Solving for the Unknown:
A comparative study of methodological approaches to submerged landscape archaeology

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ABSTRACT

This thesis investigates modes of practice in submerged landscape archaeology across the world to develop a similar mode of practice for Australia. Over the course of human history, sea levels have been substantially lower, reaching as low as −130 m at the Last Glacial Maximum. These areas were inhabited by past populations, and subsequently inundated, allowing for the preservation of archaeological remains of these past communities. These archaeological sites have been observed and studied since the early 1900s, and over time many regions have developed methodological approaches to best analyse these submerged archaeological sites and their landscape context, including Denmark, Israel, and North America.

The original contribution to knowledge of this thesis is the creation of a mode of practice for submerged landscape archaeology for Australia, based on the insights gathered from international practice. No subtidal Indigenous archaeological sites had been found in Australian waters until recently, when the first two sites were identified. This established the first successful mode of practice for the development of submerged landscape archaeology in Australia, which is considered in this thesis and then enhanced with the knowledge gained from international examples. This contributes to an effort to characterise submerged landscape archaeology and the conditions required for the preservation of material, as well as optimal strategies to locate sites.

This thesis poses the question of whether international modes of practice can inform a model adapted to the Australian context. To answer this question, international examples are evaluated to investigate factors contributing to the preservation and discovery of submerged archaeological sites. With the findings of these examples, and in consideration of the methodological approach developed with the discovery of the first two submerged Indigenous sites in Australia, this allows for a comparison of methods. The results of this comparison have been used to form a baseline 'Australian Model', based on internationally demonstrated criteria for the preservation and identification of sites.

To develop this Australian Model, a combination of desk-based study, alongside field observations, has been used. These are reinforced by thematic content analyses of select groups of literature to better understand the history of submerged landscape archaeology on a global scale. From this Australian Model, we can better understand the state of site formation processes and modelling for site preservation as is understood globally, in addition to the refinement of models for site selection and land use, as well as greater knowledge of the suitability of different remote sensing techniques.

This process has investigated and tested assumptions about site preservation and discovery under water, and these are considered for a continent, where, until recently, no sites had been found. The Australian Model proposed here will require testing and refinement over time, with scope for regional variation, but provides a baseline for further research for submerged sites on the continental shelf of Australia.

DECLARATION

I certify that this thesis:

1. does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university

2. and the research within will not be submitted for any other future degree or diploma without the permission of Flinders University; and

3. to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

Signed: Chelsea Wiseman

Date: 7th December 2021

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1.0 INTRODUCTION

1.1 Overview

This thesis examines submerged landscapes, and the modes of practice that are used to locate and study submerged archaeological sites dating from the late Pleistocene to mid-Holocene. Over the past 1 million years, sea levels have fluctuated, although mostly sea levels were lower than their present level. At the peak of the Last Glacial Maximum (c. 21 to 18 ka), sea levels were as low as −130 m (Chappell and Shackleton 1986; Lambeck and Chappell 2001; Yokoyama et al. 2001; Clark and Mix 2002). On a global scale, this contributes to ~20 million km^2 of continental shelf that was once inhabited by humans, which is now under water. These changes in sea level form the backdrop to several cultural and technological innovations and events, including migrations of anatomically modern humans and the development of seafaring, as well as the development of sedentary, agricultural lifeways alongside the exploitation of coastal resources (Bailey and Milner 2002; Milner et al. 2004; Leppard and Runnels 2017; Bird et al. 2018). On a global scale, at 18 ka, sea level began to rise rapidly, inundating evidence of human use on the coastal margins. Sites submerged by postglacial sea-level rise therefore provide crucial data to address questions of adaptation to climate change, maritime adaptation, and migration, and have been identified across the world (Masters and Flemming 1983; Benjamin et al. 2011; Evans et al. 2014; Harff et al. 2016b; Bailey et al. 2017; Flemming et al. 2017b; Bailey et al. 2020b).

The importance of these submerged sites has become increasingly apparent, with remarkable preservation demonstrated in underwater environments that is unparalleled by most conditions in terrestrial environments (Fischer 2007; Galili et al. 2020). Additionally, the presenceof these sites is a reminder to archaeologists that the landscape as it appears today is vastly changed from its past form, and to understand archaeological sites in their broader landscape context, it is crucial to look to the sea. Many archaeological questions are still informed predominantly by the terrestrial record, which becomes especially problematic when studying the history of coastal habitation. Intensive coastal resource use is, in many parts of the world, including Australia, considered a Holocene phenomenon, largely owing to a lack of evidence for earlier dates. The answer to these gaps in the archaeological understanding of coastal environments may be partly because evidence of past use may be underwater. The question that then emerges is whether these sites preserve, and how to identify them.

From the 1970s onwards, the Carmel Coast of Israel and southern Scandinavia developed as leading areas with extensive submerged archaeological material, and both of these areas were critical in the early development of submerged prehistory (Wreschner 1977; Skaarup 1983; Galili and Weinstein-Evron 1985; Fischer 1997; Galili et al. 2002). This eventually allowed for the development of modes of practices, or 'models' for survey and research of submerged landscapes in both Denmark and Israel (Fischer 1993; Fischer 1995b; Benjamin 2010b; Galili et al. 2019b). While clearly defined 'modes of practice' are not published for many other parts of the world, similar publications and frameworks can be evaluated, such as those based on the coast of North America (Gagliano et al. 1982). The analysis of submerged prehistoric sites has become a distinct sub-discipline within underwater archaeology in the Northern Hemisphere (Bailey et al. 2020b), however the Southern Hemisphere is also now receiving increased academic focus in evaluating the archaeological potential of submerged landscapes. Australia is one such example. While underwater archaeology also emerged as an academic discipline in Australia in the 1970s, the research has predominantly focused on historic shipwrecks and sunken aircraft (see Chapter 3 for detailed review). Despite abundant archaeological evidence for coastal habitation and resource use corresponding to the Holocene (McNiven et al. 1999; Barker 2004; Ulm 2006; Rowland and Ulm 2011), no submerged marine sites have previously been located before the Deep History of Sea Country (DHSC) project (Benjamin et al. 2020). The DHSC project identified the first subtidal Indigenous archaeological sites, and assisted in the data collection and observations presented in this thesis. Prior to this project, sites within the intertidal zone are well-known (McNiven 2004; Kreij et al. 2018; Dortch et al. 2019), and sites were recorded in submerged, freshwater lake environments (Dortch and Godfrey 1990; Hudson and Bowler 1997). Several attempts were also made to identify submerged Indigenous material on the continental shelf (Flemming 1982; Dortch 2002; Nutley 2014), however none of these projects located any archaeological material. A research gap becomes apparent, where further research is required to understand where submerged Indigenous archaeology is likely to be, and how best to locate it.

Evans et al. (2014) describes the capacity for identifying significant submerged archaeological material as a formula:
W(area) + X (potential) + Y(likelihood) = Z(significance)

Where studies are conducted in a location with a well-established understanding of the physical environment of the area (W), alongside a predictive model that establishes the archaeological potential (X), combined with areas that yield a high rate of likelihood of preservation (Y), are likely to provide results that are of local, regional, and global significance. However, the influence of each of these variables must be determined, and this may not always be apparent based on the archaeological evidence and data available to researchers aiming to identify prospective locations. For this reason, this project evaluates the role of physical environments, cultural behaviour, preservation characteristics, and the ultimate significance of submerged landscapes.

This thesis is a comparative study, which discusses the Israeli Model and Danish Model, in addition to other case studies, to discuss the potential for models for submerged landscape archaeology in Australia. A critical assessment of methodology in Israel is compared alongside the Danish Model, and this informs the development of an ‘Australian Model’ for submerged landscape archaeology based on the identification of the first submerged archaeological sites in Australia. Though the factor of sea-level rise and chosen temporal period remain the same, this study recognises the distinct differences in archaeology, geology, and environment between the study regions in focus, and aims to present this as an opportunity to further the understanding of submerged landscape archaeology and site formation in vastly different areas.

1.2 Questions, Aims, and Objectives

This thesis develops a preliminary ‘Australian Model’ based on international examples of best practice for submerged landscape archaeology. With the discovery of submerged archaeological sites in Murujuga (see Chapter 6), there is clear proof that submerged archaeological sites can preserveoff the continental shelf of Australia, however suitable survey methodology to locate these sites remains debatable, and as such international case studies from Israel and Denmark (as global leaders in submerged landscape archaeology) have been drawn upon to build a methodology for future testing. Research of submerged landscape archaeology in Australia has been relatively scarce compared to Europe and North America, with no subtidal material located until recently in conjunction with this PhD research, despite prior intensive survey efforts. This leads to an initial observation: why have thousands of submerged sites been located elsewhere, while no sites were identified in Australia until recently?

A critical review of underwater archaeological methods in several locations, including Europe and North America, is carried out in this project. This original contribution synthesises data from international case studies and uses them to generate a new mode of practice. As a methodological discussion, this thesis considers the identification of the first two submerged archaeological sites in Australian waters in the broader context of international finds. Additionally, the potential to develop a model for the prospection of Australian sites is highlighted by the success of international examples of survey and research practice, and allows for a set of criteria for the identification of Indigenous Australian sites. From this, a broad, disciplinary consideration can be put forth: how do we expand the submerged archaeological record in Australia based on international examples and the recently discovered examples in Australia? This discussion gives context to international methodologies and optimal preservation conditions, and investigates their application in Australia to address a central research question:

How can the discovery and research of submerged archaeological sites in Europe, the Middle East, and North America best inform the understanding of site formation and survey strategy in Australia?

The investigation of this question is the focus of this thesis, with a proposed 'Australian Model' as a primary result to directly answer this question.

The aims of this project are to:

1) Evaluate international examples to consider criteria relevant to the prospection of submerged Indigenous archaeological sites in Australia, through original desk-based study and field observations of international case studies;

2) Consider, develop and test a suite of methodological approaches in the Dampier Archipelago (Murujuga), Western Australia;

3) Produce a baseline, broad-scale 'Australian Model' based on internationally-demonstrated preservation criteria and survey principles for submerged site prospection across the Australian continental shelf.

To address these aims, the project is guided by the following objectives:

1) Critically review site-scale through to landscape-scale studies of submerged landscape archaeology with consideration for international examples and special reference to Denmark and Israel, where field observations of archaeological material, environmental context, and methods of investigation were made;

2) Conduct a systematic literature search and thematic content analysis to assess the state of research and published stances on submerged landscape archaeology in Australia;

3) Consider, evaluate and adapt features from the Israeli and Danish Models to the Australian environment, with consideration for site identification, selection, preservation characteristics (including sedimentation and tidal patterns), physical characteristics.

4) Outline a mode of practice (model) for Australian submerged landscape archaeology based on lessons learned from international examples;

5) Identify case study areas in Australia for further research, investigation, and management based on this Australian Model's criteria;

6) Assess the potential for preservation and discovery of submerged sites across Australia and map areas of high potential.

1.3 Scope of research

The chronological scope of this thesis is focused on terminal Pleistocene to late Holocene material with a specific focus on Australia, Israel, and Denmark, with reference to other examples from the Northern Hemisphere. Throughout survey procedures in Murujuga (Chapter 6), the dates of material could not be determined through dating procedures or typology, and have been inferred based on the potential time of inundation. The temporal scope of this thesis remains broad to include this material, and to discuss examples across many different time periods. Spatially, this thesis' central area of investigation is the Australian continental shelf, with particular reference to material collected by the DHSC project, and reinforced by selected site-scale and landscape-scale international case studies.

As with all comparative studies, the limitations of this research lay in the comparative component, where each site and region examined has had a different history of engagement with submerged landscape archaeology, and in vastly different (but in some cases, comparable) depositional environments. These issues are beyond the immediate control of the researcher, however not beyond acknowledgement and transparency in the research. While at first this might lead to the conclusion that it renders any insight drawn from such comparisons with little room for similarities and only differences, I argue that this serves to enhance the research by allowing for careful evaluation of varying depositional environments. The thesis does not aim to approach submerged landscape archaeology by suggesting a 'one size fits all' method will suit a global variety of material. Instead, the aim of this study is to identify how best to start from known approaches, and adapt to a different region. The chosen study areas cannot be analysed using identical approaches, and this is not the intention of this study, which instead seeks to identify 'lessons learned' and adapt methodologies for international application.

The extensive offshore archaeological material from the Carmel Coast and Denmark is considered an existing point to begin from with a vast amount of information, and does not necessarily require additional fieldwork to inform this thesis. Nevertheless, to practice the use of available models, original fieldwork was conducted at a stone pile site in Israel, to analyse a type of material culture in this area that closely aligned with similar possible sites in Australian archaeology, and provides a case study for the process of surveying possible anthropogenic stone features under water.

1.4 Rationale of the study

This thesis contributes to an ongoing research effort to characterise submerged landscapes and identify inundated archaeological sites. The research represents an original, inter-disciplinary study, incorporating desk-based study and critical literature reviews alongside original marine geophysical survey data as well as coastal and underwater archaeological site survey data. The thesis primarily reviews published archaeological, geomorphological, and spatial data to achieve its aims. Published information is synthesised to identify characteristics of site settlement on the coast, and how this may correlate with locating sites in marine environments. The proposed study allows for an increased understanding of the widest scope of variation in archaeological material (hunter-gatherer remains and early agricultural villages), in appreciably different areas of the world that are similar in demonstrating several millennia of human engagement with the sea. This research will assist in the development of methodological aspects of identifying submerged archaeological material, and allows for the possibility to move from the known to the unknown.

The significance of these research questions corresponds with the focus on integrating studies of coastal adaptation and submerged landscapes. The analysis of coastal adaptation allows for an understanding of human-sea interactions across deep time, with significance for human mobility and seafaring, subsistence economies, and adaptation to rapid climate change. A secondary point of significance is understanding the impact of sea-level rise on coastal communities as it appears in the archaeological record. Aside from the focus on coastal adaptation, it must be considered that sites on land and those in the water are part of a coherent system of land use, and this may contribute to identifying sites under water.

Before it is possible to assist in answering these research questions, the archaeological sites must first be located and identified. But what are the most suitable approaches to identify these sites? From a methodological perspective, approaches to locate submerged archaeological sites require ongoing development, and this study represents the development of an 'Australian Model' for the identification of submerged archaeological material. The emergence of the 'Australian Model' corresponds with the environmental, and cultural aspects specific to the Australian context. The example presented here relies on elements of Indigenous material culture found across Australia, but also shows some traits specific to the Pilbara region based on the current identification of submerged sites in Murujuga. In this project, the Israeli Model and Danish Model informed the preliminary aspects of the proposed Australian Model. The European and Middle Eastern examples allow for inferences about the preservation potential of material culture, as well as landforms that could yield submerged archaeological finds, and the methods that should be used to identify this material. The issue for archaeologists is predicting a 'formula' for material resilient enough to preserve, the optimal conditions for preservation, and in some cases the optimal conditions to locate the material. This research addresses this formula, based on three focused case study areas, and then discussed in their wider international context.

Original fieldwork was conducted in both Israel and Western Australia (WA). The Western Australia fieldwork forms part of the DHSC project, discussed further in the following section. As part of the requirements of this thesis, additional fieldwork was conducted in Israel for this thesis project, contributing to a research effort spanning decades led by Ehud Galili. Submerged stone features were analysed in this area to serve as a case study for the investigation of stone features in a rocky marine environment, resembling a likely possibility for the Australian context. Past survey data from the Carmel Coast was also digitised as part of the Israeli case study, to enable the reconstruction of coastal changes in this area. Understanding the development of an Australian Model as a combined test of the Danish Model and Israeli Model, reinforced by additional field observations, provides a way to adapt existing models to the unique conditions and requirements of the Australian coastline.

The Australian Model presented in this thesis will assess the potential of preservation and discovery of submerged archaeological sites in Australia dating to the late Pleistocene to early Holocene. This will allow for the mapping of promising locations, to create a baseline for future research, and provide an essential tool for government and planning authorities. From this, the research will enable the preservation, regulation and protection of submerged sites in Australia.

1.5 Relationship to Deep History of Sea Country project

The Deep History of Sea Country Project (DP170100812) is an ARC-funded project administered by Flinders University in collaboration with the University of Western Australia and James Cook University, as well as Moesgaard Museum (Denmark). Ethics approval for this project is granted by Social and Behavioural Research Ethics Committee (SBREC) at Flinders University (project 7669). The project focuses on submerged landscape archaeology in Australia, and serves as a pioneering project to identify submerged archaeological sites based on an understanding of coastal archaeology in Murujuga. This project has an international comparative element, analysing a submerged shell midden in Denmark to identify characteristics of submerged shell middens for Australian archaeology.

This thesis is reliant on data collected by and owned by the DHSC project, and forms a subsidiary study that builds on the internationally comparative aspect of the research by using Israel as a case study, in addition to the Danish case study of shell middens already established by the project. This research contributes the characterisation of coastal archaeological sites and landscape features for prospection in the underwater environment, a major objective of the project, and assesses the methods used in the DHSC project.

1.6 Chapter Outline

Chapter 1 has introduced the key research themes, questions, and significance of the research.

Chapter 2 provides a review of submerged landscape archaeology on a global scale, underwater archaeology in Australia, as well as sea-level rise from the late Pleistocene to mid Holocene to set the wider background for this study.

Chapter 3 reviews Australian archaeology and outlines some of the research themes that relate to the emerging field of submerged landscape archaeology in Australia.

Chapter 4 assesses land use modelling, site preservation, and site visibility and discovery in order to understand trends in each of these themes globally, and their potential role in identifying submerged landscape archaeology in Australia.

Chapter 5 forms a critical assessment of method of existing survey and research ‘models’, or modes of practice, in submerged landscape archaeology. This is represented by a systematic literature review, and reinforced by a case study in Israel with an original fieldwork component. Additional examples of modes of practice are included to contextualise the detailed descriptive work on survey and excavation practice developed by Denmark and Israel.

Chapter 6 describes the methods and results of work undertaken in Murujuga.

Chapter 7 discusses the central outcome of an Australian Model, providing a comparison between the criteria presented and those within international counterparts.

Chapter 8 provides an evaluation of this Australian Model and highlights the potential for regionally distinct models to emerge, as well as locations for further research.

Chapter 9 summarises the contribution to knowledge, significance, and main findings of this thesis.

2.0 LITERATURE REVIEW: HISTORY AND THEORY OF SUBMERGED LANDSCAPE ARCHAEOLOGY

> "It was one of those thrilling moments which occasionally occur in the life of an Archaeologist. Here before us was tangible proof that the land had sunk since prehistoric times." (Crawford 1927:6)

2.1 Introduction

This chapter provides context to the theoretical discussions and practical research outcomes of this thesis. Firstly, sea-level change and the mechanisms for understanding its impacts are discussed, providing the environmental background to the material culture found in submerged sites. A concise history of submerged landscapes on a global scale is also presented to contextualise the study areas, and to present the current state of the research within the discipline. Theoretical frameworks that have found relevance in submerged landscape archaeology are also evaluated, and while they do not contribute to the design of this thesis research, they are a factor to address in understanding methodology. Similarly, site formation processes as currently understood for submerged archaeological sites are reviewed. This outlines the general trajectory of the discipline, and its challenges and the theoretical concepts that contribute to the ongoing paradigm shifts in submerged landscape archaeology.

2.2 Sea-level changes in the Late Quaternary

Sea-level changes across the late Quaternary were primarily affected by the progressive build-up of icesheets and their subsequent deglaciation, impacting the archaeological record for both Pleistocene and Holocene archaeological sites. The evidently cyclical nature of global climate change and glacial periods led to the hypothesis that the impacts on Earth's positioning relative to the sun affected long-term climate change, and these impacts were responsible for establishing the beginning and end of glacial cycles. Milankovitch (1930) assessed the variation in Earth's orbital movements, and how this affected the extent to which solar radiation reached Earth's atmosphere. These cyclical orbital movements became known as Milankovitch cycles (or Croll-Milankovitch cycles after the earlier works of Croll 1875). Milankovitch cycles include: 1) eccentricity (the shape of earth's orbit); 2) obliquity (the angle of the earth's axis tilted relative to the orbital plane); and 3) precession (the direction of earth's axis of rotation). These factors are accepted as responsible for the timing of glacial cycles, and thus also affect sea-level change over time. Global sea-level change, driven by Milankovitch cyclicity, can be locally modified by geomorphic or tectonic processes (producing changes in relative sea level). Global sea-level curves are now generally well established, for both the Quaternary period and at a more detailed level, the Last Glacial Cycle (Waelbroeck et al. 2002; Grant et al. 2014), however this remains a recent advantage and over the course of the development of submerged landscape archaeology, there has also been a push to refine sea-level curves (Fig. 1).

The dating of drowned coral reefs around Barbados by Fairbanks (1989) indicated that maximum sea level was −125 m at 18 ka, and that this lowstand may have persisted for several thousand years. Reefs are demonstrated to be an excellent indicator of sea level, and radiocarbon and U-series reef chronologies have allowed for detailed views of deglaciation following the LGM (Yokoyama et al. 2001; Peltier and Fairbanks 2006). After Fairbanks (1989), deeper corals at this location were analysed, and these indicate the LGM may have begun in this place as early as 26 ka (Peltier and Fairbanks 2006). Additional sea-level reconstructions from the Huon Peninsula in Papua New Guinea provided greater detail on the later part of the record (Chappell and Polach 1991). While higher resolution proxy data remains important to clarify aspects of deglaciation and its impacts for relative sea-level change, a general global narrative of sea-level rise has been developed.

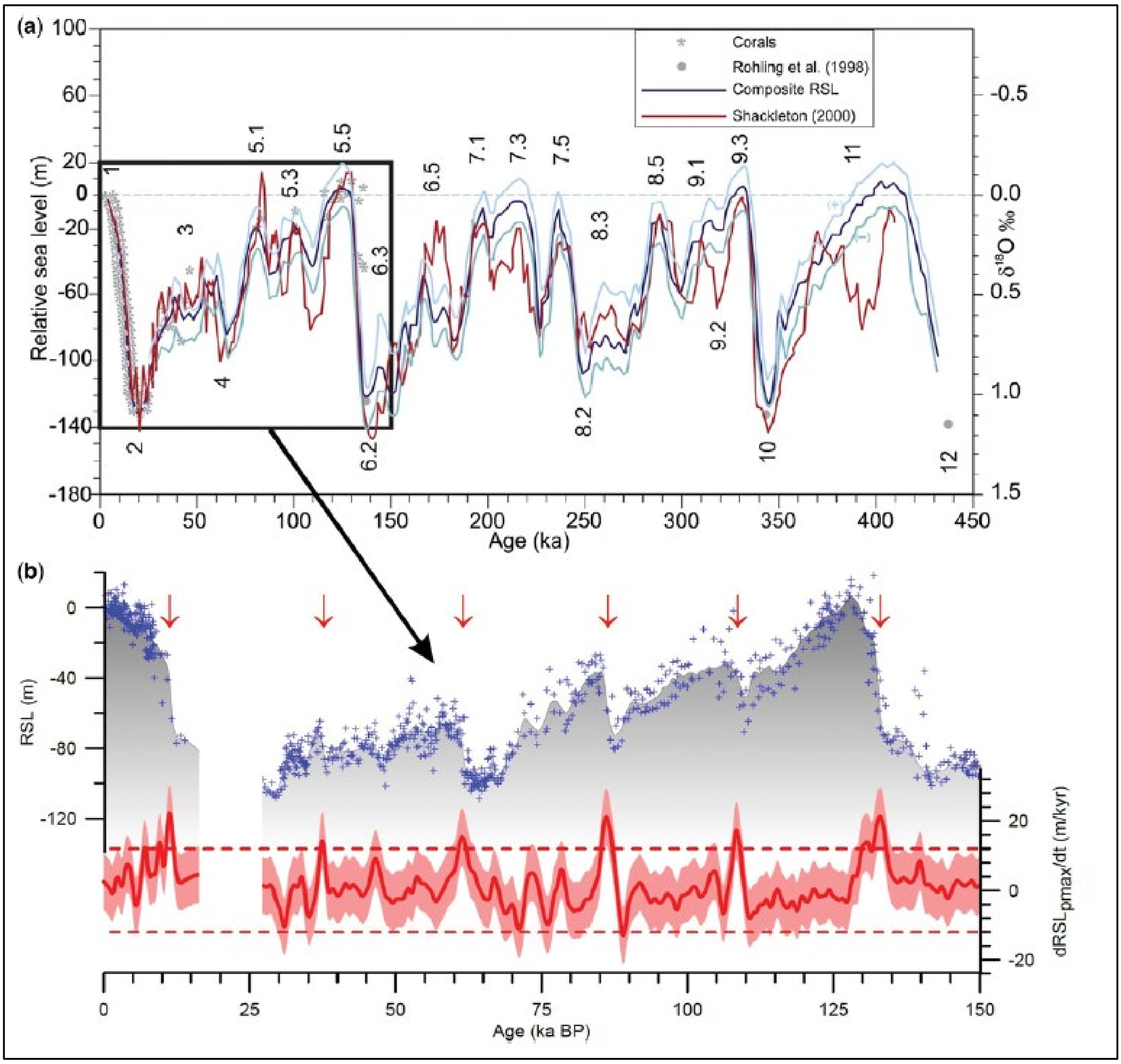

Figure 1: Sea-level changes during the Quaternary, from (Harff et al. 2016a:3), a) sea-level change over the past 450 kyr according to different oxygen isotopes with a relative sea level composite and confidence intervals (based on Rohling et al. 1998; Shackleton 2000) and b) RSL data (blue crosses) and probability of relative sea level (grey) over the past 150 kyr with rates of sea-level change (red line) and associated confidence interval (pink). The red dashed lines show higher rates of change, and high rates of sea-level rise are shown by the red arrows.

