach.

Quarrying was also identified at three locations on southwest Cape Bruguieres Island. Two of these sites comprised single granophyre boulders that had been worked on a single platform. Both of these sites were in close proximity to the intertidal zone and may represent the upper periphery of a now submerged quarry site. These isolated quarrying events do not provide enough evidence to invest the resources required to investigate the submerged landscape in this area, however the summit of this granophyre outcrop exhibits a high density of engravings, grinding patches and flaked stone, correlating with the DHSC landscape model. Aerial imagery indicates that the rocky slope on which these boulders are located extends below the MLWS. Survey of this area could be conducted by diver investigation or the use of a submerged remotely operated vehicle to test this premise. Further to this, a quarrying site was recorded on the eastern periphery of this outcrop only 500 m from the CBC. PXRF analysis should be conducted at all identified quarry sites within the CBC landscape to determine if they are the source of the CBC assemblage.

6 Conclusion

The identification of an in-situ artefact assemblage in a submerged context in the Cape Bruguieres Channel marks a major turning point in the investigation of submerged landscapes in Australian archaeology. It has validated the contention of Australian archaeologists (Benjamin et al. 2018:2; Veth et al. 2019:16) that under the right conditions, archaeological features can survive marine transgression. The implications of this research will be far reaching. It will legitimise the development of new research projects that may have previously struggled to attract funding, compel the drafting of new legislation to enshrine the protection of submerged Indigenous landscapes in law and cement the practice of a uniquely Australian submerged landscape archaeology. Integral to the success of this project was the survey methodology developed by Benjamin (2010:258) and the DHSC (Veth et al. 2019:16–21). The integration of the onshore and offshore archaeological record helps ensure that the practice of submerged landscape archaeology remains ‘grounded’ by ensuring the analysis of submerged sites is considered in the context of a pre-inundation landscape. This holistic approach informed the successful methodology developed for this study.

A broad range of archaeological features were identified through the completion of pedestrian and drone surveys that inform on how the Ngardangali interacted with the CBC landscape. These include engravings of terrestrial and marine species, quarry sites, grinding patches and ephemeral water sources. The presence of engravings of terrestrial and marine species in the CBC landscape indicates that the Ngardangali exploited both terrestrial and marine faunal species, correlating with McDonald (2015:128) and Mulvaney’s (2015:290) theory that there was a shift in subsistence strategies associated with marine transgression. Representations of turtles proximal to the CBC suggest that the channel may have been used as a hunting ground following inundation. Intensively used grinding patches, identified on all major granophyre outcrops, indicates that seed resources were also a staple of the Ngardangali’s diet in this region. The identification of an ephemeral waterway associated with engravings, grinding patches and lithics demonstrates that water would have been available to the Ngardangali during the wet season. This ephemeral waterway would have flowed through the CBC prior to marine transgression, which may explain why the Ngardangali were utilising stone tools in this area.

Several locations were identified on Cape Bruguieres Island that contain evidence of quarrying. North Cape Bruguieres Island exhibits extensive evidence of quarrying across a granophyre outcrop that extends into the intertidal zone. This site is significant for the immense scale of quarrying that it contains. Geological provenance studies at this site could reveal the source material of the CBC assemblage. Further to this, saturation survey of the terrestrial record completed in conjunction with diver investigations of the contiguous submerged landscapes will provide invaluable data for comparative analyses that can help determine if there was a change in stone tool manufacture relating to marine transgression. These analyses can be corroborated by the acquisition of minimum dates for lithic materials embedded in aeolianite extending from the shore into the sub-tidal zone on northeast Cape Bruguieres Island. High-density artefact scatters, engraving galleries and clusters of grinding patches were identified on southwest Cape Bruguieres Island on a granophyre outcrop that extends into the sub-tidal zone. This is an ideal site to test how these archaeological features preserve in a submerged context. High densities of engravings and the presence of standing stones on North Gidley Island and Collier Rocks support diver investigation of the submerged landscape between these two locations. Interviews with Traditional Owners will also form an integral element of future submerged landscape studies.

A highly revered Ngarinyin Elder, David Mowaljarlai (Mowaljarlai and Malnic 1993:68), wrote in his seminal book *Yorro, Yorro*, ‘to go back in time, you walk’. Now, following the success of the Deep History of Sea Country, to go back in time, we can dive.

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