Changes associated with global deglaciation or changes to ice density are known as eustatic changes (Suess 1888; Wagreich et al. 2014). While eustatic sea-level change describes global changes, isostatic sea-level change describes the process in which land height increases and decreases, affecting sea level at a local scale. The earth and oceans respond to these processes through isostatic adjustments to ice and water loads, particularly in the Pleistocene and early Holocene (Murray-Wallace and Woodroffe 2014). Isostasy refers to the state of the Earth's crust mantle system to attain equilibrium with respect to mass, thickness, and surface relief. In areas where ice sheets formed, crustal uplift continues. The earth's mantle deforms as a process of isostatic compensation. Formerly glaciated regions continue to experience uplift today in response to the melt of extensive icesheets, leaving shoreline features emergent such as those found in Scandinavia (Steffen and Kaufmann 2005).

In discussions of relative sea level, there is either a rise or fall in sea level, however the land, sea, or both may have changed. For example, subsidence of ocean basins may contribute to relative sea-level, creating an apparent rise in sea level. A relative rise of sea level to land is a marine transgression, and these transgressive phases are identifiable by the presence of marine facies over formerly terrestrial sediments. Uplift must also be considered, in which the rate of sea-level rise may be greater than the uplift rate, flooding terrestrial environments and creating transgressive facies. Relative fall in sea level is a regression, resulting from the global lowering of sea level (eustatic), or local uplift which may occur based on glacio-isostasy, hydro-isostasy, and a variety of tectonic processes. Local determinations are crucial in the assessment of sea levels, such as mean sea level which describes the time-averaged elevation of the sea surface with respect to land, and in particular, a fixed datum over time ranging from one month to an 18.6-year nodal cycle (Pugh 2004). Additionally, in the assessment of sea-level change at a relative level, sediment accumulation and erosion must also be taken into account (Laws et al. 2020). Sediment aggradation (which describes vertical accumulation as opposed to lateral sediment accumulation) occurs under gradual inundation, in which the influx of terrigenous sediment is in balance with relative sea-level rise, creating the vertical building of coastal barriers (Evans 1979). Marine regressions throughout the Quaternary were predominantly caused by the formation of continent-scale ice sheets (Peltier and Hyde 1987). Coastal landforms and sedimentary successions that form in response to the seaward shift of the coastline, as a fall as in sea level, are considered products of forced regressions (Posamentier et al. 1992). Regression may also refer to coastal sedimentation (progradation) resulting in an apparent retreat of the sea from the land, even though sea level may or may not have changed.

In eustatic sea-level change, glacio-eustasy refers to the changes caused by the growth and decay of ice sheets. At the LGM, an additional 13% of the surface of the Earth excluding Antarctica was covered by ice (Flint 1971; Williams et al. 1998). The icesheet thickness exceeded 2.5 km across extensive areas of the Fennoscandian Icesheet, and over 3 km for the Laurentide icesheet on the North American continent (Boulton et al. 1985; Lowe and Walker 1997). The maximum sea level lowering in the far-field of the icesheets, including Australia, is approximately −121 to −130 m at the LGM (Bard et al. 1990; Yokoyama et al. 2001). These estimates are less than model calculations of estimates of water locked in ice, such as the Williams et al. (1998) estimate that eustatic sea level should have reached −154 m. Due to the response of continental shelves to varying water loads, the value predicted and the values observed are considerably different. Over the last glacial cycle, the increase in ice volume prompts the lowering of sea level, however this becomes more complicated when assessing change created by dramatic events over short intervals.

Geographical variation in relative sea-level change is accounted for by models of hydro-isostasy. The role of hydro-isostasy is of particular relevance to sea-level studies in Australia, especially on coastlines adjacent to wide continental shelves including northern Queensland and South Australia (Lewis et al. 2013). In the postglacial record of Australia, sea-level rise was rapid, culminating in a sea-level highstand at 7 ka, with an additional 2 m of sea-level equivalent ice melting that followed, presumably from the Antarctic icesheet with some contribution from valley glaciers (Nakada and Lambeck 1989; Sloss et al. 2007). This was then revised by (Lambeck 2002), who suggested an estimate of 3 m eustatic sea-level rise. These studies demonstrate the continued influence of Antarctic Icesheet meltwater into the Holocene, with significant ramifications for coastal societies.

The wide expanses of land exposed at the LGM (up to −130 m) were landscapes inhabited by past human populations globally, and these territories may play a significant role in understanding past human movement and coastal habitation. At the same time, the rapid sea-level rise flooded these lands, requiring the reconfiguration of boundaries, social connections, and understandings of the environment. In north Eurasia and North America, these changes to sea level were amplified by glacio-isostatic uplift, which is caused by loading and unloading of ice and seawater on the crust of the Earth (Murray-Wallace and Woodroffe 2014). In addition to the economic and cultural impacts on past populations, sea-level change has impacted the preservation of archaeological material that remains for research. The emerging focus of site formation processes for underwater archaeological sites has suggested that for the remarkable preservation of organic material that is possible in submerged sites, these sites may also be subject to more destructive processes.

2.3 The archaeology of submerged landscapes: a concise history

Given the methodological focus of this thesis, a review of the history of submerged landscape research is required. This is first addressed broadly through the chronology of the discipline, spanning earliest observations of submerged landscape archaeology potential, through to shifts in approaches across the 20th and 21st centuries. Having addressed the broad chronology of the discipline, additional regional context is provided for several different regions, and this provides the background as to why Israel and Denmark were selected as the primary points of comparison for a project devoted to submerged landscape methodology.

2.3.1 A brief history

The chronological development of submerged landscape archaeology begins with a long history of observations of the impacts of sea-level change, with intermittent bursts of interest and activity, often hampered by a lack of resources for further investigation. The earliest observations of the potential for submerged landscapes to yield information about ancient humans date to the late 18th century. In Europe, researchers identified terrestrial deposits underwater, as well as anthropogenic material in inter- and subtidal environments. In Cornwall, submerged forests were described by Borlase (1758), and the nature of submerged forests became a recurring theme in scientific research across the British Isles, including the landmark publication by Reid (1913). Reid (1913) called on archaeologists and geologists to investigate these submerged forests, and highlighted the potential to illuminate the human past through the study of submerged landscapes. Crawford (1927) published a study of inter- and subtidal remains found on the Isles of Scilly, and highlighted the broader significance of these finds that could allow for a greater understanding of past societies. Burkitt (1932) then published a Mesolithic harpoon that was recovered from the Leman and Ower banks of the North Sea. Although these findings indicate a long-standing scholarly interest in submerged landscapes, further research of these areas only took place much later. Many of these early works focus on the British Isles and around the North Sea (Clark 1932), and created an interest in the submerged environment and emphasised the need for interdisciplinary research of these underwater sites to understand their formation and their importance for human history. The Mediterranean is also among the regions where submerged landscapes were investigated, with Blanc (1940) reporting bone breccia cemented to the walls of sea caves at Palinuro, Italy.

By the early 20th century, the costly and logistically challenging nature of underwater research emerged as an obstacle, in addition to the impact of the Second World War. A shift occurs in the late 1940s and 1950s, in which scuba diving became available to the wider public. Over the course of the 1960s, numerous archaeological discoveries took place under water on a global scale, including Pavlopetri in Greece, Tel Hreiz and Neve-Yam in Israel, the karstic sinkholes of southern Florida, and submerged Mesolithic settlements in the Baltic. These finds all drove further interest in researching prehistory found under water, with both archaeological and geological significance. Sturt et al. (2018) reviewed the state of publications in submerged landscapes, and noted that four areas accounted for most publications between 1960 and 1980, including Northwest Europe, North America, the Baltic, and the Mediterranean. In particular, North America has a strong history of research, but a history that is also not often widely acknowledged. According to Sturt et al. (2018), this is a symptom of a tradition of ‘siloed’ submerged landscape archaeology, which maintained heavily regional focuses with little international collaboration. While this critique of regional bias may remain relevant in the present day to an extent, much of the research area has flourished with an increase in interdisciplinary and international collaboration.

Over the course of the 20th and 21st century, the research of submerged environments and settlements progressed with the development of high-resolution remote sensing, archaeological survey and excavation methodologies, and increased collaboration between geologists and archaeologists. The regional context surrounding these developments is outlined in the following sub-sections, with a series of case studies ranging from global leaders in the discipline (mostly in Europe and the eastern Mediterranean), to locations of high potential where further research is required. Australia and its history of underwater archaeology is discussed in greater depth in the following chapter, to better explain why submerged landscape potential in this location has been often recognised, but not often pursued.

2.3.2 Europe and the Near East

Submerged prehistoric sites have been investigated in Europe for over four decades, with the potential of the continental shelf established substantially earlier. This long-term commitment to research eventually aided in the efforts of the SPLASHCOS network, Submerged Prehistoric Archaeology and Landscapes of the Continental Shelf (2009–2013), supported by the European COST Office. Among the achievements of SPLASHCOS is a database of all recorded submerged sites in Europe and beyond, which now contains over 2000 sites. The database indicates the vast number of sites, ranging in age from 1 mya to 5 ka, and from depths of −140 m to intertidal deposits. Although submerged settlements have been located across Europe (and its Near Eastern Mediterranean neighbours), Denmark accounts for an extensive number of sites (or find locations), with optimal preservation evident in many cases. Similarly, this rate of preservation of otherwise fragile materials (including plant material) is apparent off the Carmel Coast of Israel. In many ways, despite their vastly different depositional environments, these two areas appear to have environments particularly conducive to the preservation of submerged prehistoric material. Numerous sites have also been recorded in the North Sea, and this area is reaching a similar state to that of Israel and Denmark to shift to answering larger cultural questions surrounding the populations that inhabited the now-submerged regions. Unlike any of their European counterparts, both south-west Scandinavia and the Mediterranean coast of Israel have developed explicit methodologies for submerged prehistoric sites, with the abundance of submerged settlements identified allowing for studies of material culture, diet, marine exploitation technologies, hunting patterns, freshwater access, and demography. Although the submerged prehistory of Europe is extensive, for the purposes of this literature review, the Baltic, Eastern Mediterranean, and North Sea regions have been selected as examples of areas where submerged landscape archaeology has an especially long-standing history in Europe.

The North Sea

Among the earliest works describing submerged landscapes is Reid (1913), which put forth the idea of a land bridge between Great Britain and the European mainland in what is now the North Sea (Fig. 2). This early work indicated that the archaeological record on land reflects modern boundaries of land and sea, rather than the environment of the past, and that a substantial amount of the archaeological record could lie beneath the sea. Over a century later, the submerged landmass known as Doggerland has been researched extensively, yielding both archaeological finds and palaeoenvironmental data. After Burkitt (1932) first reported a Mesolithic harpoon, some of the first finds reported from this area are from the British and Dutch areas of the North Sea, and were dated to the Mesolithic (Louwe Kooijmans 1971). From this point, research has been conducted to reconstruct the drowned landmass of Doggerland, with the 'Europe's Lost Frontiers Project' (Gaffney et al. 2017) investigating the past environment. While the North Sea shows a long history of research interest, the observations of Reid (1913) and others were not able to be investigated thoroughly until decades after their initial publication. However, this research tradition has gradually created a detailed picture of the archaeological record, with more elaborate research questions surrounding landscape use and subsistence strategies emerging.

Figure 2: the Dogger Bank and approximate coastline according to the lowest submerged forest identified by Reid (1913).

A notable outcome of research efforts in the North Sea has been the focus on building collaborative partnerships with industry. Many finds from the North Sea were dredged by fishers, or located through bottom trawling operations. Off the Dutch coast, at Rotterdam harbour, a collaborative investigation was carried out to ensure the recording and protection of any submerged prehistoric finds during the extension of the harbour. This was carried out with a pre-disturbance seismic sub-bottom profiler survey (Vos et al. 2015), and then followed by controlled grab sampling on the Mesolithic site identified in the geophysical survey (Moree and Sier 2015a). In the United Kingdom, the study of Area 240 provided similar opportunities to develop a partnership with offshore industry to further the understanding of submerged prehistory (Tizzard et al. 2014). Although grab sampling is more destructive than core sampling, the chances of locating archaeological material are significantly improved in areas where strata with artefacts are located near the seabed surface. However, grab sampling is limited by its lack of stratigraphic and palaeoenvironmental context to the finds it acquires. Some of these issues can be countered by geophysical techniques, which are able to map the seabed and below the seabed.

The Baltic Sea

Due to the complex isostatic rebound and periodic damming of the Baltic Sea prompted by the retreat of Scandinavian Ice Sheet, the area is associated with a range of preservation conditions for submerged landscape archaeology. According to SPLASHCOS, Denmark has the majority of sites in the Baltic, at 1699 find spots[1], followed by 142 sites in Germany, 83 in Norway, and 44 in Sweden (Bailey and Jöns 2020). Numerous recorded site locations correspond with single finds, or unstratified, out of context artefacts, however the area remains highly prospective for stratified, in situ archaeological deposits. Although Norway borders the North Sea, it has more in common with other areas of the Baltic than with counterparts in the North Sea. These common features include a comparatively short archaeological timeframe, compared to elsewhere in Europe. In the Baltic region, humans first inhabited the area following the retreat of the Scandinavian ice sheet, with the earliest dates for occupation c. 16 ka (Pedersen et al. 2018). Very few sites corresponding to this time period exist in the Baltic area, and even fewer have been identified underwater. From the point of colonisation, however, it is clear that coastal resources and settlements play a crucial role in Mesolithic lifeways in the Baltic (Fischer 2007). In the underwater archaeological record, examples of organic preservation can be identified, including wood and plant fibres which may not otherwise preserve in contemporaneous terrestrial deposits (Grøn and Skaarup 1991; Andersen 2013).

The Baltic Sea is among the largest inland seas in the world, and is a brackish basin connected to the Atlantic Ocean via the North Sea. The Baltic was created by the gouging of basins by ice movement, subsequently erasing evidence of surface deposits that date earlier than the LGM. The Baltic Sea then underwent a series of phases, including the Baltic Ice Lake phase, the Yoldia Sea stage, the Ancylus Lake stage, and the Littorina Transgression (Christensen 1995; Astrup 2018). In the Baltic, palaeoshorelines vary in their elevations. While some shorelines were lifted past sea-level

[1] The 1699 find locations reported in the SPLASHCOS viewer includes 1686 that are registered in the Danish Agency for Culture and Places, however both of these estimates represent a 'minimum' number of finds. Fischer (2004), for example, referred to 2003 find locations and indicated that this is also likely not comprehensive of the total possible sites in Danish waters.

rise, providing evidence of early use of coastal resources on terrestrial sites, some shorelines were lifted and then partially inundated due to sea-level rise overtaking the role of uplift (particularly in Norway), and other areas were entirely submerged (Denmark, Germany, Sweden). In Denmark, the tilting of the land through isostatic adjustment has created concentrations of terrestrial Ertebølle (late Mesolithic) sites on uplifted shorelines in the north, with similarly aged sites on drowned shorelines in the south.

The earliest of the entirely submerged shorelines date to the early Mesolithic in southern Sweden (Scania and Blekinge), however the best-studied deposits in Denmark date to the middle and late Meoslithic, and to the late Mesolithic and Neolithic in Germany (Fischer 1987; Jöns et al. 2007; Andersen 2009; Hartz et al. 2014). While an interest in submerged landscapes relates to chance finds by military and recreational divers in the mid-20th century, by the 1970s systematic underwater excavations of prehistoric sites was underway with the Langelands Museum works south of Funen, and the excavation of Tybrind Vig (Skaarup 1983; Andersen 1985). Many sites were located based on a fishing model developed by Fischer (1993; 1995a), for the identification of submerged sites based on modern fishing sites and by extrapolating landforms associated with productive fishing, with the assumption that similar areas would have been exploited by prehistoric populations. This model became known as the Danish Model (Benjamin 2010b), and will be evaluated in greater depth in Chapter 5.

The Eastern Mediterranean

In the Eastern Mediterranean, submerged archaeological sites have been located off the coasts of Israel and Cyprus. The Israeli submerged settlements represent some of the best-studied groups of submerged sites in the Mediterranean, and these sites have been surveyed and studied over several decades. In Cyprus, only preliminary surveys have been carried out, but these have yielded archaeological finds and show potential for further research. The Israeli case study forms a central part of this thesis, and the development of an Israeli Model for submerged prehistory will be discussed in Chapter 5, however a brief overview is provided here.

Along the Carmel Coast of Israel, 23 sites have been located at depths up to −12 m (Wreschner 1977; Galili and Weinstein-Evron 1985; Galili et al. 2020). Middle and Upper Palaeolithic finds that do not appear to be in situ have been identified. In situ Neolithic village sites have been found in depositional environments with excellent preservation of organics, allowing for the recovery of structures, installations, human burials, woven fibres, plant material, wooden artefacts, and faunal remains (Galili and Weinstein-Evron 1985; Galili and Schick 1990; Horwitz et al. 2002; Galili et al. 2005). This extensive baseline of data has enabled palaeodemographic studies of the late Neolithic in Israel, and further research could indicate connective aspects of this area to the broader Levantine region (Eshed and Galili 2011). Another noteworthy aspect of these sites is the development of a 'Mediterranean Fishing Village' model, evident in the establishment of a dual fishing-farming economy in the submerged settlements, dating to the oldest Neolithic site of the submerged Israeli sites, Atlit-Yam (Galili et al. 2002). Extensive studies have been conducted on these sites, allowing for a better understanding of domestication and the development of agriculture in the coastal Southern Levant (Galili et al. 2020). Water wells excavated in these sites inform the study of the issue of freshwater access. Water wells have been used to address archaeological research questions, as well as providing an upper and lower limit for sea level to reconstruct the past environment (Galili and Nir 1993). Due to the excellent preservation of organics, human burials have allowed for a greater understanding of burial practices and palaeodemography (Galili et al. 2009). Also due to the preservation of organics, the exploitation of olives and the production of olive oil and table olives has been recorded in the submerged Pottery Neolithic/Chalcolithic villages (Galili et al. 1997; 2021). Additionally, human adaptation to sea-level rise has been recorded in the form of a coastal defence at the site of Tel Hreiz, with a seawall to protect the settlement (Galili et al. 2019a). Submerged inland, freshwater sites are also known in Israel, indicated by the partially submerged site of Ohalo II in the Sea of Galilee, dating to the Late Epipalaeolithic (Nadel and Werker 1999; Zohar et al. 2018).

Off the coast of Cyprus, the study of submerged landscape archaeology is in a preliminary stage with only indicative finds. However, survey finds have allowed for the identification of sites off the coast of the terrestrial Late Epipalaeolithic site of Aspros, as well as Nissi Beach. The reported survey strategy was to follow river valleys into the offshore environment, and treat these as areas with a greater likelihood of habitation in the early prehistory of Cyprus (Ammerman et al. 2011; Ammerman 2020). Aspros Dive Site C has provided a lithic assemblage, which Ammerman (2020) have tentatively dated to the Epipalaeolithic based on typological assessments of the material. It should be noted these artefacts do not appear to be found in situ, and the dating of this material remains somewhat speculative.

2.3.3 The Americas

In the Americas, research of submerged landscape archaeology has mostly been conducted in North America (Easton et al. 2021; Garrison and Cook Hale 2021), with fewer sites known in South America, though these will be discussed. In North America, prior to 1950, research was mostly confined to Florida and California, and generally by avocational archaeologists. From 1950 onward, Florida emerged as an early leader in the study of submerged prehistoric sites, including Wakulla, Little Salt, Warm Mineral Springs, and sites along the Aucilla River (Clausen et al. 1975; Webb 2006). These sites demonstrated the potential for the preservation in organic deposits, and extensive progress was made in understanding palaeohydrology, geomorphology, and changing sea levels in relation to submerged prehistoric finds. In California, Moriarty (1964) led research offshore, however these results were seldom published and lagged behind the systematic process that had been developed in Florida.

By the 1970s, systematic work was carried out underwater in Florida, such as the Douglass Beach site where an eighteenth-century shipwreck was associated above a Late Paleoindian to Archaic period site (Murphy 1990). Salvage works at this site prompted a systematic approach to documenting the material. On the West Coast, Moriarty et al. (1975), following research at La Jolla, suggested the potential for sites to preserve further offshore. However, no intensive provenance studies of the hundreds of artefacts recovered from the sea were carried out. In the California Channel Islands, the systematic recording of finds along the Santa Barbara Channel began in 1974, and around 150 artefacts were recorded (Hudson and Howorth 1985). It is also during the 1970s that development of formal methodologies was carried out on the northern Gulf of Mexico, where regional studies of submerged landscapes took place, including a pilot study in the Gulf of Mexico Outer Continental Shelf to determine a predictive model for site preservation (Coastal Environments et al. 1977). To the north, in Alaska, Dixon (1979) carried out the first remote sensing search for submerged sites on the continental shelf of Beringia. Similar to the Danish Model, the predictive model used to inform this search was based on documented foragers' land use to identify preferable features for habitation.

The 1980s saw advances in theory and excavation techniques, as well as increased use of assessments of high probability zones for site preservation offshore. This particular era also developed on previously established site formation processes. It is also at this point that federal agencies became involved in submerged landscape archaeology, such as BOEM's partnerships which funded and participated in the study of submerged sites (Garrison and Cook Hale 2021). Formalised research at Aucilla River in Florida also commenced in the 1980s, beginning the long-running excavation of the Page-Ladson site (dated 14.5 to 11.7 ka) (Halligan et al. 2016; Webb 2006). At the nearby Apalachee Bay, Dunbar et al. (1988) put forth a hypothesis that Paleoindian and Archaic sites would be focused around sinkholes, springs, and outcrops of chert associated with lithic procurement. Following systematic survey, over two dozen sites were located in Apalachee Bay based on these criteria (Dunbar 2016). Research continued in the Gulf of Mexico, with sedimentological and geochemical data collected to determine 'onsite' and 'offsite' sediments (Gagliano et al. 1982). In Canada, research of subtidal prehistoric sites had begun, such as the Little Qualicum River site located on Vancouver Island (Bernick 1983). Easton (1988) followed with a study of the Straits Salish reef-netting site. At the national and provincial level, submerged landscapes were included in management practices, and Parks Canada's underwater unit surveyed Paleoindian and Archaic period areas along the Bruce Peninsula, in Lake Huron, using sidescan sonar and diver survey from 1988 to 1991.

From the 1990s, methods in submerged landscape archaeology in North America have continued to maintain an emphasis on geoarchaeology, and the testing of predictive models (Braje et al. 2019; Cook Hale et al. 2019; Faught 2004; Fedje and Christensen 1999; Josenhans et al. 1997; Lemke 2021). In addition to submerged marine sites, submerged sites have also been located in the Great Lakes. A hunting structure was located in Lake Huron, dating to 9 ka (O'Shea et al. 2014). The development of underwater archaeology in North America follows a similar trajectory to that of underwater archaeology in Australia, as a discipline that primarily focused on shipwrecks and historical features before including pre-contact sites.

In the development of submerged landscape archaeology in the Americas, South America remains somewhat underrepresented in this research effort. Argentina has an extensive record of coastal archaeological sites and has been studied from the 1980s onward (Borerro and Barbarena 2006). With isolated exceptions, no submerged finds have been reported. However, the isolated examples provide some encouragement for submerged landscape archaeology research, in addition to the intertidal La Olla site on the Pampean coast of Argentina, dated 7400 to 6480 (^{14}C years) (Bayón and Politis 2014). La Olla is located at the limit of the lowest tide and is covered by sand the majority of the time, although it is exposed every few years. This site includes wooden artefacts as well as faunal remains and indicates the preservation potential of the submerged environment in this area. Additionally, in Chile, the discovery of the GNL Quintero 1 paleontological site in Quintero Bay yielded a faunal assemblage that dated to the Late Pleistocene, indicating that the preservation of faunal remains is possible in this location and that other organic remains are likely to preserve as well (Carabias et al. 2014; Mendoza et al. 2018; Flores-Aqueveque et al. 2021). Further research is certainly required to better understand submerged landscapes in South America, with relevance for research questions of coastal resource use and human migration.

2.3.4 Eastern Asia

Currently, the only published submerged archaeological site in Eastern Asia is in Tokonami harbour, Takashima, Japan. In a 1992 rescue excavation of the harbour, a variety of archaeological remains were identified including objects associated with Mongolian fleets, earthenware dating to the end of the Jomon period, and 19th century ceramics. These finds ranged in depths of −22 m to −17 m, and at −25 m, a submerged Neolithic (Early Jomon) site was identified (Hayashida 1993). Ceramic sherds were typologically associated with the Early Jomon period, and then reinforced by radiocarbon dating. The lithic artefacts also indicate the likelihood that this site has remained in situ, and is not a secondary deposit. Alternate explanations for the site's location were also presented in the original site report, and the possibility of a mudslide or substantial tectonic movement were eliminated as options due to the lack of associated evidence in sub-bottom profiler data, and that the site is not situated near any faults (Hayashida et al. 2014). Scattered finds from later time periods have also been identified in Japan, with the Takashima site regarded as an exemplary indication of potential for similar sites offshore.

Indicative finds have also been found off China's coast, in the Taiwan Strait. Fishers have trawled numerous Pleistocene mammal bones, including mammoths. These finds were located at around −80 m. Additionally, Chang et al. (2015) reported the discovery of an archaic hominin jawbone, which although could not be dated, is assumed to date to 190 ka. A considerable research priority for submerged landscape archaeology is understanding human migrations along formerly coastal margins. Southeast Asia, including Indonesia and the Philippines, have emerged as key areas to investigate these questions. The area last exposed at the LGM would permit migration as far to the Wallace Line, and potentially into the Philippines. Several hominins migrated through this area, in addition to the seafaring voyage undertaken for the first humans to arrive in Australia (indicated by the earliest current dates of occupation based on Madjedbebe, see Clarkson et al. 2017). Coastal resource use and adaptation is well-recorded from the Pleistocene onwards in this region, indicating a deep-time connection to the sea. Despite the area's role in these migrations, currently no material has been found on the seabed, nor has any intensive search been undertaken. A preliminary study of relevant datasets in the Philippines was undertaken by Rickard (2017). Rickard (2017) highlighted the need for higher resolution data (specifically, LiDAR), the need for a regionally specific sea-level curve, and suggested that systematic survey could be prioritised at the underwater cave formations of the Central Visayan Region. Submerged landscape archaeology in Eastern Asia, based on these examples, demonstrates immense potential for further research.

2.3.5 Africa

Two locations of the African continental shelf have been researched intensively for submerged landscape archaeology: the crossing of the Red Sea from Africa to Arabia, and Table Bay in South Africa which yielded an assemblage of Acheulean handaxes. The latter currently indicates the only direct evidence for human occupation of submerged landscapes, however the former contributes an abundance of palaeoenvironmental data and information for the reconstruction of submerged landscapes. At this point, relatively little submerged landscape research has been carried out, although the subaerially exposed continental shelf of Africa contributes the least added area at lowest sea level compared to all habitable continents, adding only 4% to the present landmass (Flemming 2021).

The Red Sea crossing has been the focus of several investigations of hominin migration (Groucutt et al. 2015; Bailey et al. 2019), and in particular the role of coastal environments in human dispersal. Bailey et al. (2019) carried out an extensive diver-based survey in conjunction with geophysical survey at the Farasan Islands, however no direct evidence of submerged archaeology was located.

The importance of marine resources is, however, apparent based on the thousands of shell middens located onshore (Bailey et al. 2015; Bailey et al. 2019). The possibility for sea crossings in this area persists for thousands of years at a time, and perhaps for tens of thousands of years. The significance of this possible sea crossing is emphasised by comparisons with fauna, as baboons arrived in SW Arabia from NE Africa, and based on the swimming capabilities for short distances of terrestrial mammals there is little reason to suggest that hominins were not also capable of this.

At Table Bay in South Africa, divers excavating Dutch East India shipwrecks identified Acheulean handaxes embedded in oxidised fossil soils and on gravel overlaying bedrock. Werz and Flemming (2001) describe the artefacts as in situ finds, given the lack of rolling evident on the artefacts which retained sharp edges. Typologically, the finds are dated to 500,000 years old, and may be among the oldest submerged archaeological finds in the world. A significant aspect of this discovery is the demonstration of the survival of lithic artefacts underwater over the course of several glacial cycles. While research of the submerged African continental shelf is an emerging area, various research efforts to reconstruct past environments offshore are ongoing, as can be seen in research of the Paleo-Agulhas Plain (De Vynck et al. 2020; Wren et al. 2020).

2.3.6 The state of research: present and future challenges for the discipline

Over the course of the development of submerged landscape archaeology, there has been substantial improvement to remote sensing technologies to identify sites and evaluate their context. However, despite these leaps in technology, it is challenging to remotely identify material at the scale of individual artefacts, although there are experiments by Grøn et al. (2018) that may indicate a signature from worked flint artefacts in sonar data. Alongside the development of technology is the development of predictive models, and modes of practice to increase the likelihood of identifying submerged landscape archaeology, which allow for the identification of landforms which are more likely to yield archaeological sites and material. These are evaluated in this thesis as case studies, and the knowledge from this is then applied to an Australian context.

2.4 Theoretical frameworks relevant to submerged landscape archaeology

2.4.1 Landscape theory and distributional archaeology

Landscape archaeology was used by Aston and Rowley (1974), and emerged through the 1980s and 1990s as a theoretical framework (Rossignol and Wandsnider 1992; Tilley 1994; Knapp and Ashmore 1999). The conceptual basis for landscape archaeology has undoubtedly changed since its inception. The earliest uses of landscape archaeology tend to address questions of settlement distribution and site patterning, carrying the assumption that archaeological sites reflect both their natural environment and a community's cultural needs. Over time, there was a gradual shift towards understanding social landscapes, which aimed to understand symbolic configurations rather than maintaining an entirely environment focus.

Landscape archaeology allows researchers to extend their view past the individual site, to its environment and cultural context. Landscape approaches are well-known in prehistoric archaeology, however specific definitions of a landscape approach are often elusive. Anschuetz et al. (2001) provide a comprehensive review of landscape theory as applied in archaeology. They argue for the determination of distinct sub-categories under the landscape archaeology umbrella, and suggest that the abundance of terminologies and uses of 'landscape archaeology' raises concerns for its ultimate usefulness as an archaeological theoretical framework. Instead, they argue for clarification of the variety of landscape approach used, which they categorise as either settlement ecology, ritual landscapes, and ethnic landscapes. Anschuetz et al. (2001) also state that there are four foundations underpinning all landscape archaeology: that 'landscape' is not synonymous with natural, and cultural systems can be incorporated; that landscapes are worlds of cultural products but that this remains distinct from a 'built environment'; that landscapes are the arena for all of a community's activities; and that landscapes are dynamic where each community contributes their meaning of a landscape to places.

Settlement ecology refers to the observed patterns of land use, occupation, and transformation of an archaeological site. Settlement ecology emphasises patterns of change in land use and occupation over time, and as such is a perspective commonly deployed in submerged landscape archaeology. This particular variation of landscape archaeology identifies aspects of the natural environment which are crucial, in addition to raw materials required for a healthy community, and items required for trade and exchange. Settlement ecology also addresses the issue of risk management, through the changes to technology, economy, and social structure. Risk management underpins many submerged landscape archaeological studies, as archaeological material is analysed to identify changes within communities to adapt to the pressures of rising sea level. Settlement ecology operates as a leading theoretical approach in many studies of submerged archaeological sites, given the ability to focus on economic factors, social structure, and adaptation. An example of this is the site catchment analysis approach by Vita-Finzi et al. (1970). Ritual landscapes are represented by socially prescribed orders by which a community defines its occupation of a site, and may be connected with patterns in spatial distribution of ritual features. In the case of the study areas presented here, ritual objects are found throughout the submerged settlements of the Carmel Coast.

It would be reductive to view the inherent vagueness of landscape archaeology as insurmountably problematic, as this vagueness allows for the integration of theoretical approaches, and could bridge the divide between processual and post-processual archaeology. Landscape archaeology remains often criticised by post-processualists as seeming too narrow and environmentally deterministic, limiting the understanding of human agency in processes across time (Trigger 1986; Knapp 1996). More recent iterations of landscape archaeology allow for detailed interpretations of social landscapes, as well as 'interpretive' approaches with connections to phenomenology (Shanks and Tilley 1987). Some examples indicate that the theoretical framework of landscape archaeology also facilitates dialogue between archaeologists and Indigenous communities (McNiven 2016). Other approaches which utilise landscape archaeology as a basis might be better suited to addressing effective work with Indigenous communities in coastal regions (such as the seascapes framework).

Landscape approaches are also used to address technology and subsistence in relation to ecological adaptation, connected to the theoretical basis of human behavioural ecology. These are questions closely connected with settlement distribution, and led to the emergence of concepts including 'non-sites', 'offsite', and 'distributional archaeology'. Landscape frameworks in archaeology also correlate with the use of GIS to address archaeological questions. The analysis of landscape-scale questions in the digital realm allows for unparalleled visualisations, and possibilities to determine the locations of submerged sites. With the predictive modelling and site mapping, several issues within landscape archaeology are emphasised. A primary concern of this thesis is the nature of commission (false positives – something non-archaeological is identified positive), and omission (false negatives, where known sites are not recognised in predictive models). The other issue is generally referred to as the Modifiable Areal Unit Problem (MAUP), describing a type of results that arise due to arbitrary scales, boundaries, or decisions in the categorisation of data. The decision of scale, site boundary, and how to classify information is frequently encountered in submerged landscape archaeology, and archaeology more broadly. Harrower (2013) warns against "archaeological gerrymandering". Although this is an over exaggeration, the issue of boundaries and categorisation becomes an important factor in submerged landscapes, particularly as submerged settlements do not always function as a 'time capsule' of human history and instead are affected by the environment and landscape in which they are formed.

The research of submerged landscapes is concerned with individual archaeological finds and features, and their place within a broader landscape. These may be consolidated into sites as a measure of classification, but submerged landscape archaeology allows for a variety of scales in research ranging from individual artefacts to the landscape in which they were sourced and used. Indeed, the use of the term 'submerged landscape archaeology', implies the use of landscape archaeological approaches, but in the underwater context by addressing the inundated environment as it would have been at periods of lower sea level.

Binford's call to extend archaeological research beyond site boundaries gave rise to several theoretical frameworks for archaeology associated with landscape archaeology (Binford 1980), including off-site archaeology (Foley 1981), non-site archaeology and siteless archaeology (Dunnell and Dancey 1983; Dunnell 1992), and distributional archaeology (Ebert 1992). For the purposes of this literature review, these concepts are reviewed beneath distributional archaeology as an umbrella term. Each of these concepts corresponds with regional-scale research, with descriptive methods aiming to better understand the formation of sites across a landscape.

It is this consideration of archaeological artefacts and features within a landscape that is often central to many studies of drowned landmasses. The basic premise suggests that human activity cannot be localised to points within the landscape but is instead continuous across a region. This premise may have appeared controversial at its initial publication, but conceptually is relatively incontestable at this point in archaeological research. Distributional archaeology suggests that activities will vary across a landscape, with different tasks taking place depending on the location of different resources, with varying material signatures.

In regional-scale studies of surface lithic scatters throughout the 1990s and 2000s, non-site and distributional archaeology provided a way to organise human activity over a landscape as opposed to the restriction of assigning material to arbitrarily defined sites (Young 1987; Schofield 1991). Critique of non-site approaches include that it is prone to generalisations of the archaeological record, reducing human action to basic categories. Pollard (1998) also suggested that although not explicitly stated by most proponents of this framework in surface scatter studies, there was a tendency to view mixed scatters and spatially amorphous material as corrupted data, where the capacity for categorisation is significantly reduced.

The proponents of distributional archaeology sought to confront the commonly held idea that sites as units of spatial analysis were reliable indicators of distribution. Additionally, it was a framework to respond to the subjectivity in survey-based work that affected site delineations, that units of analysis are teleological, and the assumption that sites of the same temporal phase were strictly contemporaneous (creating the issues of MAUP). It sought to emphasise that studies of spatial distributions of artefacts, features, and other material remains were more accurate.

The concept of non-sites connects to broader discussions of survey methodology, including the nature of opportunistic vs systematic survey methods. This is especially relevant for submerged landscape archaeology, where local knowledge and finds located by chance have contributed extensively to the discipline. Systematic survey methods are necessary to provide appropriate representation of an area, particularly in a regional-scale, landscape analysis. However, some regions may not allow for this approach, for reasons of safety, cost, and time. The flexibility of the notion 'site' in distributional archaeological approaches may be laudable, but presents the issue that most archaeological analyses require some level of boundary and categorisation for the sake of practicality and usefulness of the data. It is important to evaluate how archaeologists set these boundaries, but it is unwise to dismiss them altogether.

There is, however, value to distributional archaeology in submerged landscape archaeology. The approach can be implicitly identified in projects, particularly those concerned with palaeoenvironmental reconstruction. Landscape approaches are perhaps implied in the term ‘submerged landscape archaeology’, involving the reconstruction of landscapes at periods of lower sea level. While this sub-discipline of marine archaeology has not often involved explicit discussions of theoretical paradigms (with some exceptions, see Lemke 2021), greater focus on landscape approaches and their use may contribute to more significant theoretical contributions in submerged landscape archaeology. In many cases, non-site approaches, where the archaeological material is viewed as continuous across a landscape, could also contribute meaningful interpretation. However, it is also important to avoid generalisations in the interpretation of material through the use of landscape approaches and distributional archaeology, and thus these approaches should be utilised with clear boundaries and definitions. In developing survey models for submerged landscape archaeology, creating a way to understand the distribution of material culture across a landscape is crucial to the establishment of models capable of accurately predicting submerged environments.

2.4.2 Seascapes and maritime cultural landscapes

Connected to the concept of landscape theory in archaeology, this section will analyse the history and function of ‘seascapes’ and ‘maritime cultural landscapes’, and their relevance for understanding seafaring and interaction with the sea in the context of submerged landscape archaeology. The ‘seascapes’ approach was established as a subsidiary within landscape archaeology as a mechanism of viewing ‘the land from the sea’. It is mostly associated with the archaeology of Indigenous peoples, and partly intended to challenge concepts of seascapes which echo European capitalist understandings of human-sea interaction (McNiven 2008). The Eurocentric understanding of seascapes is particularly evident in some works, which tend to describe the sea as a barrier and a hindrance (Washburn and Lancaster 1968). These early studies also focus on the material aspects of the sea, and productiveness and procurement above all else and often to the detriment of understanding non-tangible aspects of human-sea interaction. ‘Seascapes’ are often ambiguously defined, and sometimes used interchangeably with the idea of ‘maritime cultural landscapes’ (Westerdahl 1992).

McNiven (2008) provides the most cohesive definition of seascapes:

> “the lived sea-spaces central to the identity of maritime peoples. They are owned by right of inheritance, demarcated territorially, mapped with named places, historicized with social actions, engaged technologically for resources, imbued with spiritual potency and agency, orchestrated ritually, and legitimated cosmologically.”

Within this definition of seascapes, McNiven (2008:151) acknowledges that the fluidity of seascapes presents “unique challenges for cultural inscription and place-marking not generally encountered for landscapes”. This acknowledges a research gap in this framework that the analysis of submerged landscapes could improve upon, by identifying anthropogenic features at depth that can be connected with other features in the coastal environment.

The seascape concept emphasises the role of spirituality in the past, and is also connected to the idea of spiritscapes. In this, certain marine features and fauna are given immense significance, and often express human cognitive and social qualities. The sea is also given these human qualities, and can react consciously. Archaeologically, seascapes include a variety of intangible material, and in some cases presumably ethnographic analogies. This can include maintenance rites for subsistence species of flora and fauna, mortuary rites, song and dance, initiation rites, hunting rites, and other activities intended to control elements of the sea (wind, waves, tides). For example, Van de Noort (2004) describes two sewn-plank boat sites within the framework of seascapes. From this analysis, it is established that one site is associated with everyday life and devoid of ritual material, while the other appears imbued with meaning and significance in relating to ancestors. In a different context, Barber (2004) advocates the use of the study of seascapes to research Māori fishing, where archaeological interpretations traditionally favoured extractive opportunism without consideration for the role of ritually proscribed behaviour and subsequent possible restrictions. McNiven (2004) also highlights the possibility to integrate seascapes with foraging and subsistence focused studies. This study demonstrates the role of marine stone arrangements, not functional for the procurement of fish, as possible structures that play a spiritual role in promoting extensive fish migrations. Stone fish traps are found throughout Australia, thus far at mean sea level, so it is important to consider that stone structures found in a subtidal environment might not necessarily represent procurement strategies, despite their resemblance to a structure intended for marine resource exploitation (Rowland and Ulm 2011).

The idea of seascapes provides a way to view submerged landscapes in association with the coast and sea as imbued with spiritual and social meaning, rather than solely as production and economically focused landscapes. This thesis largely focuses on marine and coastal economies, given its reliance on the development of an Australian mode of practice based on past frameworks that have prioritised marine-based economies in their research of past societies. It must be recognised, however, that not all submerged sites will show evidence for marine adaptation, and may have relied on inland resources instead. Marine adaptation is not altogether economic in its cultural manifestations, and spiritual and social impacts are likely in all areas impacted by sea-level rise. Caution must be taken in this approach in relation to Indigenous Australia, recognising that Indigenous Australian tradition is not static and changed substantially over the course of millennia. Nonetheless, McKinnon et al. (2014) emphasised that the concept of seascapes could provide a voice to Indigenous cultures, as opposed to Eurocentric approaches, as it focuses on the sea itself rather than the relationship of sea to land . While the seascape framework is often applied in both pre-contact and post-contact scenarios, it is generally associated with Indigenous contexts, and should not be recognised as the only available theoretical framework.

The 'maritime cultural landscape' (MCL) was described by Westerdahl (1992) and aimed to place maritime material culture within its broader landscape. This framework is relevant to studies of coastal and submerged hunter-gatherer archaeology. The original proposed 'maritime cultural landscape' includes shipwrecks, land remains and monuments, place names, sailing route names, and transport routes as parts of a combined cultural landscape focused on maritime lifeways. The maritime cultural landscape approach is less commonly used in studies of hunter-gatherer societies, with some notable exceptions (Braje et al. 2019; Gusick et al. 2019; Lira 2017). Both seascapes and the maritime cultural landscape approach sought to shift the boundary of landscape archaeology from solely being concerned with the land. Specifically, Westerdahl aimed to avoid the particularism that had emerged in underwater archaeology, focused extensively at the time on studying shipwrecks as disembodied entities and time capsules rather than features within a broader landscape.

The concept of scale and scope of cultural landscapes is an inherent issue in both seascapes and maritime cultural landscapes. While the approach of seascapes focuses on the sea as an entity in and of itself, this approach also risks disembodying the sea from its cultural, social, and economic landscape. At the same time, the maritime cultural landscape approach is often criticised for its sheer breadth. Tuddenham (2010:5) poses the question: "Does the maritime cultural landscape as a concept bridge a division between land and sea, or does it maintain a gap?" Maritime archaeology is criticised for its lack of engagement with theoretical paradigms, and uncritical use of maritime cultural landscape frameworks is another symptom of this lack of theoretical interaction. With appropriate systemisation and clearly defined boundaries of what the theory accomplishes, MCL framework provides a useful theoretical framework to assess material culture with the understanding of how it relates to its surrounds and cultural influences. Without appropriate systemisation, however, it is rendered vague and contributes little critical assessment of material culture. Neither seascapes nor maritime cultural landscapes have been relied upon as a theoretical underpinning for this thesis research. However, these frameworks which are well-known in coastal (terrestrial) archaeology have demonstrated significance in their effectiveness as theoretical approaches, and could inform a less economically focused exploration of submerged landscapes in the future.

2.5 Site formation of underwater archaeological sites

The theoretical associations with submerged landscape archaeology address the ways in which material may be interpreted, however it is also important to consider the nature of the material, whether it is in situ or re-deposited, and what processes may have impacted the material. This requires an understanding of site formation processes in underwater environments. Site formation processes can be broadly categorised as cultural (anthropogenic), and natural (physical, chemical, biological) (Goldberg et al. 1993). Cultural and anthropogenic processes include the disturbance and use of a site by human activity (including modern industry), as well as excavation by archaeologists. There are also physical processes to be considered, such as abrasion by wind and water in coastal and terrestrial contexts, as well as tides and wave action in the submerged context (Jazwa 2017:184). Chemical processes include soil chemistry, as well as chemical reactions, which tend to occur at different rates in the marine environment compared to the terrestrial environment. In terms of biological processes, bioturbation takes place at submerged settlements in both their coastal and initial terrestrial context, as well as following inundation by marine organisms (Goldberg 2006). It should also be noted that type of sediment and the rate of sediment deposition are additional factors contributing to site preservation and formation in the marine environment. Stewart (1999:565) argues that “the single most important factor is the rapid burial of sediment” which enables a protective element between the archaeological remains and the impacts of the ocean. Flemming et al. (2017a:66) revisit this assumption and demonstrate that while rapid rate of sea-level rise is not a singularly determining factor, rapid burial does appear to increase chances of site survival.

The best understood factors contributing to site formation processes in the underwater environment tend to relate to shipwrecks. Although sites submerged by postglacial sea-level rise are subject to different influences and they form a unique aspect of underwater archaeology, there are lessons to be taken from shipwreck studies of site formation processes. For example, shipwreck site formation may include biodeterioration or biofouling. This may also be relevant to submerged landscape archaeology in sites where organic materials have also preserved, depending on the depositional context of the material. Shipwrecks may be viewed through ‘time capsule’ approach, which treats shipwrecks as unique and created by a specific set of circumstances, deposited in a specific place (Muckelroy 1978). This approach considers shipwrecks as ‘snapshots’ of the past, comparable to the ‘Pompeii premise’ (Binford 1981). Although shipwrecks typically reach equilibrium with their surrounding environment and the concept of a ‘time capsule’ may remain accurate in this case, shallow water shipwrecks do not tend to fall under this category and may often be broken up and scattered. O’Shea (2002) states that these shallow wreck sites may, ironically, have more in common with “conventional terrestrial sites”, and the view of terrestrial sites as palimpsests of distinct, short-term events. Formation theory underpins the majority of these studies, dealing with two key issues: 1) how archaeological material passes from a systematic context to an archaeological context, and 2) what happens to the archaeological material over time, with particular consideration as to how this impacts where archaeological material may be located (Schiffer 1987).

O'Shea (2002) observed that in underwater archaeology, site formation was characterised by an extensive, although usually implied, anecdotal understanding of factors that affect sites, including storms, waves, marine borers, looters and treasure hunters, and reef formation. The issue according to O'Shea (2002) is the inconsistent manner to which these factors are considered in archaeological research, creating an "illusion of site uniqueness". The need for inter-disciplinary dialogue between archaeologists and geologists/geomorphologists remains, although the increasing use of geoarchaeological frameworks has developed this capacity and improved the issue of inconsistency and anecdotal understanding of site formation.

Muckelroy's (1978) model acted as a key work for site formation of underwater materials, although focused on the site formation of a wreck site, evaluating the degradation of a wreck site and its subsequent impact on the distribution of material on the seabed. Muckelroy (1978) was then revisited by Ward et al. (1999) to model shipwreck site formation with a predictive component. Ward et al. (1999) observe that Muckelroy's (1978) approach fails to acknowledge the difference between process-related and product-related attributes, viewing wreck disintegration as a singular process with an underlying premise that things simply fall apart over time. Their revised model proposes an assessment of physical deterioration, biological deterioration, and chemical deterioration, at various time points of the wreck's existence on the seabed including the wreck event, following wrecking, storm onset, storm peak, and immediately following a storm.

While fewer studies have been dedicated to the mechanisms of site formation for submerged landscapes, there are noteworthy exceptions. Flemming (1983) assessed the 31 sites submerged by sea-level rise recorded at the time, representing an international comparison of depositional environments and preservation characteristics. At the time, it was noted that all sites were in shallow water above −10 m, with two sites at −20 m in Florida. From this, Flemming (1983) established six types of location that were conducive to the preservation of sites: 1) Lagoons and estuarine environments; 2) sheltered alluvial coasts; 3) exposed equilibrium or accumulating beaches; 4) submerged caves; 5) karstic caves and sinkholes; and 6) islands and archipelagos. While this statement encompasses a broad range of potential site locations, the factor common to all (except 3) is the wind fetch which is restricted to a few kilometres by the topography and adds a protective element to archaeological sites. More recently, Flemming et al. (2017a) indicate the importance of understanding site survival to predicting where archaeologists are most likely to encounter a submerged archaeological site, and they question the possibility of drawing together large volumes of field data to derive general rules for site preservation.

Flemming et al. (2017a) describe a hypothetical deposit consisting of unconsolidated strata of terrestrial deposits, with anthropogenic material in clastic deposits of soil or sand, or in cohesive deposits such as clay or peat. The main concern for destruction in this example is direct waves of height of 1 to 2 m, which can partially erode the site. For short-term processes, even in cases where sea level rise is occurring at a rate of metres per century, the archaeological site could be exposed to breaking waves for the duration of that century. The impact of storm surges and other associated destructive processes requires further investigation, however preliminary work by Marks (2006) suggests that lithic material may be more resistant to these impacts than might otherwise be assumed.

In general terms, some ‘rules’ for site formation are acknowledged as better for increased preservation potential. The more time that the sea has occupied a particular level, the further the coastal process is likely to have eroded landward, relative to the gradient of the surface. As such, preservation of material on a short-term scale may depend on the local topography, and the response of lateral sediment transport. Protective environments can be created by barrier features which prevent large waves from destroying the site, or by the offshore gradient dissipating water movement at the seabed, reducing a wave’s erosive capacity. Other protective situations include longshore drift and beach progradation, which provide an overlying screen. In cases where the protective screen is hard rock, or a rocky island, the sheltered site could preserve for several glacial cycles. In many cases, processes may be combined. When the shore adjusts to the impact of rising seas, local response may protect sites, yet the local response may vary to the extent that a site located a few kilometres away might be destroyed.

Protection may also be enhanced where the stratum is buried in several metres of soil, sand, peat, or rock, and this cover prevents wave action from eroding to the archaeological site. However, this does create the issue in which the cover that protects the site could also prohibit the site’s discovery. Erosion of the overburden counters this issue, or excavation for industrial purposes such as that observed at Area 240 (Tizzard et al. 2014). Additionally, rapid submergence allows for improved site preservation compared to slow inundation, which provides increased time for waves and currents to affect the distribution and preservation of archaeological material (Stewart 1999:572). Sedimentation may contribute to preservation in areas where rivers deposit a significant amount of sediment over a site, to provide protection against the prevailing ocean conditions, though it should be noted that rates of sedimentation tend to change over time. The site formation processes of submerged sites are complex due to their dynamic nature, as the sites originate in a terrestrial environment and are then gradually altered by an eventually marine environment.

Rate of sea level may also contribute to additional protection to archaeological sites. Flemming et al. (2017a) suggest that rapid vertical change, for example, 2.5 m over a century during a meltwater pulse, as opposed to the 0.6 to 1 m range since the LGM, is more likely to allow for site preservation given the reduced exposure to wave action, though it is not to be considered an ‘absolute’ for preservation of a site and variable preservation may exist in spite of the rate of sea-level rise. The one exception to this rule is in the event of a deposit that is already buried by several metres of overlying terrestrial, and then later marine sediments, requiring a significant erosive force to eventually damage the archaeological layer. It should be noted that waves can exert force to several metres depth, and in such a case the site would be exposed to similar forces and still possibly destroyed if exposed to 100 years of rapid sea-level change or several centuries of slow change. When combined with low gradient, protective topography, and rapid horizontal transgression of the surf zone, this likelihood of site preservation may be enhanced.

A common, but recently contested, method for assessing the effects of sea-level rise is the Bruun Rule (Bruun 1962). The Bruun Rule is used to calculate shoreline recession in response to sea-level rise. The formula suggests that, as sea-level rises, the shoreface adjusts itself to re-establish equilibrium profile, and thus the sediment at sea level is eroded, and deposited down-slope of its original location. Flemming et al. (2017a) highlighted the problematic assumption for submerged landscape archaeologists that all sea-level rise results in beach recession, and they suggest that "if this were universally true, no prehistoric deposits would survive transgression, unless very deeply buried." The Bruun Rule has received substantial criticism otherwise (Cooper and Pilkey 2004), particular for the issue that the formula ignores longshore transport. Alternative models have been suggested, including the R-DA model (Davidson-Arnott 2005), and a modified Bruun Rule by Rosati et al. (2013), though these maintain the assumptions that limit the suitable use of the Bruun Rule. Another alternative is the Dynamic Equilibrium Shore Model (DESM) for its ability to quantify coastal geomorphological change based on three-dimensional source-to-sink transport models (Deng et al. 2014).

Substantial experimental work and geoarchaeological research is required to better understand the formation of submerged landscape archaeology sites. However, some basic preservation criteria can be established. High input of sediment to the coast may be beneficial for the preservation of the material, but with the limitation of hindering visibility of the site. Low energy coastlines remain optimal for site preservation, although further research is required to understand the preservation capacity of higher wave and current energy. Protective barrier features may also contribute to preservation potential. Early and fast diagenesis may not be the central factor to preservation, but does appear to assist in protecting archaeological material. In this thesis, these assumptions of site formation processes are outlined for their possible contribution to the state of research in Israel, Denmark, and Australia, and their role in developing predictive models and modes of practice.

2.6 Conclusion

This chapter has outlined the general background to sea-level and environmental change across the timescale of this thesis' focus, in addition to discussing the main examples of submerged landscape archaeology across the world. This creates a summary of the history of the discipline, and outlines the challenges for its present and future. From this, it is important to consider the broader theoretical implications for submerged landscape research, as well as the understanding of site formation and geomorphological processes influencing the preservation of archaeology. This allows for a comparison of the development of the discipline globally, to the discussion of the development of submerged landscape archaeology in Australia. This sets out the background for an original comparative study of a series of international case studies alongside Australian material, which will be addressed in the following chapter.

3.0 LITERATURE REVIEW: AUSTRALIAN ARCHAEOLOGY AND SUBMERGED LANDSCAPE RESEARCH

> "We need an archaeology of the sea to match that of the land. This does not simply mean maritime archaeology as it is currently defined (though this will play a part), but an archaeology of the dynamics of maritime culture at a given period." (Broodbank 2000:34)

3.1 Introduction

In the context of Australian archaeology, submerged landscapes may be crucial in addressing several major research questions. The first of these questions relates to the routes which people took to arrive in Sahul and then spread across the continent of Australia. The second relates to the understanding of coastal lifeways and maritime subsistence strategies across the Holocene and into the late Pleistocene of the Indigenous Australian archaeological record. These are both questions that are reliant on material that is now underwater, and have relied on the archaeological record that has preserved on land. The coastal environments and a review of sea-level rise contextualises the environmental backdrop to Australian submerged landscape archaeology, and is then discussed in terms of important archaeological research questions for the Australian context, and the role of settlement dynamics in contributing to submerged landscape archaeology. This chapter emphasises the research gaps in Australian archaeology that can only be addressed through the research of submerged landscapes.

3.2 Coastal environment and sea-level rise

The continent of Australia and its coastal processes can be broadly categorised by the northern coast and the southern coast. The former characterised by meso to macrotidal environments, low sea waves, and southeast trade winds, and the latter's microtidal environments with variable swell and west through south winds (Short 2020). From the LGM lowstand, approximately one-third of the continental landmass of Sahul was lost to postglacial inundation, in addition to a mid-Holocene sea-level highstand (Fig. 3). The present coastline of Australia encompasses around 30,000 km of open shoreline, including sandy beaches, rocky shores, reefs, and mangrove flats. This present level was achieved at around 7 ka. Geologically, approximately half the coastline is bedrock, rocky shore. Across the continent, erosion of hinterland bedrock has allowed for the transport of terrigenous sediments to the shelf, through extensive river networks. Palaeoshoreline features can be found across the shelf, as demonstrated by Brooke et al. (2017), with concentrations at 30–40 m and then 50–60 m depth.

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Figure 3: Australian and the submerged continental shelf (Brooke et al. 2017).

The geology of the Australian coastline ranges in 3500 Ma old granites, to recent sediments. A mesoscale study by Porter-Smith and McKinlay (2012) assessed the Australian coast and shelf morphology, and concluded that straighter coastlines were associated with homogenous lithology in comparison to mixed lithologies, interpreted as lithology as a determining mechanism for coastal complexity, with wave energy acting as a secondary mechanism. Although regionally specific reviews of geology exist across Australia, Johnson (2004) provides a review of Australia's geology.

Tides across the Australian coastline vary substantially, ranging micro- (< 2 m), meso- (2–4 m), macro- (4–8 m), and mega- (> 8 m). The first comprehensive overview of tidal ranges and systems in Australia was presented by Easton (1970). The highest ranges can be found on the Northwest Shelf of Australia, with a mean spring tide range of > 8 m, and also the southern Great Barrier Reef platform with a range of > 7 m in Broad Sound (Fig. 4). The southern coasts of the continent tend to be microtidal, with the exception of the Bass Strait and the South Australian gulfs with a range of 3 m (Church and Craig 1998). While tidal currents may be strong in areas with a high tidal range, they may also be strong in mesotidal regions and microtidal gulfs, such as the Gulf of Carpentaria. In the Torres Strait and along the Great Barrier Reef, narrow channels and shallow sea depths create strong tidal currents (Condie and Harris 2005).

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Figure 4: Wave and tide dominated coastlines of Australia, with tidal ranges shown (Porter-Smith and McKinlay 2012).

Tropical northern Australia is subject to high-energy cyclones, whereas the southern coast may experience low-pressure storm events (Condie and Harris 2006). Wave height data for the northern coasts indicates that significant wave heights are < 1.5 m for up to 70% of the time, whereas in the south, wave heights are > 3.5 m for up to 50% of the time (McMillan 1982). Storm surges occur across the Australian coastline, however the highest surges reaching several metres occur across northern Australia, including the Northern Territory, Gulf of Carpentaria, and eastern Queensland coast (Silvester and Mitchell 1977). Some of the highest recorded surges include 13.7 m in Bathurst Bay, Queensland, and 9.2 m in Cossack, Western Australia (Nelson 1975). Groote Eylandt in the Northern Territory as well as the southern Gulf of Carpentaria are subject to high risk of damage by storm surge, due to the shallow shelf and microtidal environment, as well as their exposure to tropical cyclones.

The Australian continent is relatively tectonically stable, and is located in the 'far-field' of former ice sheets. This relative stability is due to the intra-plate setting of the Australian continent, in addition to the lack of impact from major ice sheets. In terms of sea-level rise, no glaciation occurred across Australia during human occupation, and thus the impact of isostatic effects is minimal. Nonetheless, some smaller effects were caused at periods of lower sea-level by hydro-isostasy. The coast of Australia is bounded by a shallow continental shelf of variable width, which has experienced limited hydro- and sedimentary isostasy during the Last Glacial period. The effects of hydro-isostasy on tectonic uplift are below 10 m, and generally below 2 m, based on the study of MIS 5e formations (Murray-Wallace 2002). In southern Australia, a more tectonically active region has experienced 0.7 m of uplift over the Holocene (Cann et al. 1999). The lack of tectonic uplift is in contrast to adjacent plate-margin locations, including the Huon Peninsula in Papua New Guinea which has undergone uplift of 20–30 m over the same period. The major factor of sea-level rise for the Australian continent remains eustatic sea-level change. Although the continent shows a high level of tectonic stability, the elevation of a Holocene highstand varies around the margins. The variation is caused by the timing in the response of ocean basins and shallow continental shelves to the increased ocean volumes following ice-melt.

The interpretation of past sea level in Australia has involved the use of several different proxy datasets, including erosional features, coral reefs, sedimentary facies, beachrock, mangrove remains, encrusting organisms such as barnacles and oysters, and foraminiferal assemblages. At the Last Glacial Maximum, initial estimates for the lowstand reported −130 m at 18 ka (van Andel and Veevers 1967). This was revised by studies in both the Great Barrier Reef and New South Wales (Phipps 1970; Veeh and Veevers 1970), with further confirmation by Murray-Wallace et al. (2005) that sea levels were at least −120 m. Yokoyama et al. (2001) provide an estimate of −124 m at 20 ka, based on cores collected in Joseph Bonaparte Gulf in the north of Australia. Although a general range of −130 to −120 m has been accepted for the LGM lowstand, the precise timing of the LGM in Australia remains debated. The LGM has been projected to have lasted 3–4 kyr (Barrows et al. 2002), with cooling focused around 21 kya (Williams et al. 2009). An extended LGM record has also been observed in eastern Australia (Petherick et al. 2017).

Following deglaciation, rapid sea-level rise and then a slowed rate have been identified in association with Meltwater pulse 1A and the Younger Dryas, respectively. Ooid deposits in shallow marine environments in the Great Barrier Reef indicate a sea level of −100 m at 16.8 ka (Yokoyama et al. 2006). Based on mangrove facies across the Sunda Shelf, sea level then rose 16 m across 300 years from 14.6 ka to 14.3 ka (Hanebuth et al. 2009). The rate of postglacial sea-level rise and the development of sea-level curves at local scales remains an ongoing area of investigation. A highly episodic rate of Holocene sea-level rise was suggested based on data from the Great Barrier Reef (Larcombe et al. 1995), based on radiocarbon dates from coastal and marine sediments. The sea level drawn from this data indicated a series of stillstands or minor falls, and a possible 6 m regression at 8.2 ka. Harris (1999) countered this assertion based on the lack of evidence for a 6 m regression evident in ice sheet models, or the $\delta^{18}O$ record, followed by the critique that the error terms associated with the data did not allow for the precision required to identify the proposed oscillation (Hopley et al. 2007). However, while a regression according to the Great Barrier Reef data remains debated, there may have been a rapid sea-level rise at 8.2 ka, based on a sea-level reconstruction from Singapore (Bird et al. 2007).

While sea level in Australia reached modern level at a time between 9 ka and 7 ka (Lambeck and Nakada 1990), regional variability can be seen in the various studies from across the Australian coastline in the mid-Holocene highstand (Dougherty et al. 2019). Fairbridge (1961) reported a sea-level rise of 3 m in Western Australia, and further research followed on the east coast (Hails 1965; Gill and Hopley 1972; Belperio 1979). At this time, evidence was mainly drawn from low-resolution sea-level indicators including beachrock, mangrove deposits, shell beds, and peat. Nonetheless, the timing of the mid-Holocene highstand appears to vary. Chappell (1983) confirmed a 1 to 1.5 m sea-level rise in northeast Australia, based on coral microatolls. Most studies around Australia indicate a mid-Holocene sea-level rise and then highstand of 1–2 m above present levels (Baker et al. 2005; Sloss et al. 2007; Lewis et al. 2013), however a rise of 2–3 m may also be present in some cases. Further investigation is required to evaluate the late Holocene sea-level fall, to determine whether a smooth fall occurred, or the sea-level highstand was prolonged and then followed by a later fall, or whether there was an oscillation of sea level between the mid and late Holocene.

The changes in sea-level rise across Australia from the LGM had a profound impact on Indigenous people living on the now-submerged coastlines (Williams et al. 2018). Reconstruction of these past environments contributes to better understanding the ways in which people interacted with their environment, and also provides important data to predict locations where archaeological sites may preserve.

3.3 Underwater archaeology in Australia

McCarthy (2006:8) writes, "The fact that maritime archaeology in Australia did not begin with the study of the Aborigines [sic], of their inundated or inter-tidal material culture might appear strange." Instead, as McCarthy (2006) acknowledges, it began with shipwrecks. Maritime archaeology in Australia remains skewed towards the study and management of historical features and artefacts over submerged Indigenous sites, and addressing the origins of underwater and maritime archaeology in Australia is important to identify the ways in which this affects underwater archaeology in the present. The development of views on submerged landscape archaeology, and how it has been approached and discussed, are reviewed through a thematic content analysis in Chapter 7, however it is important to review the general history of underwater archaeology in Australia to understand this chronology.

In Australia, underwater archaeology was museum-led to start, following the discovery in the mid-1960s of five East India ships off the coast of Western Australia (McCarthy 2006). The Western Australian Museum led the study and protection of these vessels. This emergence of underwater archaeology in Australia coincided with the infancy of recreational diving, though shipwrecks appear to have captured the public's imagination even at this early stage in maritime archaeology in Australia. In 1969, the Western Australian Museum Act was amended, and staff at the Western Australian Museum were hired to act as 'site police', now seen as the earliest attempts in Australia to manage and protect underwater cultural heritage. These actions were partly driven by concern across the late 1960s as the location of East India wrecks became more widely known, and looting became a significant factor.

The lack of suitably trained personnel in Australia soon became an obstacle to effective management, and the Western Australian Museum sought out candidates from Europe. The Western Australian Maritime Archaeology Act was passed in 1973, allowing for the protection of all wrecks before 1900. This also encompassed the Australian Netherlands Committee on Old Dutch Shipwrecks Agreement, creating a logistical framework for the cooperation of the State of Western Australia, and the governments of the Netherlands and Australia. This also allowed for the creation of the Australian Netherlands Committee on Old Dutch Shipwrecks, a committee that included international scholars and Australian historians.

A legal challenge to the State Act eventually gave rise to the federal Historic Shipwrecks Act 1976 (McCarthy 2006). At this time, the Maritime Archaeological Association of Western Australia (MAAWA) emerged as a group of recreational divers with an interest in maritime heritage. This group assisted the WA Museum in research and in the development of shipwreck databases. Around the same time, the Society for Underwater Historical Research (SUHR) in South Australia was formed, undertaking research projects on wrecks and ports. Additional volunteer and recreational diver groups emerged across Australia, with some of these groups conducting survey and excavation for state heritage work, such as SS John Penn and Sydney Cove (McCarthy 1979; Atherton and Lester 1982; Lorimer 1988). It is clear from these examples that 'avocational' archaeologists played a significant role in the development of maritime archaeology in Australia, and by the early 1980s, most states had developed shipwreck management strategies and legislation. This allowed for the creation of 'shipwreck units', intended to be specialised researchers for the management of wrecks in Australian waters.

There remained an issue of trained personnel to undertake research, which prompted the WA Maritime Museum and the Western Australian Institute of Technology to establish a postgraduate course for maritime archaeology which ran until the 1990s. Most people enrolled in this course had little archaeological training, and by extension scarce knowledge of archaeological theory. Gould (1983) called for a greater emphasis on theory in shipwreck studies and questioned the lack of theoretical backing to research approaches demonstrated. This similar issue of a lack of training was also observed by Green (2004). Australian maritime archaeology courses thus eventually shifted from technically focused programs to those that incorporated instruction on archaeological theory.

Veth (2006) reviewed theoretical approaches utilised in maritime archaeology in Australia, including 21 studies that had an explicitly stated theoretical basis. Theoretical approaches included the Swiss Family Robinson model, colonial survival, neo-Marxism, historical materialism, and evolutionary ecology. The lack of theoretical engagement in maritime archaeology is observed on a global scale, but has been criticised in the Australian literature as well. McCarthy (1998) for example, was highly critical of the historical particularist/mitigation approach at the Western Australian Museum. By the mid-1990s, Hosty and Stuart (1994:17) write that the isolation of underwater archaeology from the rest of archaeology creates the issue of lack of theoretical engagement, in addition to an "ad hoc attitude to individual sites" and "lack of interdisciplinary exchange." This lack of engagement with theory is attributed by Veth (2006) to a legacy of "predominantly descriptive 'grey literature'".

Gradually, non-disturbance cultural heritage management became the preferred strategy for management of shipwrecks in Australia (Veth et al. 2013; Richards et al. 2016). Limited excavation was conducted, and data collection was primarily done through surface material survey and historical research throughout the late 1980s and 1990s. Public access to data soon became a priority, and was supported by the Commonwealth Government through the Historic Shipwrecks Program, responsible for directing project funding to the Australian states and territories.

On a theoretical basis, the past few decades have seen emphasis on the importance of understanding site formation processes, including the study of physical, chemical, and biological changes to wreck sites (Ward et al. 1999). This also allowed for the emphasis that wreck disintegration is not a unidirectional phenomenon. Shipwreck disintegration also became the focus to determine salvage strategy (Richards 2002). The concept of site formation processes is a matter that underpins both shipwreck archaeology, and submerged landscape archaeology, and its influence may have generated more interest around the latter specialisation in underwater archaeology in Australia.

From an ethical and legal perspective, among the earlier legislative frameworks for the protection of underwater cultural heritage in Australia was the Historic Shipwrecks Act 1976, which has since been replaced by the Underwater Cultural Heritage Act 2018. The former was introduced to protect all wrecks from lowest astronomical tide, to the end of the exclusive economic zone or continental shelf, depending which extended further. Viduka (2012) wrote that the Historic Shipwrecks Act 1976 no longer reflected the world's best practice, as outlined in the UNESCO Convention for the Protection of the Underwater Cultural Heritage 2001, nor was it effectively incorporated in the planning process at government level.

Aplin (2019) wrote an evaluation of both acts, and changes that the Underwater Cultural Heritage Act 2018 provided. Among the changes was a broadening of the term 'cultural heritage', as well as 'cultural significance', in line with other heritage legislation such as the Burra Charter. While the act has succeeded in the inclusion of historical structures and submerged aircraft that were not otherwise addressed by Historic Shipwrecks Act, the lack of acknowledgement of Indigenous heritage, and particularly sites submerged by sea-level rise, remains a weakness in its implementation. Shipwrecks and submerged aircraft are granted automatic protection in Commonwealth waters, while a submerged Indigenous site is only granted protection with ministerial approval. From a more theoretical perspective, Aplin (2019) hypothesises that part of the success or failure of the 2018 act will be its ability to protect intangible cultural heritage of Indigenous Australian communities, frequently overlooked by Western legal systems and creating legislation that is often tipped in favour of Australian colonial history. Aplin (2019) provides a case study of the Brewarrina fish traps, a series of stone-built fish traps located in the Barwon River in New South Wales, and estimated to be around 40,000 years old. The fish traps have been subject to neglect, and damage through the construction of a weir. Limited support was provided to the Traditional Owners to protect this site. The lack of prioritisation of maritime Indigenous archaeology looms as a central aspect of the flawed management of this site, and remains a key issue for the UCH Act 2018. Although submerged Indigenous sites may be protected under the act, it will not apply to sites located in State and Territory waters, creating an immense gap for heritage management in practice as a substantial number of sites are located in coastal State and Territory waters. The responsibility of protecting underwater Indigenous cultural heritage thus falls to State and Territory governments, and their ability to collaborate with Indigenous communities as well as the Commonwealth government to recognise the significance of underwater sites.

In Australia, the DHSC project is the first large-scale investigation that successfully located an Indigenous site below the low tide mark. However, other investigations of submerged landscapes are known across the continent, and contributed to the development of the DHSC project's strategy (Table 1). The first was the Sirius project, undertaken by Flemming (1982). Flemming (1982) explored the Cootamundra Shoals, located 240 km northwest of Darwin, with the knowledge that the shoals would have been high ground during periods of lower sea level, corresponding with the projected sea level for the earliest known habitation of Australia (c. 30 ka at the time). Cliffs, terraces, submerged reefs, and fossil beach ridges were surveyed, and substantial environmental documentation was accomplished, however no archaeological sites were located. Flemming (1982) suggested that significant results might be obtained with better technology than was available at the time.

Submerged landscape investigations of Australia			
Project Location	**Details**	**Outcome**	**References**
Sirius Project, Cootamundra Shoals, NT	Survey and core sampling of shoals north of Australia which may have served as an attractive location in peopling of the continent	No archaeological material found, however extensive environmental reconstruction	Flemming 1982; Flemming et al. 1986
Lake Jasper, WA	Survey underwater environment of a freshwater lake	Concentrations of flaked stone artefacts found at shallow depths and up to −10 m	Dortch and Godfrey 1990; Dortch 1997
Dampier Archipelago, WA	Survey seven ‘dive stations’ to assess submerged petroglyph potential	No material found, “shore-based approach” recommended	Dortch 2002
Quarry Site at Port Cygnet, Tas	Survey intertidal quarry to see if it extends to the sub-tidal zone	Deemed prospective but offshore sediment coverage was an issue, coring was recommended	Lewczak and Wilby 2010
Port Hacking, NSW	Survey rock overhangs up to −9 m	No surface material found, coring/dredging recommended	Nutley et al. 2016

Table 1: Projects undertaken to locate submerged Indigenous sites in Australia.

After the Sirius project, Dortch and Godfrey (1990) demonstrated that Indigenous archaeological material could preserve in freshwater settings, with the survey of Lake Jasper (Fig. 5). Drought conditions in 1988 prompted the drying of substantial parts of the lake, and tree stumps and flaked stone tools were identified as part of a pre-inundation landscape. In an initial 1989 survey, a shoreline survey was undertaken in addition to underwater survey, with further survey efforts to the submerged environment in 1990. The issue of site formation formed a major part of the goals of this research. The project at Lake Jasper drew attention to the preservation potential of organic material and stone tools in the underwater environment.

The survey by Dortch (2002) aimed to locate petroglyphs in the Dampier Archipelago (Murujuga) on submerged granophyre outcrops, based on the extensive rock art assemblages found on similar outcrops on land. This survey is significant to this research as the only previous underwater archaeological work assessing the potential for submerged Indigenous sites in the Dampier Archipelago. Prior to the fieldwork, a review of onshore sites was conducted to establish a basic predictive model of material that would survive inundation. According to Dortch (2002), this included rock engravings, quarry sites, and stone artefacts and material embedded in indurated carbonate deposits. Seven dive stations between −10 and −20 m were selected across the archipelago, and while no engravings were located, some rock faces without marine growth were located which supported the premise that rock art may preserve underwater. Based on this survey, a shore-based approach was recommended for future work (Dortch 2002), and it was concluded that locating rock art in the marine environment did not warrant the expenditure of a large sea-going expedition.

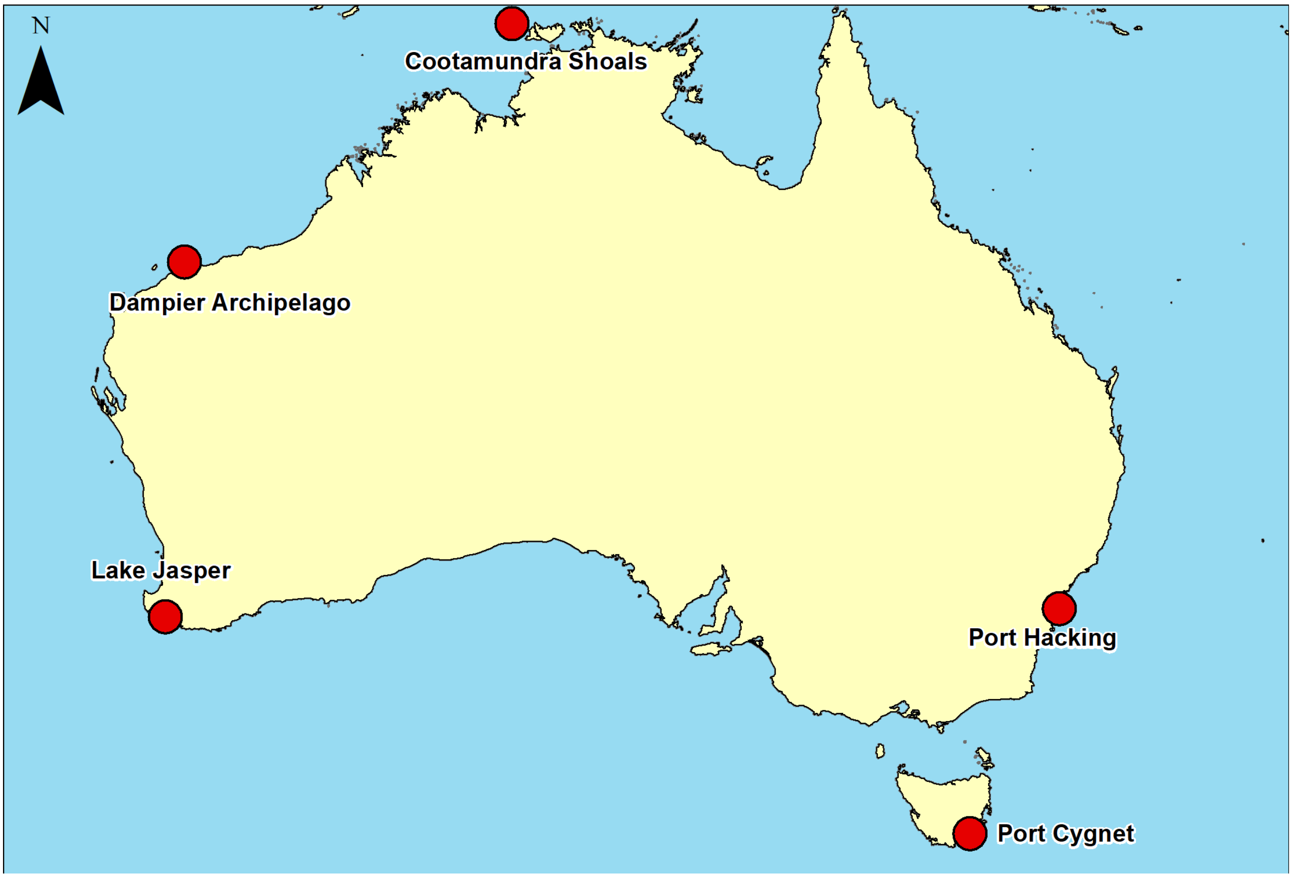

Figure 5: Map of submerged landscape archaeology research in Australia.

Both Flemming et al. (1982) and Dortch (2002) demonstrated that diver survey of archaeologically prospective areas conducted over a short time could be informative for preliminary research and reconnaissance of a study area. While Flemming et al. (1982) suggest that increasingly advanced remote sensing technology would contribute greatly to such investigations, Dortch (2002) recommends a shore-based diving approach as a sustainable option for a larger project. In these examples, a variety of 'high tech' and 'low tech' approaches were used to target and investigate prospective underwater locations with a submerged landscape context, however, the relative size of the study areas remains a major factor. Remote sensing and technological approaches are especially effective for the delineation of priority survey areas in larger, landscape-scale studies, which can then be assessed by diver survey.

To the south of Australia, a survey of Rocky Bay in Cygnet, Tasmania, was undertaken by Lewczak and Wilby (2010). The South East Tasmania Aboriginal Corporation (SETAC), representing the Traditional Owners of this area, received funding for the protection and management of archaeological sites, including an intertidal quarry located in Rocky Bay. In this case, SETAC wanted to know whether the intertidal material continued further offshore, and contracted Cosmos Archaeology to investigate the submerged areas of this location. Although further intertidal material was identified, and it was confirmed that the quarried boulders extended past the low water mark, no flaked artefacts were found in a subtidal environment, although Lewczak and Wilby (2010) describe the influence of sediment cover on the site and suggest that more intrusive methods including coring might yield encouraging results.

Nutley et al. (2016) investigated South West Arm, Port Hacking, in New South Wales to assess the potential for archaeological material in rock overhangs (rock shelter sites) to preserve underwater. Site prediction was based on the geomorphological characteristics of terrestrial rock shelters at South West Arm. The project was designed with a staged approach in mind, as follows: 1) understand submarine topography; 2) survey selected areas for potential rock shelters; 3) conduct a pre-disturbance survey of potential rock shelters; 4) carry out disturbance-based investigations of prospective locations. From the pre-disturbance survey, no surface material was collected however several rock overhangs were identified as prospective and warranting further research.

Nutley (2014) reviewed the state of research in studies of inundated Indigenous sites in Australia, including the Cootamundra Shoals survey and the Dampier Archipelago survey, and set forward potential preservation scenarios for various types of material culture. The proposed features include shell middens, carved trees, earthen circles, fish traps, stone artefacts, quarries, rock shelters, and rock art. Fish traps, quarries, and rock shelters are relatively resilient features, and Nutley suggested that these should be prioritised by future survey strategy emphasising the need for Australian archaeology to progress submerged landscape research by demonstrating submerged landforms associated with human habitation (see Nutley 2014). These predictions are similar to those put forth in the regionally specific example by Dortch (2002), as rock outcrops are both resilient features and features where evidence of quarrying would preserve.

Underwater archaeology in Australia remains strongly focused on shipwrecks, and has historically ignored the potential for submerged Indigenous material. However, there are noteworthy exceptions to this. These examples provide important guidance for ongoing work in submerged landscape archaeology in Australia.

3.4 The peopling of Sahul

The first people to have arrived in Australia crossed the sea, and initially walked on coastlines now submerged by sea-level rise. In the event that these submerged sites could be located, this may reinforce the understanding of the peopling of Sahul. People arrived in Sahul between 50 ka and 60 ka (Clarkson et al. 2017; Kealy et al. 2018), although some research puts forth later dates (Allen and O’Connell 2014; Allen and O'Connell 2020). Sahul is located at the end of the Southern Dispersal Route, which facilitated the movement of anatomically modern humans (AMH) from Africa at 100 ka, through southern Arabia, through Southeast Asian coastlines, and then into Australia. Balme et al.

(2009) write that this route and the eventual arrival in Australia facilitated the development of complex information exchange systems and symbolic behaviour, with significance for complex communication associated with boat-building and maritime technologies (Balme 2013).

Early models of the timing of the settlement of Sahul were initially constrained by the upper limits of radiocarbon dating (Roberts et al. 1994). The advent of optically stimulated luminescence (OSL), and the ongoing discoveries of Pleistocene sites in Australia, has allowed for these dates to be pushed further back into the Pleistocene (Veth 2017). Two prevailing views exist of the timing: a long chronology or a short chronology. The long chronologists consider the colonisation of the Australian continent to have occurred earlier, around 50 ka to 65 ka (Roberts et al. 1990; Clarkson et al. 2017; Hiscock 2017; Veth 2017). An OSL date at Madjedbebe indicates that the date of colonisation could be pushed back to 65 ka (Clarkson et al. 2017). The short chronology advocates suggest that colonisation occurred at between 45 and 50 ka, although likely at the older end of this scale (Allen 1989; O'Connell and Allen 1998; Allen and O'Connell 2003; O'Connell et al. 2018). A key component of the short chronologists' position is scepticism of OSL dates, arguing that the association of artefacts and dated sediments is not well supported.

A significant point in favour of the long chronology is the increasing number of sites with dates between 45 and 50 ka (Hamm et al. 2016; McDonald and Berry 2017; Veth et al. 2017). Although the short chronology advocates raise important points about taphonomy and context, researchers have addressed the concerns of sample integrity (Clarkson et al. 2018). Additionally, there are several sites with older dates located further into the continent and lower latitudes of Australia to support an earlier colonisation date based on the time required for the settlement of the continent. At the same time, a key argument of the short chronologists also revolves around dating, identifying the lack of dates in Wallacea that mirror the antiquity of the 65 ka date produced by Madjedbebe as evidence of a later peopling event. While they acknowledge that evidence may have been submerged by rising sea levels, O'Connell et al. (2018) emphasise the lack of dates in Sunda ranging 47 to 51 ka that could overlap with sites in Sahul.

The increased use of GIS-based studies has also contributed extensively to the discussion of the peopling of Sahul, and in particular the routes taken to arrive there (Fig. 6). Early suggestions of settlement routes include those proposed by Birdsell (1977), who identified a northern and southern route. Kealy et al. (2018) studied routes determined by island intervisibility. This study emphasises the potential significance of several submerged Wallacean islands that could have been exposed at lower sea level, and this research highlights the need to understand the seascape and island environments in reconstructions of the settlement period. Kealy et al. (2017) provide palaeogeographical reconstructions of sea levels and uplift rates, used to construct models of island intervisibility from Timor to northwestern Australia at 62 ka and 47 ka. This particular study also reinforced the northern route to Sahul as a 'preferable' option for seafaring, based on island intervisibility, which was also supported by a follow-up study using least cost pathway analysis (Kealy et al. 2018).

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Figure 6: Possible routes taken to arrive in Australia (Kealy et al. 2018)

To address the potential for 'accidental' settlement, Bird et al. (2019) use drift and demographic modelling to quantify the intervisibility between islands between 65 to 50 ka, in addition to the likelihood of successful accidental crossings at 17 crossing points on both the northern and southern routes. Bird et al. (2019) demonstrated that in using conservatively high probabilities of successful transit between islands, the likelihood of 'randomly' voyaging from Wallacea to Sahul is low. Their demographic models also indicated that the northern route from Sunda to Sahul was more likely to result in "successful peopling", concluding that the settlement of Sahul accidentally is unlikely. This study acknowledged the gap in archaeological sites of similar dates on the Wallacea islands, with the oldest currently known as the AMH layers at Liang Bua in Flores (c. 46 ka). The northern route yields younger dates still, with dates of c. 35 ka from Golo Cave on Gebe Island. They also note the factor of inundation by postglacial sea-level rise as a mechanism to obscure earlier sites in this region and create the disparity in site dates between Sunda and Sahul.

Assessments of populations required to sustain a permanent settlement of Australia have also reinforced the unlikelihood of 'accidental' settlement. Allen and O'Connell (2020) argue that genetic studies demonstrate a colonisation that involved potentially thousands of individuals, in a time period shorter than one millennium. The concept of movement as a 'radiation' rather than direct west-to-east movement is proposed by both Kealy et al. (2016), and reinforced by Allen and O'Connell's (2020) interpretation of the DNA research. They suggest, based on recent surveys of Y-chrosome and mtDNA haplogroups in Wallacea, that a staged spread took place. According to this model, the first spread involved an initial, pioneering movement of AMH, followed by a second Pleistocene dispersal from around 40 to 10 ka, suggested by Karafet et al. (2010) to have occurred post-LGM.

In much of the literature discussed in this section, 'minimalist modelling' of the peopling of Sahul is prevalent. That is to say, a focus on identifying assessments of the smallest populations required, the simplest watercraft, and shortest route. While this is a necessary boundary for the debate, particularly when further archaeological evidence is required to establish the extent of maritime adaptation of the earliest seafaring populations, the likelihood that skilled fishers and seafarers were involved is also a consideration. Our assumption of the most straightforward pathway to Sahul may not represent reality. The assumption of engagement with the sea as a matter driven by necessity and in which ‘the minimum’ is the goal appears to mirror similar global debates around marine resource use, which often also discuss the minimum skill and technology required for resource procurement and tend to consider resources such as shellfish a resource that is only procured under starvation conditions. Coastal hunter-gatherer economies, and those that involve shellfish as a major subsistence target, are increasingly recognised as having contributed to creating areas of interest for humans moving through Wallacea.

A key critique of the broader discussion on the settlement of Sahul maintained by Allen and O’Connell (2020) is that the research seems to be “discovering more and more about less and less”, with a tendency to reinforce currently understood criteria rather than developing new insight. In particular, they highlight that Kealy et al. (2018) reflects a similar conclusion to that reached by Birdsell (1977). Although this may be the case, rigorous testing of models for the peopling of Sahul should be emphasised, particularly in the current absence of submerged material that could build upon the established discussion.

Following the peopling of the continent, several models exist for the dispersal of Indigenous peoples across Australia (Fig. 7). The first is the Birdsell (1977) colonisation pathway, which proposed a rapid settlement across the continent, as maritime-adapted humans developed terrestrial subsistence economies. This was followed by Bowdler (1977), who instead suggested a coastal route of settlement of the continent, particularly given the seafaring nature of the groups that settled the continent, and argued that initial occupation of the interior was limited. Tindale (1981) and Horton (1981) added to these discussions with the proposal that on arrival in the north or northwest, humans dispersed along northern and eastern woodlands along interior riverine corridors. Bird et al. (2016) revisited these potential pathways, maintaining the significance of freshwater sources to navigating the continent, and reinforcing the likelihood of a scenario such as those suggested by Tindale (1981) or Horton (1981).

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Figure 7: Routes for the settlement of the Australian continent, including Birdsell 1977 (A), Tindale 1981 (B), Horton 1981 (C), and Bowdler 1977 (D). (Bird et al. 2016:11478).

A series of ‘superhighways’ is proposed for human dispersal by Crabtree et al. (2021). This model of human dispersal across Sahul is based on topography, the visibility of features in the landscape, freshwater availability, and demography. Many of these pathways identify parts of the Sahul continent which are now under water (Fig. 8). The debate surrounding the dispersal of Indigenous Australians across the continent is also one which could be aided through the discoveries possible in investigations of submerged landscapes.

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Figure 8: Pathway probability calculated across the continent of Sahul. Green indicates rarely or never chosen paths, while red indicates higher probability of an optimal path. Yellow paths have a 50% probability. Black dots mark the location of archaeological sites older than 35 ka (Crabtree et al. 2021).

The peopling of Sahul has been a contributing factor to academic interest in submerged landscape archaeology in Australia. Flemming et al. (1982) selected the Cootamundra Shoals off the coast of the Northern Territory given its potential to have been an attractive location to humans arriving in Sahul. Ongoing research is likely to illuminate areas offshore that are conducive to further research, not only in the regions associated with the former landmass of Sahul, but also in now-submerged parts of Sunda which may predate the currently known range for human habitation.

3.5 Marine resource use and maritime adaptation in the Australian archaeological record

Maritime adaptation in Australia dates to deep-time sequences of the occupation of the continent, however it requires further investigation across both the Pleistocene and Holocene. The chosen definition of ‘maritime adaptation’ here describes a society’s sustained use and exploitation of marine, estuarine, lacustrine, and/or riverine resources. Connected to this concept is ‘coastal adaptation’, which implies significant use of coastal and marine resources, often in addition to terrestrial resources associated with inland environments. Many societies can be considered both maritime adapted and adapted to coastal environments, but the latter term implies greater reliance on the terrestrial, surrounding coastal environment in conjunction with subsistence strategies directly involving the sea (Erlandson 2001). Additionally, some submerged sites may not show any indication of maritime adaptation, and may instead focus on inland resources. The definitions of maritime and coastal adaptation proposed here are not necessarily the most widely accepted, as the parameters of maritimity in studies of human prehistory are rarely explicitly defined. Instead, the definitions described are based on a variety of studies, to provide a framework for outlining regional differences in interactions with coastal and marine environments (Fitzhugh 1975; Yesner et al. 1980; Lyman 2010; Tuddenham 2010).

The Australian record for coastal occupation and resource use is rare until the mid to late Holocene (Bowdler 1995, 2010; Rowland et al. 2015). While this may reflect submerged coastal adaptations from earlier periods, it may also suggest that sites found in submerged environments may demonstrate inland adaptations. Of the dated sites in Australia, 90% of coastal sites retain mid to late Holocene evidence (Barker 1999), and demonstrate a majority reliance on marine resources. In coastal Queensland, three sites have yielded dates that predate the mid-Holocene (Ulm 2011). There are some regional differences in coastal archaeology in Australia. Most of the research was conducted in the southeast in New South Wales and Victoria until the 1970's (Bowdler 1976). These early syntheses of coastal sites often portray coastal habitation as seasonal (Poiner 1976). Subsistence strategies varied in coastal archaeological sites in the tropical north and in the temperate southeast. While specialised fishing and open sea exploitation emerged in the north of the continent, the southeast appears to have placed greater reliance on shore-based resources and combined coastal and terrestrial economies (Barker 2004). In the southwest of the continent, Hallam (1987) observed that sites on the coastal plain demonstrate a combined reliance on terrestrial plants and animals, in addition to fish as a subsidiary resource.

To fill the research gaps in understanding marine resource use and maritime adaptation in Australia, the potential for submerged material must be addressed. Currently, although there is substantial research dedicated to coastal occupation and resource use, this record remains skewed to later sites that can be found on land. Marine ecosystems in the Pleistocene were capable of supporting coastal habitation and responding quickly to sea-level change (Manne and Veth 2015; Ward et al. 2015), despite the under-representation of sites. The lack of evidence predating the mid to late Holocene led Beaton (1985) to develop the 'coastal lag hypothesis', which suggested a cultural and economic lag in the use of coastal resources until the late Holocene. Beaton (1985) based this hypothesis on work conducted at Princess Charlotte Bay in Queensland, where no shell middens could be found that predated 4.7 ka. Beaton (1985) took this to indicate that occupation of the coast did not take place until 1500 years after the stabilisation of sea levels. According to Beaton, this lack of evidence was due to the postglacial marine transgression, which stopped the formation of productive coastal ecosystems due to the instability of sea levels, and even once stabilised, 'lagged' in the development of productive ecosystems. Having reviewed other coastal areas, Beaton (1985) concluded that this was the case in other Australian coastal contexts as well. If this were the case, this would be a particularly major factor to consider in the prospection of submerged sites, requiring evaluations of the stabilisation of sea-levels permitting coastal human habitation. However, there is extensive evidence that contradicts the coastal lag hypothesis. In northwestern Australia, Pleistocene and early Holocene sites with coastal economies were identified following Beaton's publication of the coastal lag hypothesis (for example, Mandu Mandu Creek Shelter at North West Cape, Western Australia, dated c. 25 ka, see Morse 1988), in addition to counterarguments such as that of Morse (1993) that coastal resources were likely always part of past Indigenous economies. Hiscock (2006) writes that Pleistocene and early Holocene occupation is not easily assessed at Princess Charlotte Bay, although it is clear that Walaemini Shelter (dated 5.5 ka) was occupied and included a dense midden of marine shell (Harris et al. 2017). To Hiscock (2006), the destruction of earlier middens does not seem surprising, noting the potential impacts of cyclones and storm surges. However, Hiscock also notes the potential for the build-up of chenier ridges which would preserve mid and late Holocene middens, and suggests that the issue is not a matter of lack of interest of capability to engage with marine resources, but a lack of preservation.

Veth (2007) argued that late Pleistocene and early Holocene economies were broad-based, and included coastal, terrestrial, and marine resources, however these early sites remain rare compared to later counterparts. Prior to the LGM, Veth et al. (2017) describes the use of marine resources in the northwest as mostly utilitarian, without significant evidence for dietary use, with increasing reliance on marine resources following sea-level rise. This contrasts with sites located in northern Sahul and East Timor, where near-shore marine resource use is identified in addition to pelagic resource exploitation dating to c. 40 ka at Jerimalai (O'Connor et al. 2011). However, there is encouraging evidence of late Pleistocene marine exploitation in Australia, particularly in the northwest of Australia, approximately 100 km to the west of Murujuga (the Dampier Archipelago), where a substantial part of this thesis research takes place. Noala Cave and Hayne's Cave (dating c. 31 ka to 8 ka) on the Montebello Islands demonstrate broad-spectrum exploitation of mammals and reptiles, with the dietary use of shellfish emerging at around 12 ka (Veth 2007; Veth et al. 2017). This pattern is generally reflected in Boodie Cave and John Wayne Country Rockshelter on Barrow Island (Ditchfield et al. 2018). By the late Holocene in Murujuga (c. 4 ka), mangal environments declined, and shell midden sites in the Murujuga show an inclination to rocky shore, mudflat, and sandy beach shellfish (Vinnicombe 1987a; Bradshaw 1995). McDonald and Berry (2017) predict that the late Holocene saw the introduction of watercraft in Murujuga, as resource exploitation on the outer islands re-commenced.

Moving into the early Holocene, from the Whitsunday Islands of northeast Queensland, Barker (Barker 1999; Barker 2004) researched forager resilience. At Nara Inlet 1, stone artefacts which could only be acquired from a hilltop on South Molle Island were identified. The area surrounding this island was inundated at around 10,000 years ago, indicating the use of watercraft during the site's settlement at around 9 ka. Lamb (2005) suggested that early Holocene groups relied on stone tools to butcher large marine mammals, and also for the manufacture of fishing and boating gear. The archaeological record of Nara Inlet 1 shows that many kinds of marine fauna were exploited, including fish, molluscs, crabs, and marine mammals. Contrary to the 'coastal lag hypothesis', this shows that Aboriginal people did not avoid engaging with the rising sea, and found ways to adapt to the dynamic coastal environments. Despite the fact that island use and watercraft tend to be associated with the mid to late Holocene across Australia, Bowdler (1995) highlighted that this would be surprising given that the peopling of Australia involved an extensive sea crossing. Rowland et al. (2015) raise the possibility that following arrival, ocean-going vessels were no longer considered necessary and watercraft technology simplified as a result. As is the case in assessments of seafaring and watercraft in deep time elsewhere (see Leppard and Runnels 2017), much of this question may also correspond with varied preservation of organic materials.

The early Holocene on the Arnhem Land coast in the Northern Territory was characterised by abrupt environmental changes, with significant impacts for coastal resources. Woodroffe et al. (1986) studied the South Alligator River and how changes in the river affected past economies. At the terminal Pleistocene the South Alligator River was part of a river valley of eucalypt woodland, and then as rising sea level flooded the valley 9000 years ago the area was transformed into a shallow marine mangal embayment. This formed what Woodroffe described as the ‘transgressive phase’, in which the embayment was made up of intertidal flats and channels. As the mangroves began to take hold of the embayment at 7.8 ka, this soon resulted in a mangrove forest up to 100 km long. Termed the ‘Big Swamp phase’, the mangrove environments of the South Alligator River and across Arnhem Land persisted during sea-level rise, initially dominated by *Rhizophora* mangrove, and then eventually becoming largely *Avicennia*. By 4.5 ka, the Big Swamp had vanished, having been forced out by sedges and plains grasses. Changes in the Big Swamp phase have been interpreted as ‘mirrored’ in archaeological middens, with their eventual declined taking a toll on populations who relied on the productiveness of these habitats for mollusc exploitation. The eventual abandonment of rock shelters at 3 ka may also suggest that the economic value of these environments without the extensive mangroves was greatly reduced.

Across the Australian coastline and coastal regions, shell middens serve as a key indication of Indigenous use of marine resources. Shell middens first appear in the mid-Holocene in northeast Queensland as the earliest examples across the continent, followed by widespread appearance of shellfish remains dating to the late Holocene (Ulm 2011). *Anadara* mounds are a noteworthy aspect of coastal resource use in northern Australia, and mainly a feature constrained to late Holocene, although examples have been reported from northwest Australia dating to 5 ka (Harrison 2009). Primarily formed by *Anadara granosa* bivalve shells, these middens are found across over 3000 km of the northern tropical coastline, ranging from the Kimberley region to Cape York Peninsula (Bailey 1977; O'Connor and Sullivan 1994). These piles of shell typically contain sediment, artefacts, animal bones, and ash, and while they vary in size the largest may be over 10 m high (Bailey et al. 1994; Fig. 9). The mounds typically occur in clusters, and are often located on cheniers or laterite slopes, where the coast has prograded and left them inland. *Anadara* mound building ceases around 600 years ago, with the cause linked to diversification of diet, and changes to mobility in coastal territories. There is substantial potential for offshore shell midden preservation, assuming suitable conditions.

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Figure 9: Large shell mound from Albatross Bay. Some shell mounds may reach as tall as over 10 m in height (Holdaway et al. 2017).

A similar feature that corresponds mostly to the late Holocene is the prevalence of stonewalled, intertidal fish traps. These are found across the northern coast of Australia, and are believed to date to an era following the stabilisation of sea level at its present level, based on the currently known examples and how they are required to function. Rowland and Ulm (2011) created a typology following a review of fish traps found across Queensland (Fig. 10), and also outline the difference between fish traps and fish weirs in Australia, in which they acknowledge the term may be used interchangeably but note that 'weir' is often associated with organic brush pens and nets which are found in rivers and creeks, and 'trap' with stone arrangements where two walls form a pen shape. It is possible that fish traps were constructed at times predating modern sea level, and may have yet to be identified if they coincide with lower sea levels. Given that these features are manufactured from stone, they may also serve as a more resilient form of Aboriginal Australian archaeological signature following inundation. Kreij et al. (2018) recorded 13 stone fish traps in Queesnland through UAV photogrammetric mapping, and provided a refined chronology of their construction (within the past 2000 years). Both Rowland and Ulm (2011) and Kreij et al. (2018) have highlighted a general lack of archaeological engagement with stone-walled fish traps, and the need for improved quantitative techniques to allow for consistent recording of these sites.

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Figure 10: Schematics of fish traps identified by Rowland and Ulm (2011), including V-shaped (top left), U-shaped (top right), rectangular (middle left), straight (middle right), and an organic weir across a river (bottom) (Rowland and Ulm 2011:4).

Marine resource use in Australia largely follows the terrestrial archaeological record. In order to answer questions about the antiquity of marine resource use, it is necessary to investigate the submerged environment as past coastal environments. Patterns recognised in terrestrial sites may not be reflected in submerged archaeological sites, and this is an important area for further consideration. With encouraging evidence of late Pleistocene and early Holocene maritime adaptation, the understanding of marine resource use remains a key area for future research of submerged landscapes.

3.6 Settlement dynamics of hunter-gatherer sites

This section provides context to the socio-economic differences in hunter-gatherer and early agricultural societies which are represented in the submerged archaeological record. The differences here are not exclusive to economy, but also involve human-environment relationships, and contribute to settlement dynamics and hunter-gatherer mobility. In the context of submerged landscape archaeology research, this is important in understanding material culture and its relation to settlement dynamics and mobility. However, this is not to say that material found on land will accurately inform settlement patterns in submerged sites, as these theories require rigorous testing alongside recorded inundated sites. Inland sites may, at least, provide a baseline for testing these concepts (see Chapter 4).

Practically, there is an ongoing methodological discussion about the logistics and likelihood of locating hunter-gatherer material under water. The search for hunter-gatherer material is a logistically complicated and expensive issue, due to the substantial depths associated with older Palaeolithic material. Based on current models, the prevailing assumption of preservation is that ephemeral traces preserve variably, and only some resilient examples of hunter-gatherer archaeology such as lithic scatters will preserve in the long term. Another point highlighted is that palaeoshorelines may not have been exposed long enough to permit settlement before they were inundated by further sea-level rise (Galili et al. 2017). There is a somewhat circular nature to these arguments, which suggests that permanent coastal settlement, social stratification, intensification, and population growth can only be associated with increasingly sedentary early agricultural sites, and currently this assumption is based entirely on a lack of evidence to the contrary, but at the core of this lack of evidence is a lack of research of deeply submerged palaeoshorelines. To adapt the insights from the case studies of Israel and Denmark for the prospection for hunter-gatherer archaeology on the Australian continental shelf, this section outlines the currently understood distinctions in settlement patterns and structure, and their potential impact on what may preserve under the sea.

It is firstly important to establish that the 'ladder of progress' interpretation, in which there is a singular and inevitable line from 'simple' hunter-gatherers to 'complex' agricultural societies, does not represent global human history and that subsistence economies are often varied. The term 'low-level food production' may also be used to describe societies that are neither wholly hunter-gatherers or agricultural (Holdaway et al. 2010), portrayed as a poorly understood middle ground, particularly during the transition from Mesolithic (or Epipalaeolithic) to Neolithic (Smith 2001). A difference in subsistence that relates to settlement is the idea of immediate and delayed return hunting and gathering. Immediate return involves consumption shortly after acquisition, with little evident storage. Delayed-return hunter-gatherers may rely on storage technologies in seasonally variable environments. Binford (1980) addressed this in the distinction of 'foragers', and 'collectors', in which foragers move the consumers to food, exploiting resources around a base camp and then moving onto the next location. Collectors then establish a base camp with access to a variety of resources, relying on 'task groups' to move food to the consumers. In the context of all archaeological sites, but particularly submerged settlements, storage may be a significant factor for coastal communities where seasonal variation in resource use may be apparent (for example, the submerged Neolithic village of Atlit-Yam).

Holdaway et al. (2010) considers the archaeology of Indigenous Australia as indicative of low-level food production, given that there is no evidence for agriculture, however there is an extensive history of plant management and environmental modification across the continent (Yen 1989; Fullagar and Field 1997). Relationships between humans and their surrounding environments vary in the case of hunter-gatherer and agricultural economies, particularly in terms of resilience to 'bad years', and abrupt environmental change, including sea-level rise. In this case, long-term mobility that encompasses a series of territories may be advantageous to hunter-gatherer groups.

The nature of mobile societies, and sedentary societies (with the capacity for overlap between these two ideas) is important to distinguish. Mobility, as a concept, has received a great deal of attention in studies of hunter-gatherer populations, and has relevance here for the predictive capacity of spatio-temporal patterns of past societies and subsequently the process of prospection for submerged sites. Definitions for the concept of mobility remain elusive, however more recent work has emphasised the role of mobility as representing movement, including both individual movement or movement of a group (Kent 1992; Close 2000; Barnard and Wendrich 2008; David et al. 2014). Binford (1980) suggested the use of ethnographic parallels for understanding mobility. In this study, the definitions of "residential" and "logistical" mobility were outlined, as the movement of the entire group from one camp site to another, and foraging movements from and to the residential camp, respectively.

Eder (1984) suggest a revision of the assumption of a continuum from mobile to sedentary was the underlying mechanism for the transition from hunter-gatherer subsistence to agriculture. With consideration for Binford (1980) and the roles of residential and logistical mobility, Eder (1984) noted that Binford's study overlooked an ethnographic case study in the Philippines in which foraging societies changing subsistence strategies often became more mobile, indicating the capacity for 'middle ground' societies which are often overlooked in the development of typologies. Additionally, Eder (1984:838) observed a tendency to juxtapose the terms and conflate multiple meanings, and warned against assessments of economies as the product of a "jumble of disconnected 'old' and 'new' activities". The definitions of these terms also remain debated. Rafferty (1985) highlighted that archaeologists often use the term sedentary to refer to different concepts. In some cases, settlement size may be the implied criterion for sedentism, or it may also be described as an all-or-nothing phenomenon. Bird et al. (2019) note that in groups with higher residential mobility, the incentives for material wealth accumulation and storage decline, and suggest that wealth is maintained in social networks that emerge from this high residential mobility. Although factors such as site size and artefact density are often used as indications of reduced mobility, these may also be associated with other factors including reoccupation frequency.

In terms of how these principles may affect the material record, it must be recognised that each case study put forward in this thesis deals with a vastly different set of observations of socio-economic criteria, and vastly different environmental backgrounds. The aim is therefore to adapt observations made of certain examples in Israel and Denmark for an Australian context, in light of the terrestrial archaeological record in Australia. Depending on the location in Australia, this too may vary substantially. For example, a possible domestic stone structure was identified on Rosemary Island in Murujuga (the Dampier Archipelago), dating between 8 ka and 7 ka, and could indicate more permanent occupation of the region. Studies of mobility in the Indigenous Australian archaeological record are ongoing, and it is likely that more nuanced and higher resolution understandings of mobility will contribute to a greater understanding of how this may impact spatio-temporal patterns in sites located offshore.

3.7 Conclusion

This chapter has provided a baseline of ongoing research questions and debates specific to Australian archaeology where submerged landscape archaeology may prove crucial to their progress. There are two central aspects of predicting locations for submerged landscape archaeology: site selection (the cultural processes involved in a site's location within a broader landscape), and site preservation (including sedimentary, geological, hydrological, and oceanographic processes). In the Australian context, the existing focus on archaeological questions of migration and maritime adaptation may guide the former, while ongoing research efforts may help to characterise the latter. These factors allow for a comparison of the international case studies alongside an area in which little is currently understood about submerged landscapes.

4.0 THE LOCATION, PRESERVATION, AND DISCOVERY OF SUBMERGED ARCHAEOLOGICAL SITES

> "Sites are not discrete entities that can be discovered and interpreted, through their existence, as evidence of past ways of life. Instead, it is more profitable to investigate the archaeological record by asking 'Why can I see this artefact here?', and then to answer this question by determining what sets of processes led to the accumulation, preservation and visibility of the archaeological record in places where it is apparent." (Holdaway and Fanning 2014:194)

4.1 Introduction

This chapter reviews the international examples of submerged landscape archaeology to compare with, and inform, emerging research from Australia. The mechanisms for the identification of a submerged archaeological site are considered in three categories: the processes affecting site selection and land use, post-depositional processes and their role in preservation or destruction of material, and the impact of site visibility on survey procedure as has been shown in international case studies. While there are thousands of submerged archaeological sites located across the world, this chapter has selected particular examples from the literature as representatives of their associated deposition, land use modelling, or circumstances surrounding site visibility. The specific case studies in this chapter are included for their international significance, and their capacity for comparison to the Australian continental shelf. These case studies relate primarily to international 'hot spots' for submerged landscape archaeology, with some inclusion of Australian literature as relevant to inform submerged landscape archaeology research. This assessment of site formation and processes affecting the likelihood of site identification is crucial, and directly impacts the development of a mode of practice optimised for the Australian environment.

4.2 Site selection and land use models

This section addresses the cultural processes that influence the selection of an archaeological site's location in past landscapes, and how these factors have been included and predicted in other studies. There are substantial challenges in attempting to understand the spatial patterns of cultural behaviours, and it is crucial that transparency is maintained about the assumptions that underpin models and modes of practice, and these are reviewed here. As submerged landscape archaeology is closely connected to landscape archaeology frameworks, many of these models attempt to map the potential for submerged landscape archaeology based on ideas connected to human behavioural ecology and landscape theory (as discussed in Chapter 2). The models are introduced here as examples of process to understand how they have dealt with understanding site selection, and the impact of past land use on ultimately identifying submerged archaeological sites.

4.2.1 Location models and predictive criteria

Modelling for site location and land use is an archaeological practice that does not necessarily require specific tools, and these methods may be based on extensive datasets to derive a series of predictions which can then be tested against field observations. There are three examples of location models and predictive criteria that are discussed here. The first is the fishing site location model developed as part of the 'Danish Model'. The term 'Danish Model' is often used to refer to the predictive model that underpins its success, in addition to the mode of practice it represents (as discussed in Benjamin 2010b). In this thesis, the mode of practice is specifically referred to as the Danish Model, and the predictive model is referred to as the topographic fishing site model. In the case of predictive criteria underpinning the Israeli Model (Galili et al. 2017), some predictive elements can be outlined, including prediction based on water depths, the presence of palaeosols, locations embedded between kurkar ridges, and access to high ground water.

Denmark

Among the established and clearly defined frameworks analysed for this thesis, Fischer's fishing site location model, which underlies the success of the 'Danish Model' (Fischer 1995a; Benjamin 2010b), pays the most considerable attention to the specific features influencing site settlement and land use. These high priority locations include narrow inlets connecting large bodies of water, between small islands and mainland, the tip of a headland, and at the mouth of a stream. In each of these locations, the aspects of human settlement that are prioritised relate to lithic procurement, freshwater access, and crucially, optimised fishing areas. These features were based on present-day locations used for fishing. Having adjusted for the depth-time ratio and plotting against nautical charts, Fischer (1995a) followed the relevant bathymetric contour and identified places consistent with high potential areas based on the topographic model. This model was tested by surveying areas that were also considered low potential based on the fishing site model, and it was identified that these areas lacked archaeological material. However, Grøn (2018) has argued that this model does not produce reasonable results, and that its underlying premise is outdated, with the sample used to test the model an inadequate justification. Nonetheless, the Danish Model provides the earliest outlined framework for submerged landscape archaeology, and so its inclusion and the underlying topographic fishing site model must be assessed further. The Danish Model focuses on coastal adaptation and marine resources as key features of Mesolithic Denmark, and could be applied in areas with similar evidence for site locations on land and with environmental parallels, as well as providing an important starting point to consider where optimal fishing locations are in the present landscape (Fig. 11).

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Figure 11: Orientation map of submerged settlements in Denmark (Bailey et al. 2020a:42).

Israel

In the context of the development of the Israeli Model, Near Eastern prehistory has seen a focus on several different models for site selection. Among the earliest works to consider this was the site catchment analysis framework developed by Vita-Finzi et al. (1970), which aimed to identify the boundaries and important resource areas of prehistoric archaeological sites in Israel. Following the discovery and research of submerged Neolithic sites in Israel, Galili et al. (2019b) state that site selection on the now-drowned Carmel Coast was guided by subsistence requirements of past communities. According to these predictive criteria, although hunter-gatherers used coastal resources, permanent settlement in the coastal area was not possible until the Pre-Pottery Neolithic C (PPNC) and coincided with the development of water wells. Thus, projected locations may be identified based on the subsistence requirements of a village as well as geomorphological patterns (Galili et al. 2019b). Based on the agro-pastoral-marine economies of the submerged villages, these sites require arable soils (paleosols, which are embedded on or between coastal kurkar ridges), appropriate areas for pasture, in addition to permanent water sources (Fig. 12). High ground water and the presence of palaeosols in the coastal, now submerged, landscapes guide the likelihood of identifying a submerged archaeological site off the coast of Israel, with most recorded sites and finds localised to the Carmel Coast region.

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Figure 12: Orientation map of submerged settlements on the Carmel Coast of Israel (Galili et al. 2020:446).

Northwestern Australia

In Murujuga, the model by Veth et al. (2020) outlines the likelihood for preservation and identification of material known from the terrestrial archaeological record, ranking stone features and lithic artefacts as some of the more durable materials to survive inundation. This is based on archaeological data across Murujuga, and reinforced by the archaeological record of the Pilbara region (Fig. 13). This model is guided by the predictive criteria set out by McDonald (2015), which establishes a predictive model for coastal occupation in Murujuga. While coastal occupation is the focus of the model by McDonald (2015), it is noted that earlier habitation of the archipelago might have involved exploitation of inland resources. McDonald (2015) states that the preferred location for petroglyph production is on steep inclines, as well as enclosed valleys which border reliable watercourses and rock pools. Additionally, rock platforms in proximity to the ocean also demonstrate more rock art. McDonald (2015) recommends mapping palaeochannels and springs to identify priority targets for survey, as important resource in the landscape. Both Veth et al. (2020) and McDonald (2015) serve as local predictive models, while the mode of practice described in this thesis represents a general model.

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Figure 13: Regional map of the Pilbara showing significant archaeological sites (Ditchfield and Ward 2019:541).

Comparison of case studies

A focus on coastal resource use is seen across the Israeli, Danish, and Australian examples assessed in this thesis. While it cannot be assumed that all underwater sites represent interaction with an adjacent coastline, as older, inland sites could be located at elevations associated with more recent time periods, it is recognised that submerged settlements yield insight into coastal subsistence economies and lifeways that are not otherwise identifiable based on the archaeological record on land. Location models such as those described are less common than GIS-based predictive models and simulations, however the extensive use of predictive criteria across the history of the discipline indicates that valuable information may be identified through the recognition of these principles.

4.2.2 GIS and simulation-based predictive modelling

The issue of land use and site selection is dealt with in both qualitative models that outline specific features as more or less likely to contain archaeological material, and quantitatively derived spatial models created by GIS or agent-based modelling. In the earliest implementations of GIS in archaeological research and the generation of predictive models, there was abundant criticism of these models for their focus on environmental variables, with the suggestion that many of these models were environmentally deterministic and did not adequately address the fact that human populations are not passive inhabitants of their environment. Gaffney and Van Leusen (1995) note that this issue is often an “involuntary product” of limited datasets, or alternatively, of limited use of GIS, and this issue persists in more recent literature. Llobera (2012) advises the need for bridging concepts to place models in a context-rich narrative, and seek out how processes appear in particular contexts rather than aiming to identify universal norms. Richards-Rissetto (2017) states that although some models can rightly be deemed overly reliant on environmental factors, it is important that cultural variables grounded in archaeological thought and society are included to avoid this issue.

North America

North America has seen an abundance of GIS-based models for submerged landscapes. Krier (2018) developed a predictive model for Beringia based on the importance of salmon in past economies, reflecting a similar approach to the fishing site model developed by (Fischer 1995a). Krier (2018) based the strategy of this project on the Danish Model, and although there were issues in this study regarding the ability to truth the target areas, and the resolution of data used to produce this model, it bears a similarity to other models which prioritise the role of marine resources and the knowledge that ancient communities understood optimal areas and methods to target these resources. To the south of the continent, Cook Hale and Garrison (2017) provide a model to locate archaeological sites offshore in Georgia, based on site patterning on the adjacent coastal plain. This model focuses on the productivity of the landscape, in addition to proximity to the coast, chert outcrops, and proximity to fluvial features. Braje et al. (2019) develop a GIS-based predictive model for offshore geophysical mapping of prospective areas, based on the distribution of subaerial sites on the Northern Channel Islands of California. Monteleone (2019) and McLaren et al. (2020) present models for the Northwest Pacific coast of North America, with Monteleone (2019) focused on the development of a predictive GIS model, with McLaren et al. (2020) focused on modes of practice. Currently, no submerged sites have been located through the work of Monteleone (2019) and McLaren et al. (2020), however, these studies have assisted in a greater understanding of past landscapes and refining criteria to identify submerged sites. In addition to GIS-based models, agent-based modelling has also been conducted. Fogarty et al. (2015) approached the investigation of submerged landscapes of Lake Huron through serious game modelling of caribou to then predict the location of hunting sites. Although North America has seen numerous predictive models developed for its various coastal environments, truthing these models and understanding the cultural behaviours that contribute to land use is required to improve the accuracy for these models.

North Sea

Research undertaken off the coast of Great Britain to understand the submerged landscape known as 'Doggerland' has focused extensively on the development of GIS models, in addition to agent-based models and simulations to establish past cultural behaviour (Gaffney et al. 2007; Gaffney et al. 2017). Unlike GIS predictive models, agent-based modelling and computer simulations rely on creating scenarios to develop testable hypotheses of site location, choices made by past populations, or artefact use. In agent-based modelling, the ‘agents’ move across a landscape making decisions according to rules set out by the model. These studies have often yielded testable hypotheses and insight to develop and speculate about the archaeological record. This is the case in the research of Doggerland, which has used extensive spatial datasets to reconstruct past landscapes, and evaluate the trends in land use that might have occurred. This has allowed for detailed palaeoenvironment reconstruction and an assessment of how humans interacted with the landscape. It should be noted that while the extensive modelling undertaken has identified areas of considerable potential, it has not necessarily yielded sites.

South Africa

Although without the same number of archaeological finds from the southern North Sea, agent-based models were also developed for the coast of South Africa to project the possibility for submerged material on the now inundated Paleo-Agulhas Plain. In this example, a “resourcescape model” is created based on modern studies of habitat productivity (Wren et al. 2020). An agent-based approach is then used to investigate behavioural and economic change during the early Holocene along the coastline of the Paleo-Agulhas Plain. This provides insight to the changes prompted by climate change and sea-level rise, and allows for a greater focus on the activities of past populations than is otherwise evident in other examples of predictive models.

Comparison of case studies

The use of GIS, agent-based modelling, and computer simulation becomes important to form part of an inductive process, moving between data and methods to establish new hypotheses. Essentially, there are several categories that emerge as recurring themes in the research of site selection in models for submerged landscape archaeology: 1) topographic features and terrestrial analogy, 2) freshwater access, 3) proximity to coastline and resources, 4) lithic procurement, and 5) ethnographic analogy. Each of these has been implemented, to various extents in different models, to understand the cultural variables that influence site selection and to develop testable models of where submerged archaeological sites are likely to preserve. These models are equally testable compared to their qualitative counterpart, such as the fishing site location model, but rely on high-resolution spatial data to derive predictions.

4.2.3 Terrestrial analogy

In moving from the known, to the unknown, it is possible to rely on the terrestrial archaeological record to inform predictive criteria for submerged archaeological sites. However, as highlighted by (Veth et al. 2020), this creates an issue in that continuity is assumed from the onshore environment to the offshore, without testing this hypothesis. While this continuity was confirmed in Denmark (Fischer 1993; Fischer 1995a), this is not the case in all areas it has been used. For this discussion, the examples of Denmark, North America, and emerging research from Northwestern Australia are considered, for their varying viewpoints on approaching terrestrial analogy for submerged landscape archaeology.

Denmark

The Danish example emphasises a similar process in the associated topographic fishing site model, which uses the analogy of fishing locations and their topographic context as the basis to locate submerged archaeological sites (Fischer 1993). Over time, the validity of these assumptions and this continuity is well-supported by the submerged archaeological material found using the topographic fishing site model (Fischer 1995a; 2007). The success of this Danish predictive model indicates terrestrial analogy can yield results, particularly in environments that reflect the similar landscape changes over time to the Baltic coastline.

North America

In Cook-Hale and Garrison (2017) and Monteleone (2019), trends associated with terrestrial sites serve as an important part of the model to extrapolate terrestrial data to the submerged environment. These GIS-based models have investigated data associated with sites found on land to increase the likelihood of identifying sites under water. These areas require further investigation to confirm the assumptions and predictions set out by these models, however they have identified useful locations to begin to better understand the probability of locating settlements offshore.

Northwestern Australia

The process of terrestrial analogy to inform predictive models, both conceptual and GIS-based, has seen extensive use in submerged landscape archaeology and has been used in the work at Murujuga. Veth et al. (2020) developed a model based on features present on land, and their context. Additionally, McDonald (2015) provides several predictive statements that apply to engraving sites on land in Murujuga, and these could be easily applied to submerged environments as well. The detailed investigations surrounding site location in Murujuga, and the density of archaeological material on land, contributes to this area's high potential for submerged archaeological material.

Comparison of case studies

At Murujuga and in Denmark, the process of deriving principles for site selection relies on identifying known trends in spatial patterns of sites, and using this to then identify sites, and then test this back against the model. While terrestrial analogy has been applied in GIS-based predictive models in North America, these require further verification against the submerged archaeological record. It is worth noting that not all submerged landscape archaeology relies on terrestrial analogy to locate sites. Survey undertaken in Israel does not rely on terrestrial analogy to identify sites, and instead uses the information gained from decades of survey experience, following initial chance exposures and finds, to establish the trends known in submerged settlements. However, in areas that lack the information generated by decades of sustained research effort on submerged prehistory, a comparison with archaeological sites found on land creates an important set of assumptions for survey results to support or refute.

4.2.4 Ethnographic analogy

The capacity for ethnographic analogy to inform past cultural processes remains debatable in submerged landscape archaeology, and relies largely on the suitability of the analogy. There is substantial potential for discrepancy between material on land and submerged material, and this gap between material may be further obscured by the time and cultural shifts between the occupation of submerged settlements and the ethnographic data used to predict submerged landscape archaeology.

The Danish Model successfully includes an ethnographic component which emphasises the involvement of the local fishing community to identify areas suitable for fishing, which are then applied to the prehistoric landscape. This example highlights the importance of ensuring suitability of ethnographic analogy for submerged landscape archaeology.

Of the two explicitly outlined frameworks studied in this thesis, the Israeli Model and the Danish Model, the latter is has found substantial success in the use of an ethnographic component. The Israeli Model, although it places importance on community engagement and heritage management, does not include ethnography analogy. From this, it seems that ethnography may contribute useful information where a relevant and plausible comparison can be seen (as in the Danish example). Additionally, culturally appropriate comparisons must be sought out, as considering cultures to be unchanging over millennia through the assumption of continuity may generate faulty predictive criteria for site locations.

4.2.5 Modelling hydrology

Despite having outlined environmental determinism as an important consideration for modelling land use in submerged landscapes, in most models the availability of freshwater plays a considerable role. Besides playing a vital role in sustaining past populations, other material culture may also be focused on freshwater features. This has been addressed in several predictive assessments, including the Eastern Mediterranean, and in Northwestern Australia.

Eastern Mediterranean

In the Eastern Mediterranean, the Israeli example emphasises the importance of high groundwater for the settlement of Neolithic villages. In these coastal environments, the presence of freshwater can be seen as significant to both Neolithic villages located along the Carmel Coast. Additionally, a survey strategy used in Cyprus to identify submerged stone tools which followed palaeochannels as highly prospective areas (Ammerman 2020) and led to the discovery of Aspros Dive Site C along the bank of a palaeochannel, with the material (not found in situ) tentatively and typologically dated to 12 ka (Fig. 14). It is unclear if the palaeochannels served as a focus in the landscape, or whether the artefacts were transported by the streams.

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Figure 14: Projected palaeochannels off the western coast of Cyprus, with the terrestrial site of Aspros shown (indicated by the A). (Ammerman et al 2020:431)

Northwestern Australia

McDonald (2015) also notes the importance of freshwater features in the arid Pilbara region of Australia, and identified that many sites including engraving sites and sites for lithic procurement would be focused around freshwater features. This indicates the importance of not relegating freshwater features to a basic survival requirement, but rather, recognising these features as part of a cultural landscape and important to understand in the context of coastal environment change caused by sea-level rise. These factors are reflected in the predictive criteria developed by Veth et al. (2020).

Comparison of case studies

Although not necessarily an ultimately limiting factor for a site's location and use, it is clear that modelling palaeochannels, palaeolakes, and other bodies of freshwater is important to reconstructing resource foci in the past landscape. This must be assessed in association with other cultural factors influencing site location, and should be viewed as a mechanism to inform site selection but not necessarily to limit the choices conducted by past populations. This may also be reinforced by ethnographic analogy of areas where freshwater was prioritised, as well as terrestrial analogy as demonstrated by McDonald (2015).

4.2.6 Modelling coastal resource use

Many models either implicitly or explicitly prioritise the significance of coastal resources. Location models such as the one presented by Fischer (Fischer 1993; Fischer 1995a) maps archaeological sites based on optimal fishing locations, once adjusted for depth-time ratio. Distance from coast can be included as a factor in GIS-based models. In all cases, the assumption of the significance of the coastal environment relies on understanding the role of coastal and marine resources in the past economy, and also a detailed understanding the coastal environment of the past.

Carmel Coast

In the Israeli example, the role of Neolithic fishing may be more complex, and could be used to support a primarily agricultural economy (Galili et al. 2002; 2004). Present coastal landscapes and ecosystems do not represent the past environment, however this acts a useful starting point for considering the likelihood of human habitation. Permanent coastal habitation, at this point, is primarily associated with the later part of the Neolithic and Chalcolithic. This indicates that at the relatively shallow depths associated with these periods (−1 to −15 m), the probability of encountering sites reliant on coastal, or partially coastal economies, is increased.

Denmark

In the case of the Danish Mesolithic, marine resource use is seen extensively in the archaeological record (Fischer et al. 2007; Larsen et al. 2018; Lewis et al. 2020). Fish traps are another example of this engagement with the coast, and it is this significance placed on fishing that the Danish Model has attempted to focus on for the development of a topographic model. The prevalence of shell middens and marine-based economies is an element of the Danish Mesolithic that is considered in studies of the submerged prehistory of the area, and guides survey efforts. This is reflected especially at the site off the coast of Hjarnø, given the preservation of an in-situ shell midden (Astrup et al. 2021).

Comparison of case studies

The importance of coastlines to past populations is often seen in submerged sites. Fishing tools have been identified in both Israel and Denmark, and the presence of shell middens in Denmark also reinforces this point. From these two examples as leaders in submerged landscape archaeology, modelling and gauging the importance of coastal resources forms a significant aspect of predicting material's survivability offshore.

4.2.7 Summary

This section has outlined the main ways in which land use and site selection has been modelled and included in assessments of submerged landscape preservation, and indicates that several of the land use and site selection models still rely on economic features and priorities. Cultural behaviour remains challenging to model, particularly for GIS-based models. This is not to suggest that economic aspects should be considered isolated from cultural processes, and increased use of agent-based models may assist in filling the gap of cultural behaviour in models for land use for submerged landscapes. Terrestrial analogy and ethnographic analogy may be used in land use models to take data from a known example and apply it to an unknown area. However, these must both be used conscientiously, as they assume a level of continuity that may not represent the archaeological material. To counter this, assumptions of continuity should be tested to assess if this is accurate depending on the material encountered. Models of hydrology and coastal resource use are also significant for submerged landscape archaeology, but it is important not to assume coastal adaptation will exist in all submerged sites. In many models for submerged landscape archaeology, economic variables are emphasised, however there is scope for mapping of existing sites and spatial patterning of artefacts to better understand submerged landscapes.

4.3 Post-depositional processes and preservation

This section summarises some of the common factors that have been addressed as post-depositional processes in models and frameworks for submerged landscape archaeology, and areas which are especially relevant to the varied Australian coastline. Broadly speaking, an example of a preferable inundation scenario for settlements submerged by postglacial sea-level rise is one where the site is inundated rapidly to minimise time exposed to wave action, but at a steady rate to minimise the erosion potential (Stewart 1999). Sites that are exposed and battered by waves and currents during a slow inundation process risk destruction, or this may affect their distribution. An example presented by Flemming et al. (2017a) suggests that waves of 1–2 m in height will, over time, cause considerable damage to an unconsolidated archaeological deposit. Understanding the past and present oceanographic conditions as well as local sea-level rise, and thus rates of sea-level rise, creates greater context around the inundation process.

The consideration of site formation processes is crucial to understand the probability of site survival, having established where a site is likely to have been located in the past landscape. Flemming (1983) outlined a framework of locations that were deemed the most conducive to the preservation of sites. This includes estuarine environments, sheltered alluvial coasts, accumulating beaches, submerged caves, karstic caves and sinkholes, and archipelagos. Although several decades of research and site discoveries have occurred following this publication (and the criteria revisited, see Flemming et al. 2017a), these locations all speak to some of the general trends in preservation which are discussed here. The section aims to seek out similarities and differences between preservation criteria for submerged landscape archaeology, and reviews the established principles of site preservation alongside the sites that are reported. This represents a 'top down' approach to understanding site preservation, however this approach has its limitations given the issues in extrapolating preservation criteria and applying these principles in a different environment. A 'bottom up' approach that reviews individual site composition and characteristics will contribute additional detail and context, however, given the scale of the survey models that this project draws from, a more broad and somewhat generalised discussion is appropriate.

4.3.1 Barrier features and coastal environments

As a general principle, low energy coastal environments contribute to better chances of preservation. Adjacent protective features such as barrier islands and shoals may contribute to this, in addition to positioning with respect to prevailing wind, and through gentle sloping topography. Given the association of high energy environments with greater impact from waves and storm events, and the association of scouring and other indicators of erosion, this is a straightforward and logical assumption incorporated in most models that aim to understand preservation criteria for submerged landscape archaeology. Nonetheless, Fischer (1995) emphasised that is it also important to test areas deemed less prospective to verify this observation.

Denmark

Sheltered inlets and embayments are recommended as high potential features by several scholars including Flemming (1983), and form a prominent aspect of the Danish Model (Fischer 1995a). The topographic fishing site model within the Danish mode of practice emphasises these features for their ability to protect submerged archaeological material from the more destructive impacts of exposed, open coastlines. Wave height frequencies are dominated by a 0.3–0.7 m interval in the

Baltic, and sheltered inlets assist in protecting archaeological material from damage by wave energy (Bjørnsen et al. 2008).

Carmel Coast

Although the Carmel Coast of Israel is a more exposed location than the sheltered Danish Baltic coastline, prehistoric sites are still able to survive due to the depositional and erosional processes of this area, and a survey strategy has been developed to maximise the information collected from these sites (Galili et al. 2017; 2019b; 2020). The presence of rocky barriers and extended rocky ridges may also contribute to protecting submerged archaeological sites (Flemming 1983). These features serve to reduce the impact of waves activity, currents, and swell on sheltered submerged sites. Waves in the Eastern Mediterranean are usually less than 1 m in spring and autumn, with swells of up to 2 m in the summer (Carmel et al. 1985; Galili et al. 2017). Wave heights are known to occasionally exceed 5 m during winter storms. The best-known example of these protective barrier features is the submerged kurkar ridges along the Carmel Coast of Israel. The kurkar ridges, following the inundation of the submerged Neolithic settlements, have helped to shield these sites (Galili et al. 2017).

4.3.2 Depositional context and role of sediments

Having established that the topographic depositional context may influence a site's preservation, the sedimentary depositional context also plays a factor in material preservation. The equilibrium required for preservation (ignoring the issue of visibility), is very much oriented towards increased sedimentation to afford layers of protection. Erosional processes may also alter an archaeological deposit, but rarely erase it altogether. For example, arrays of lithic artefacts can be reworked due to sea-level rise. This process is similar to the deflation of a site on land, and in the submerged landscape context is best described as a lag deposit, in which sediment is removed and leaves behind a 'lag' of larger particles including stone artefacts. The balance of sedimentation and erosion for submerged landscape archaeology contributes significantly to rates of preservation, as demonstrated by examples from Denmark and Israel.

Carmel Coast

A dark, hard palaeosol (termed Carmel Coast Clay, see Galili 1985) is associated with the submerged settlements along the Carmel Coast, as the prehistoric material is usually found embedded in this palaeosol (Singer 2007). During postglacial sea-level rise, the sites were covered by sand from the Nile delta brought by a longshore current, and this sand layer provides a barrier thick enough to prevent exposure and erosion in antiquity. However, due to human activity in the coastal zone (including sand quarrying and marine construction), the sand layer is often eroded. Consequently, the palaeosols and sites are exposed and could be detected, but also undergo erosion. In the Israeli example, many features, including burials, wells, and storage pits, are dug below the surface during the settlement's use. These sub-surface features allow for greater preservation potential as they are not as exposed to the impacts of the sea during sea-level rise (Galili et al. 2017). The prevalence of stone in building structures and features in the submerged Neolithic settlements of Israel also likely contributes to their preservation, given the durability of stone.

Denmark

In the archaeological deposits in Denmark, these have been partly exposed by erosion of an overlying veneer of sandy sediment, with ongoing erosion in this area continuing to expose more sites. In Denmark, the erosion of coastal environments has increased with climate change and pollution, creating the removal of the eelgrass beds that stabilise protective sand layers over submerged prehistoric settlements (Skriver et al. 2017; Krause-Jensen et al. 2019). Deposits of peat and gyttja are also associated with the preservation of submerged prehistory (Astrup et al. 2020).

Comparison of case studies

In both examples, coastal erosion both allows for the exposure of archaeological material, but also may contribute to its destruction. While protective sedimentary environments are preferable for submerged landscape archaeology, it is also important to identify areas that may be at risk of erosion and could expose submerged archaeological material.

4.3.3 Tidal regimes

Submerged archaeological sites have been found in micro-tidal (e.g. the Baltic) through to macro-tidal areas (e.g. Great Britain) (Benjamin et al. 2011; Bailey et al. 2020; Evans et al. 2014). Despite the global variation, tidal regimes and currents may have considerable impact on preservation. Strong tidal currents may adversely affect preservation potential of an area, and contribute to the movement of and eventual erosion of artefacts. In Australia, efforts have been made to reconstruct past tidal regimes (Ward et al. 2013) in Murujuga, to assess the impact of tides on this archipelago. The modelling of past tidal regimes may contribute useful information towards understanding shoreline environments, providing greater detail to how the shoreline may have been used rather than relying on estimates of eustatic sea level. In landscape reconstruction, modelling hydrology and palaeochannels may also provide some insight into potential fluvial transport that could affect the movement of archaeological material. Tides, swell, and currents must be considered for their possibility to disperse or shift archaeological material from where it was deposited, and understood in conjunction with fluvial processes. Here, the two examples used to illustrate the role of tides include Denmark, and Great Britain. One representing a highly microtidal environment, the other representing an extensive tidal range.

Denmark

Tides on the Baltic coast of Denmark are <1 m, and may be as small as 20 cm (Nordberg 1991). The microtidal environments of the Baltic have also contributed to the preservation conditions of this area, providing very limited movement to submerged settlements. This gentle tidal environment reduces the impact of tidal currents across sites, adding to their likelihood of preservation given their sedimentary cover.

Great Britain

Tides of c. 15 m occur off the coast of Great Britain, and this creates an extensive intertidal archaeological record (Westley 2017). The intertidal zone is often challenging for archaeological work, given the brief windows of opportunity for systematic, detailed recording, and the potential for ongoing erosion as the area is continually submerged and exposed. Despite these challenges, an understanding of intertidal material allows for increased understanding of coastal adaptation, and indicates areas that could be prioritised for further offshore survey (Fig. 15).

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Figure 15: Submerged archaeological sites in Great Britain (Bailey et al. 2020c:191).

Comparison of case studies

Given the significance of tides, intertidal archaeological sites are also an important part of submerged landscape archaeology. While not always considered truly 'submerged', as they are only submerged for part of the time, these sites may also demonstrate use at lower periods of sea level. The information gained from these sites may also indicate the preservation potential of material that has been situated in the intertidal zone for extended periods of time. Intertidal sites also indicate areas where material could preserve further offshore, and provide information about material prior to complete inundation and a final location in a subtidal environment. A large tidal range will expose vast flats that may once have been inhabited by people, and this reveals an important part of drowned landscapes. Although smaller tidal ranges are associated with less damaging tidal currents, as is seen in the Danish example, excellent preservation characteristics can be seen in the extensive intertidal zone of Great Britain.

4.3.4 Storm impacts

The impact of storm events and cyclone and hurricane activity on submerged archaeological features requires further research, however some case studies may provide information as to the state of preservation for material subject to storm conditions. The role of extreme and catastrophic events in the destruction of submerged sites also requires further investigation, however, for the purposes of this research and the issue of storm impacts along the Australian continental shelf, the focus here is oriented towards storms. These have been factored into studies of submerged landscapes, including studies on the Carmel Coast, Florida, and in a case study from Northeastern Australia to establish the preservation potential of shell middens on land.

Carmel Coast

Along the Carmel Coast of Israel, regular exposures caused by storm impacts remove the overlying sand deposits and allow for the recording of submerged prehistoric material (Galili et al. 2017). In this way, storm events can be seen to assist survey efforts. Wave-induced current is very effective during storms, and the velocities of the longshore currents during storms has been estimated at 2 m/sec (Zviely et al. 2007). However, this also exposes the archaeological material to erosive processes. Additionally, Shtienberg et al. (2020) identified a deposit which was interpreted as evidence of a Pre-Pottery Neolithic B (PPNB) tsunami event off the Israeli coast. This study suggests that the destructive nature of the tsunami destroyed any villages that were situated along this coastline dating to the PPNB, and that this event is the reason no sites prior to the PPNC have been located off the coast of Israel. However, this is currently based on a single shell deposit, and has yet to be confirmed in further studies across the coast of Israel.

North America

Apalachee Bay off the coast of Florida is also subject to storms and hurricanes. Marks (2006) researched wave data for this area, and tested the force required to shift stone artefacts in a flume, in addition to on-site experiments. From this, it was established that only the smallest artefacts at the site of Ontolo were impacted by storm events. At Ontolo, artefacts are further protected by rock outcrops, which would allow for additional protection against storm impacts. This study demonstrates the potential benefit of experiments designed to assess post-depositional processes on submerged archaeological material.

Northeastern Australia

Research regarding cyclone impact on the archaeological record was carried out on the coast of northern Queensland (Fig. 16). Bird (1992) researched 93 shell midden sites dating from 3 ka to 2 ka, and then re-recorded these sites following cyclone events. This established that over half of the shell middens were either dismantled, or destroyed entirely (Bird 1992). In this case, shell middens were situated on dunes, and confronted with storm surge up to 3 m high. Sites that survived cyclone impact were located on hind dunes, or stable beach ridges, and thus protected by a buffer of foredunes or further inland from storm surge. This also indicates prospective landforms that can be found under water.

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Figure 16: Beachmount, where the erosion of several shell middens was assessed following a cyclone (Bird et al. 1992:76)

Comparison of case studies

The selected case studies demonstrate that although storm impacts may present challenges to the preservation potential of submerged landscapes, there is still potential for material to preserve. This suggests a more nuanced approach is required to understand the capacity of storms to rework archaeological material, and in what cases material may remain relatively unaffected. Additionally, areas in which sand coverage changes vastly due to storm impacts may suggest that storm events can assist archaeological research as well.

4.3.5 Marine life and vegetation

Vegetation may obscure an archaeological site or artefacts, however, it may also contribute to the stabilisation of a site. While these factors may impact the integrity of a site, it is possible to observe their potential impact on the distribution of material culture. Examples have been selected to address this point, and the impact that elements of the marine environment may have on the visibility of submerged material culture.

Denmark

At many shallow water sites in Denmark, a thin layer of sand is deposited across submerged sites, with eelgrass that holds the sand and forms a protective layer (Skriver et al. 2017). Eelgrass (Zostera marina) forms roots on muddy seabed and prevents the exposure of material underneath (Fischer 2011). The 20th century has seen considerable changes to eelgrass, including a pandemic which led to the death of substantial amounts of eelgrass, and subsequent erosion, as well as pollution which prevents the eelgrass from photosynthesising (Rasmussen 1977). The role of eelgrass in the preservation of the submerged Mesolithic is significant, but should also be noted as a factor that complicates the identification of submerged archaeological material.

North America

Similar to the Danish example, eelgrass is also observed as a stabilising feature of the seabed off the coast of Florida, in Apalachee Bay (Faught and Donoghue 1997; Cook Hale et al. 2019). With consideration for the natural environment of submerged sites, creatures such as urchins and lobsters also have the potential to alter the distribution of a submerged site. Marks (2006) observed this at the site of Ontolo, where sea urchins collect debris, from the ocean floor, including artefacts to cover themselves. Pinnipeds were also observed to have a destructive influence on sites during marine transgression (Braje et al. 2011). Through this, the distribution of an archaeological site may be affected by marine life.

Comparison of case studies

While some aspects of the environments in the Danish and American example may be similar, they are significantly different in terms of oceanographic impacts and archaeological material. Nonetheless, these two examples illustrate the need to consider the impact of the marine environment, including seabed vegetation and marine life that may shift archaeological material.

4.3.6 Summary

This section provides a brief discussion of the major factors impacting post-depositional processes and preservation potential of submerged landscape archaeology. Some generalisations can be made to contribute to the discussion of preservation potential. It is clear that lower energy coastlines remain optimal for site preservation, but further testing of what allows for preservation in higher wave energy environments with strong currents is needed (Flemming et al. 2017a). Sediment cover along the coast is beneficial for preservation, but impacts site visibility and detection (Galili et al. 2019b). Barrier features and sheltered inlets may also increase chances of site survival, along with early and fast diagenesis (Stewart 1999). However, further research is needed to establish trends at local and regional scales for preservation. Increased focus on geoarchaeological methods to understand site formation and taphonomy are likely to contribute to 'bottom up' approaches. Eventually, this detailed insight can then be applied to relevant examples elsewhere, but firstly requires assessments operating at a landscape-scale such as the predictions presented here.

4.4 Site visibility and discovery

The factors that may impact the preservation of an archaeological site under water also often impact its visibility to researchers. In this case, visibility is used here to describe the likelihood of locating an archaeological site through diver-based survey, or by using geophysical methods such as sub-bottom profiler or sidescan sonar. The influence of the depth-time ratio creates a global bias towards younger, Holocene sites in shallower environments, which is particularly evident in settlements in Israel. Exposed sites are considered more unusual based on the likelihood that these sites would have been destroyed due to their lack of protection from potentially destructive processes, while stratified and buried deposits may not be identified without investigation by invasive methods. To understand the factors that facilitate site visibility, the process of regional familiarisation is crucial.

4.4.1 Chronology

The depth-time ratio describes the relationship between approximate dates and bathymetric contours based on sea-level curves, and is used to target submerged sites of a specific age. This association is best represented by both the Israeli Model and Danish Model as part of survey strategy.

Carmel Coast

From the Carmel Coast of Israel, palaeosols between depths of −1 and −15 m are deemed most productive for submerged settlements as these are the depths that have yielded finds dating from the Pre-Pottery Neolithic to Middle Chalcolithic. Galili et al. (2019b) state that research should focus on these areas where the thickness of sand cover provides a balance between shielding the settlement, and occasional exposure to facilitate survey and excavation. Based on this, they recommend focusing efforts on these younger, shallower sites given the more imminent threat of erosion. Additionally, the stance of the Israeli Model is that prehistoric sites are less likely to be found in deeper water compared to shallow water. It is argued that because the deeper shelf was dry land for less time the chances of finding sites are lower, and any older sites are likely to represent more ephemeral remains.

Denmark

In Denmark, depth-time ratio is somewhat affected by a complex sea-level record involving substantial isostatic rebound. Southern Denmark mostly underwent submergence, while northern Denmark was slightly uplifted due to the glacio-isostatic adjustment after the retreat of the Scandinavian ice sheet (Astrup 2018). In the north, most Mesolithic coastal sites are above mean sea level, and include over 350 shell middens dating to the Ertebølle period. Southern Danish Mesolithic sites are generally below mean sea level, and include hundreds of submerged sites made up of isolated finds, cultural deposits, and organic features including wooden objects and fish traps (Pedersen et al. 1997; Fischer 2004; Andersen 2013). In all survey operations, the expectation of where sites are located should be guided by a suitable sea-level curve, and local changes to sea-level factored into reconstructing the past landscape.

Comparison of case studies

In both of the selected case studies, and more broadly in submerged landscape archaeology, the importance of understanding local sea level is critical to establishing where sites are likely to be in accordance with depth. This not only guides where sites should be of a certain age to address particular research questions, but is also important to note for the potential for erosive processes to influence the exposure of material, as is the case in the Israeli example.

4.4.2 Geological and sedimentary context

Sites located on exposed, rocky seabeds are generally not expected to preserve as well as sites located in sheltered areas and sites covered by sediment. Quarry sites are considered prospective in these rocky areas, in addition to other stone structures including stone-built fish traps. Despite the potential for erosion or movement of archaeological material, the uninterrupted exposure of material on rocky seabeds can facilitate their discovery, as these features are not covered by sediment, or alternatively, may be thinly veiled by mobile sand. Upstanding objects on rocky seabeds may also be identified through sidescan sonar or the use of drop-cameras, depending on the resolution of the instrument. As distinct from exposed areas, sedimentary contexts in which archaeological material is covered present a ‘trade off’ in less visible sites and artefacts compared to rocky seabeds, but an increased likelihood of preservation due to a more protective environment. Archaeological deposits with associated sedimentary strata (unlike surface finds on rocky seabeds) are well-known in the northern hemisphere, and especially in Israel and Denmark.

Carmel Coast

The Carmel Head stone pile site located on the Carmel Coast was suspected to be a prehistoric site, and reinforces that stone features may be more resilient features on rocky coastlines (Galili et al. 2019b). Although rocky coastlines may be less conducive to the preservation of more fragile elements of the archaeological record, stone features can preserve well. Additionally, lithic material may also be found in association with rocky environments. However, the stone pile site represents an unusual example for this coastline, and thus is of interest. As such, it was checked as a case study in this thesis. Submerged settlements and material embedded in palaeosol are more common. Excavation of submerged settlements off the Carmel Coast has allowed for detailed assessment of these villages, however they are only occasionally exposed which affects their discovery and opportunities for research.

North America

In North America, quarry sites were used as a focus point for survey strategy, as highly resilient and relative visible features (Faught and Donohue 1997). These quarry sites indicate a durable form of material culture that was relied upon to identify archaeological material. This reinforces the likelihood that stone tools may be found in association with rocky seabed environments, as well as other stone-built features.

Denmark

In Denmark, submerged settlements are associated with a peat layer known as gyttja which contributes to the preservation of organic remains. In the context of potential for Australian research, in situ shell midden deposits are a possible site type to be encountered which is also found in Denmark, however, these deposits may be challenging to detect depending on sand cover in an area, and other overlying sediment. In these cases, the use of sub-bottom profiler is crucial to map the past landscape, and may also detect features below the seabed (as demonstrated by Astrup et al. 2020). While sites covered by sand and sediments from rivers may assist in the protection of sites, it presents a challenge for identifying sites which may be assisted by geophysical survey to delineate prospective areas based on the past landscape.

Comparison of case studies

Despite the fact that their preservation is mostly considered less likely, the increased visibility of exposed sites and potential for ongoing erosion or dismantling of features suggests that recording these features should be prioritised. These case studies also indicate that rocky contexts may yield submerged archaeological material, however better preservation is expected in sheltered areas with protective sedimentation. In this case, the contribution of sedimentation may make sites more challenging to identify, but is more likely to preserve material.

4.4.3 Temporary exposure of archaeological material

The role of partial sand cover in the Carmel Coast generated a strategy of regular survey, especially following winter storms which remove the sand cover. However, the coverage along the coast of Israel varies substantially, and although some settlements have preserved due to the protective sand layer that has not been exposed until recent years, some areas may be covered by especially dense layers. The area of Haifa Bay on the Carmel Coast is a partly protected area and would warrant further survey work theoretically, but no submerged prehistoric sites have been identified here as the sand layered over palaeosols is up to 20 m thick. Despite this, the partial visibility of submerged settlements along the Israeli coast is maximised through a process of regular monitoring, which includes snorkel surveys in addition to shore walking to establish where possible exposures may occur on the seabed. This also provides an opportunity to identify material that has washed ashore and follow up with diving as necessary for recording. This strategy is entirely applicable internationally in areas subject to drastic changes in sand cover, and represents a relatively cost-effective manner to monitor a prospective area for archaeological sites.

4.4.4 Intertidal landscapes

The intertidal zone is discussed here at a more general level than previous sections, to address broad themes of survey strategy given the challenging conditions presented by the intertidal zone. Despite the assumption that the storm waves and tidal currents of the intertidal zone would hinder preservation, sites may preserve well in the intertidal zone in some cases. For example, human and animal footprints have preserved in intertidal sediments in many locations across Great Britain, with the earliest at Happisburgh dated to 0.78 to 1 million years ago (Ashton et al. 2014). In Britain, archaeological material is usually found beneath submerged forests, or peat beds (Wilkinson and Murphy 1986; Hazell 2008; Benjamin et al. 2014). The majority of underwater finds in Britain are recorded in the intertidal zone, and include wooden objects, dugout canoes, and other in situ archaeological features. These sites have yielded archaeological material, as well as paleoenvironmental material. Although not the only area in the world where intertidal material has been identified, the influence of tides in the British example is greater than in most other cases, and this is a relevant parallel to areas in Australia with substantial tides as well.

The erosion of intertidal deposits also highlights the paradoxical nature of variation in site exposure: erosion permits site discovery, but also threatens the preservation of sites that have not been discovered. Intertidal sites are also subject to erosive impacts by coastal development, including tourism, seashore defences, and the development of other infrastructure. This issue may be assisted greatly by the involvement of local communities, who have an understanding of the shifts in exposure of intertidal deposits and can monitor changes over time. Additionally, research programmes to address rates of coastal erosion may be used to assess the potential for damage to particular areas. The intertidal zone is highly accessible, however, challenging to record given that the opportunity for investigation may represent a small amount of time. And once no longer exposed, the same deposit may only be exposed again months or years later.

Intertidal areas can be easily mapped by drone and then reconstructed in 3D photogrammetry, which allows for smaller features of an intertidal landscape to be surveyed either on foot at low tide or by snorkelling at high tide. Aerial photography and satellite imagery has also been used to map rates of coastal erosion. Mapping features such as lithic scatters and fish traps associated with the present intertidal zone in Australia may allow for examples of the digital and acoustic signatures of these objects in the intertidal zone, with the possibility of identifying them at greater depth.

4.4.5 Collaborative efforts to site identification

The involvement of local communities in the identification and recording of submerged archaeological material is important, as well as cooperation with marine industry to further archaeological research. The concepts of community archaeology and development-led archaeology are both well-established on land (Greer et al. 2002; Marshall 2002; Flatman et al. 2011; Atalay 2012). Thus it is not to say that the issues of community engagement and industry collaboration are unique to submerged landscape archaeology, as is demonstrated by examples from maritime archaeology that are focused on shipwrecks (Cohn and Dennis 2011; Scott-Ireton and Moates 2019), however, submerged landscape archaeology faces significantly different challenges of visibility and identification.

Denmark

Denmark has a long history of community engagement in the efforts to locate submerged prehistoric sites. Submerged prehistoric sites had been observed by fishers for some considerable time, and by 1957, a Danish weekly magazine launched a competition to find the earliest submerged prehistoric site in Denmark (Sturt et al. 2018). This allowed for the identification of several Mesolithic settlements, including Tybrind Vig (Andersen 2013). By the 1970s, the Langelands Museum began a partnership with local recreational divers to investigate submerged landscape archaeology (Grøn and Skaarup 1991). Through this effort, sports divers carried out survey and systematic excavations, led by professional archaeologists. This long-term investment in Danish submerged prehistory has allowed for the collection of data that would not necessarily be possible by academic researchers alone, and has facilitated a high level of engagement in submerged prehistory over time. While there are other examples of community-led approaches to submerged landscape archaeology, the Danish example is among the earliest attempts to include local community members in the discovery and investigation of submerged sites.

North Sea

Two examples of marine industry cooperation with archaeological research are discussed for the North Sea: the work conducted on the marine aggregate area known as Area 240, and the excavation of Maasvlakte 2 at Rotterdam. At Area 240, the discovery of archaeological material in gravel spoil from aggregate extraction off the coast of Britain allowed for an opportunity to sample sediments in the area of this discovery, in addition to important palaeoenvironmental data (Tizzard et al. 2014). At Maasvlakte 2, geophysical surveys were first conducted to locate target areas, and this was then followed by coring and excavation in the areas deemed to be of high archaeological potential (Moree and Sier 2015b; Peeters and Amkreutz 2020). These examples represent a different situation to engaging with interested local volunteers within a community, however the data obtained by marine industry may be beneficial to archaeologists for landscape reconstruction, and may allow for room for collaborative efforts for excavation and coring, as demonstrated by the examples in the North Sea.

Comparison of case studies

In the examples discussed here, both the inclusion and cooperation of local communities and industry entities may generate significant results for submerged landscape archaeology. The training and awareness of divers for submerged landscape archaeology is also an issue that impacts site identification, in that there is a possibility that small stone tools and other artefacts are less likely to be noticed by divers. At the same time, training and awareness of local archaeological material has not always yielded results, chance finds are a familiar concept in submerged landscape archaeology on a global scale, with many artefacts and sites located by sports divers and fishers. To maximise the likelihood of site discovery, submerged landscape research should prioritise engagement with local groups in addition to relevant industry partners. This also allows for the possibility of the development of community-based approaches to monitoring underwater archaeological sites, which has already been successful in the 3DMAPPR shipwreck project in Western Australia (Edwards et al. 2016). Cooperation with the wider community increases the likelihood of chance finds being reported to relevant researchers, and allows for this information to guide ongoing survey and research priorities.

4.4.6 Summary

From the examples of the Danish and Israeli Models, the conditions that permit for the preservation of both durable materials such as stone, and more fragile organic materials, rely on a balance of sediment cover and then exposure to facilitate discovery. The process of regional familiarisation, especially in surveying areas that have not otherwise been assessed for submerged landscape archaeology, comes to the fore in predicting whether material will preserve and be easily noticed by divers and adjusting high potential areas to address this, as well as ensuring all divers understand what features they should expect to find, and the potential state of the features. Regional familiarisation can then be enhanced through community engagement, to consider local groups and Traditional Owners of an area as the experts and gain insight from their knowledge. Additionally, collaboration with marine industry, fishers, and sport divers may facilitate access to datasets crucial to understanding the past submerged landscape.

4.5 Conclusion

This chapter brings together the comparisons and contrasts established through original desk-based research and field observation of international case studies for submerged landscape archaeology, which can then be applied to the Australian environment. As observed by Faught (2014), there is a disproportionate amount of literature and discussion on the development of models for submerged archaeological potential, as opposed to actual testing and direct observation by diving or coring. Some of this relates to issues of funding and logistical hurdles for underwater archaeology, although these are not insurmountable problems. This chapter critically reviews the current literature on the establishment of predictive criteria, which is important to advance the testing process, however clearly outlined methods and methodological recommendations for submerged landscape archaeology are also critical to the discussion. Here, the foundations of site preservation and identification have been addressed as a ‘snapshot’ of the collective archaeological understanding, to enhance the methodological discussion of best practice to move submerged landscape archaeology forward in Australia.

5.0 MODELS IN SUBMERGED LANDSCAPE ARCHAEOLOGY: A CRITICAL ASSESSMENT OF METHOD

> "All models are approximations. Assumptions, whether implied or clearly stated, are never exactly true. All models are wrong, but some models are useful." (Box et al. 2009:61)

5.1 Introduction: Methods, Models, and Modelling

This chapter considers original field data and methods undertaken in Murujuga, Western Australia, compared with two case study regions in order to compare methodological similarities and differences. Each mode of practice is reviewed and discussed, with greater detail provided on the work at Murujuga in the next chapter. There are two concepts relating to 'models' and 'modelling' that require greater definition. The first is the concept of a predictive or high potential model, either based on topographic principles or as a GIS-based model of potential including a combination of variables. The other refers to 'model' as a mode of practice that is more likely to result in site discovery. Both senses of this term are involved in the Danish Model, with the survey strategy reliant on the development of a topographic predictive model, and the Danish Model outlining the mode of practice undertaken to test the predictions for site discovery. The Israeli Model also requires the use of predictive modelling, as well as criteria for the detection and study of submerged sites.

The Danish Model and Israeli Model are assessed as case studies where distinct modes of practice have been effective. The development of a survey model for Australia then becomes the primary objective of this thesis project based on the international examples. In this respect, this thesis considers the field from what is known, into what is unknown, leveraging off the decades of experience in the Northern Hemisphere. Thus, this chapter undertakes a review of the Danish Model, the Israeli Model, other international models in submerged landscape archaeology, and a terrestrial analogue model created by Veth et al. (2020) for research in Murujuga. These reviews are mostly based on individual, key papers representing each reported mode of practice, however an additional review of the 2010 JICA Forum is also included to provide a rounded representation of perspectives on the applicability and implementation of the Danish Model. In the Israeli case study, additional fieldwork was conducted on the Carmel Coast to provide a case study of a known archaeological site requiring further investigation within the framework set out by Galili et al. (2019b). This chapter uses international models to review similarities and differences, and variations in methodological approach across some key areas for submerged landscape archaeology.

5.1.1 Variations in scale and practice

This section outlines some of the differences between models in scale, design, and practice. Clarke (1972:1) poses the question as to what constitutes a model, urging scholars to avoid "a hopelessly broad or a pointlessly narrow definition", and instead describes at a general level that models are "pieces of machinery that relate observations to theoretical ideas, they may be used for many different purposes and they vary widely in the machinery they employ, the class of observations they focus upon and the manner in which they relate the observations to the theory or hypothesis."

Land use models, or high potential models, are common models throughout archaeology. These models aim to reconstruct the factors contributing to the spatial patterns of humans in the past. In this case, Kvamme (2005) describes these models as a collection of polygons mapped onto a landscape, identifying areas that are 'probable' to contain an archaeological site. High potential models for archaeological sites are sometimes criticised for their lack of theoretical engagement, and in some cases, unsuitable applications. Predictive models have often been used as a method of non-destructive heritage management, providing a way to integrate past landscapes into spatial planning.

Predictive modelling is described by Verhagen and Wheatley (2012:52) as providing a "quantitative estimate the probability of encountering archaeological remains." In predictive modelling, there is a choice between mathematical or graphical methodology. While both are often used, and arguably the graphical representation is an important step in the development of a mathematical predictive model, mathematical predictive models utilise multivariate statistical methods to establish a correlation between the location of an archaeological site and the variables selected by the researcher. Distinct from these models, graphical predictive models rely on developing a model as a series of map overlays.

Another form of modelling is the 'intuitive model', these are based on a heritage practitioner's experience, and the expertise that this creates in identifying locations for an archaeological site. Although these remain somewhat untestable by their nature, they are usually composed of a series of statements based on previous experience that influences an archaeologist's notion of where a site is likely to be (Canning 2005). The predictive statements in this case may be considered 'expert knowledge', which is crucial to any archaeological project, but especially those in which a research team of personnel less familiar with an area are involved.

Lycett and Chauhan (2010) provide a definition of analogue models, as models which "explicitly use information from better known or empirically documented situations (e.g. experiment or ethnography) to generate predictions. It is this sense of analogy between one set of empirical phenomena and another from which this subset of models takes its name." These are also often used in submerged landscape archaeology, whether in the form of using terrestrial archaeological sites to predict site patterns and preservation characteristics, or in the case of adapting ethnographic information to identify sites or better understand the archaeological record of a submerged settlement.

Most models can be considered either inductive, or deductive. Inductive models are characterised as data-driven and move towards generalised theory, while deductive models are theory-driven, and begin with a theory as to how people used a landscape and deduce where materials should be located based on this theory (Kohler 1988:37). While inductive models tend to be statistically based, this is not usually the case for deductive models. However, the difference between the two is not recognised universally, and some models may incorporate both (Wheatley and Gillings 2002). Kvamme (2005) outlines how statistical models may also be used to derive weights for theoretical variables, which is to say, how to inductively model deductive variables. Crucially, all models must be testable, and in this testing, consistency and evaluation are vital. All models must be tested before they can be operationalised (usually through some form of ground-truthing), and a model is operationalised if all terms are defined so that different people may arrive at the same predictions using the same model.

Altschul et al. (2004) assert that there is some misunderstanding surrounding the use of GIS, and that some archaeologists confuse the use of GIS as a tool, and predictive modelling. As a tool for research, GIS is effectively theoretically neutral. There is no inherent theoretical premise associated with the use of GIS. Mehrer and Wescott (2005) provides some criticisms of predictive modelling, including that site locations cannot be modelled due to an impossibility of modelling ancient cultures, that it is flawed due to sampling errors surrounding known sites, and that site models involving environmental factors are environmentally deterministic. In many ways, these criticisms can be dealt with by adjusting the expectations placed on a predictive model. At this point in time, for a variety of reasons, no predictive model can ever expect to represent the past with absolute certainty and impeccable accuracy, however predictive models can be useful in generating testable hypotheses about the past which can be interrogated more thoroughly through the archaeological record.

Archaeology shifts from a range of scales, from the unit of artefact, to sites, to features/landforms, to landscapes, to regions (Verhagen and Wheatley 2012). The scale of analysis and the scale of results may not be the same in every case, and scales must be apparent in communication of research. Otherwise, the site/environmental context represented at one scale may be erroneously extrapolated to another, creating what is called ‘ecological fallacy’ (Harris 2006; Verhagen and Whitley 2012). In the case of projects where remote sensing data is used, scale has significant impact for the applied technology to be used. Where low-resolution, large-scale landscape mapping may be suitable to achieve certain research outcomes, high-resolution site imagery and artefact recording may be required for others. In the case of the models discussed here for submerged landscapes, the scale often shifts and ‘zooms in’ to increasingly finer scales, from a landscape, to individual prospective features, to identifying a site, to the recording of artefacts (Missiaen et al. 2017).

5.2 A review of the 'Danish Model'

5.2.1 Fischer 1993/1995

The Danish Model describes a mode of practice designed for the identification of submerged Mesolithic sites. It relies on a topographic predictive model, as well as guidelines for the prospection of sites. While this model was developed for use in the Baltic, international applications have been proposed by Benjamin (2010b). This model deals with survey operations, and does not address the research and management of material once it is located.

Underwater excavations of submerged prehistoric settlements commenced in Denmark in the 1970s in the South Funen Archipelago. In 1975, the well-known settlement of Tybrind Vig was located, though material had been found in this area two decades prior (Andersen 1980, 1985). In 1984, Mesolithic occupation was identified in the Småland Bight at Argus Bank, dating to the Kongemose culture. Fischer (1993; 1995) developed a fishing site location model based on ethnographic and archaeological observations from Roskilde and Karrebæk Fjords. A correlation was found between fishing locations used by local fishers, and the topographic characteristics of Mesolithic sites. The model assumes that settlement occurs in proximity to these optimal fishing locations, however Fischer (1993) notes in the observations of traditional fjord fishing practice that ideal fishing locations vary on a seasonal basis. As outlined by Fischer (1993:66), this topographic model operates as follows:

> "Settlements were placed on the shore immediately beside good sites for trap fishery. Such places were at the mouths of streams, at narrows in fjords, and on small islands and promontories close to sloping bottom in the fjords."

To elaborate on this model, Fischer (1993) provided details on the survey model's application in Denmark. The Småland Bight was designated as the area to first test this model, with work on submerged prehistoric material in this area dating back to 1984, with some earlier reported finds. Based on the outcomes of the fishing site location model, Fischer (1993) identified that Kongemose culture was focused to depths of −4 to −6 m. In the methodological development of this model, categories were used to evaluate visibility, a crucial factor in the identification of material on the seabed. These categories include 'good visibility' (mostly free of vegetation and younger sediment), moderate visibility, and conditions impossible. The visibility categories are then connected to the number of finds located per diving minute for each site, to compose a formula to provide an evaluation of whether a site has been found. Three options are given for this evaluation: "very probably that there has been a settlement in the area examined", "probable that there has been a settlement in the area examined or close to it", or "improbable that there has been a settlement in the area examined or close to it”. This is a system that can be recognised in many assessments of archaeological potential, as a ranking of high, medium, and low potential. In the primary survey project to test the model, most sites were typologically dated based on lithic material, with radiocarbon dating deemed possible at two sites. Fischer (1993; 1995) also demonstrated a correlation between the age of material and depth contours. The primary motivator of this model was to locate submerged prehistoric sites in order to protect them, particularly in areas where industrial development took place.

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Figure 17: Topographic locations of Danish Mesolithic settlements according to Fischer's (1995:374) fishing site model, including A) Narrow inlet connecting large bodies of water; B) Between a small island and mainland; C and D) At the tip of headlands; E and F) at the mouth of a stream (Benjamin 2010b:257).

Although the fishing site location model proved useful in this survey project, it has received criticism for its reliance on topography/bathymetry (Fig. 17). Grøn (2018) argues that the fishing site location model echoes a form of landscape ecology abandoned in the 1990s, and utilises simplistic assumptions about prehistoric subsistence strategies. While these are valid concerns about any land use model, the Danish Model remains one of the only clearly defined survey models developed to identify prehistoric material on the seabed and maintains relevance to furthering survey models.

Fischer (2007) returned to the issue of adapting the Danish mode of practice for submerged landscape archaeology for international applications. The basic steps outlined in this paper are as follows: 1) topographic predictive models of site potential; 2) depth contour maps of the sea floor (at a scale of 1:40,000, or more detailed); 3) a small boat with standard echo sounding equipment; and 4) divers with some degree of archaeological field experience (Fischer 2007:58). This iteration of the Danish Model provides both a topographic model to guide the selection of target locations, and the mode of practice employed to the test the fishing site model.

5.2.2 A review of the 2010 JICA Forum

The 2010 JICA Forum began with Benjamin (2010b), and was subsequently responded to by several scholars. In this section, Benjamin (2010b) and the reinterpretation of the Danish Model are reviewed, and methodological issues, debates, or points for improvement in the response papers are also discussed.

The Danish Model, as set out by Fischer's fishing site location model, is separated into 3 phases by (Benjamin 2010b:258):

> "Phase I—Map plotting;
>
> Phase II—Localization and delimitation for sites by echo-sounder; and
>
> Phase III—Marking of the theoretical site with a marker buoy, and diving to investigate."

Fischer (1993:57) wrote that "the model and working method described can be applied to the recording and protection of undersea Stone Age settlements in many other countries of the world." The necessity for an international framework and development of best practice is discussed by Benjamin (2010b), where the Danish Model was re-evaluated to develop a baseline survey methodology applicable on a global scale. Additional phases were added to develop a global survey model, as follows:

> "Phase I—Regional familiarization: archaeology, geography, geology, geomorphology, oceanography, and hydrology.
>
> Phase II—Ethnographic component: cultural parallels, historical research, and modern interviews.
>
> Phase III—Map, chart and aerial imagery analysis, and location plotting.
>
> Phase IV—Observation of potential survey locations, physically and with sonar.
>
> Phase V—Marking of theoretical site with GPS and diving to investigate.
>
> Phase VI—Post-fieldwork analysis, interpretation and dissemination." (Benjamin 2010b:258)

The regional familiarisation aspect was added to the re-evaluation of the Danish Model, highlighting that the original fishing site location model assumed that the parties carrying out fieldwork began with a level of familiarity with the study area that may not always be a given, particularly in the case of international teams conducting fieldwork. According to Benjamin (2010b), this should include familiarity with settlement distribution and subsistence strategies of prehistoric communities, in addition to areas productive in resources and raw materials for lithic production. Evaluations of erosion and sedimentation are crucial to identify prospective areas, and may be assessed through the use of boreholes and other regional, geological and sedimentological survey data. Sea-level curves and palaeolandscape reconstructions should also be understood, particularly to develop depth to age ratios for archaeological material.

This crucial early phase of the model also allows for the omission of areas deemed problematic based on geomorphology, in addition to erosion rates or, to the contrary, high sedimentation rates. Benjamin (2010b) indicates that this aspect of Fischer's model was not discussed in Fischer's early work, this is because of Fischer's extensive experience with the region, thus areas with high sedimentation were automatically omitted from the survey process. However, as Fischer (1997) and Benjamin (2010b) suggest, 'undesirable' or high rates of sedimentation does not equate to a lack of site discovery or preservation. This indicates that models are not necessarily prescriptive in nature, but allow for hypotheses surrounding site location, deposition, and preservation to be addressed.

Phase II of the Danish Model considers ethnography. This phase seeks to evaluate cultural parallels, historical research, and modern interviews. To an extent, this was practiced in Fischer's original implementation of the fishing site location model, where "traditional" fishing practices and local fishers were consulted to inform the likelihood of prehistoric fishing site locations. This phase may vary in international implementation, depending on availability of information and relevance to the time period. The second phase also highlights the potential to consult local divers in a study area, and emphasises the importance of chance finds.

Phase III corresponds with Fischer's proposed Phase I, relating to map, chart, and imagery analysis, and plotting possible locations. Benjamin (2010b) notes that maps and charts may vary drastically in accuracy, and appropriate scales should be selected to allow for suitable levels of detail for the identification of prospective areas and features. The examples given in this case include nautical charts and satellite imagery, as well as regional topography and bathymetry maps. In Fischer (1993), this involves the use of the Royal Danish Administration of Navigation and Hydrography charts at a scale of 1:70,000. Benjamin (2010b) notes the easily accessible nature of satellite imagery, with increasingly higher resolutions available since the initial publication of the re-evaluated Danish Model. Based on these maps, Fischer (1993) then suggests the selection of features consistent with the topographic fishing site model (Figure 16).

In Fischer (1993), possible diving targets were then further localised and delimited using an echo sounder. This forms Phase IV of both the Danish Model and its re-evaluation (Benjamin 2010b). Benjamin (2010b) emphasises that a methodological debate emerged around how to prioritise submerged landscapes through diving and remote sensing operations, observing that high-resolution marine geophysical data is imperative to improving the precision to locate sites, but that it cannot replace fieldwork. Consumer-grade sonars and fish-finders are also suggested as a low-cost method to utilise sonar to delimit targeted areas.

The final phase of Fischer (1993) and Benjamin (2010b) is Phase V, where a theoretical site is marked by GPS and then diving is undertaken to survey the area. In Fischer (1993), GPS was used, although weakly defined in proposed international application. Benjamin (2010b) suggests guidelines for selecting divers to participate in projects, noting that amateur divers and local divers have been highly successful in underwater archaeological projects, but also that all projects require appropriately trained archaeologists and divers.

Phase VI, describing post-fieldwork analysis, interpretation, and dissemination of results is also an additional phase to the model included by Benjamin (2010b). This is described as "standard practice in archaeology and is no exception here" (Benjamin 2010b:262). All material obtained via survey should be processed according to appropriate standards, however this phase of the Danish Model provides limited advice in working with material obtained from submerged settlements and the kinds of data and information that can be collected. Data management, storage, and data sharing, depending on the design of the project, may require published observations of best practice are needed, however it could be questioned whether these kinds of methodological discussion fit within the scope of a model where the central aim is site discovery. This is not to say that these discussions are not also important, but rather that they fit with a wider scope ‘research model’ more than a survey model. In many areas, best practice for the processing of material from archaeological sites is also well-established on land, and fills the gap outlined.

In this thesis, the JICA Forum paper and its subsequent responses are reviewed against a series of research themes. NVivo was used for a systematic review of each paper. In the NVivo software, sections of text (‘references’) can be attributed (‘coded’) to a theme they represent (‘a node’). The themes (nodes) are set out as follows:

- A) Research priorities
- B) Survey methods
    - B1) Planning and logistics
    - B2) Accessing existing map data
    - B3) Ethnography
    - B4) Coastal survey as a parallel
    - B5) Remote sensing
    - B6) Georeferencing data
    - B7) Chance finds
    - B8) Industry collaboration
    - B9) Modelling
- C) Preservation
    - C1) Sea-level change
    - C2) Sedimentary and geological processes
    - C3) Tides
    - C4) Wave energy
    - C5) Currents
    - C6) Storm and cyclone impacts
- D) Archaeological material
- E) Interpretation of material
- F) Post-fieldwork
- G) Heritage management

These research themes were established as key issues to investigate towards the development of a research model for submerged landscape archaeology in Australia based on existing models, and each ‘theme’ defined based on the information gathered in the process of creating the literature reviews presented in Chapter 2 and Chapter 3. In this case, the JICA 2010 Forum is treated as a dataset for qualitative assessment. This approach bears some similarity to thematic content analysis and framework analysis, although these approaches are not often used in archaeology. \This approach is also used in this thesis to reflect on the past perspectives and approaches to submerged landscape archaeology reported in Australian academic journals (see chapter 7).

The research themes are reviewed here, with the information collected described and evaluated for insight to inform an Australian mode of practice.

Research priorities

This section was included to address the research priorities evident from a paper written on submerged landscape survey methodology a decade ago, and to discuss whether the priorities have changed. The forum piece author's response, Benjamin (2010a), describes the importance of shallow water sites (described in the Danish Model as depths above -20 m) in answering "critical questions to human prehistory." In the response papers, themes surrounding the balance between pursuing deep water sites and research questions, and the logistics involved, were a recurring theme (see discussion below).

Survey methods

'Survey methods', as a theme, is discussed here in somewhat general terms, with several 'sub-themes' to build upon this idea (nodes B1 to B9). Besides the general outline of the Danish Model itself, there are more specific methodological points pertaining to survey that should be discussed. Firstly, Benjamin (2010a:255) acknowledges it is "virtually impossible" to create a universal methodology, however the "fundamental aspects" of assessing a region for submerged landscape archaeology remain broadly similar. This has relevance in the pursuit of a baseline Australian Model.

The inclusion of an ethnographic/historical research component was not included in the early guidelines for international practice, however Benjamin (2010a) notes the clear advantage to the investigation of traditional fishing practices in understanding Mesolithic Denmark. This highlights two points of significance: 1) An understanding of the broader time periods (ie historical and prehistoric) to a region may provide insight to past subsistence, and 2) where appropriate, communication with relevant community members may provide crucial 'insider' knowledge to potential survey areas.

In a response, Flemming (2010) notes the impact of ensuring archaeologists "maximize the chances of finding submerged prehistoric deposits", as it may correlate with future funding. This is especially important in areas with limited finds, including Australia.

A suggested change is provided by Ford and Halligan (2010), which is to modify Phase IV to:

> “Phase IV—Observation of potential survey locations, physically and with sonar, marking potential site locations with GPS;
>
> Phase V— Observation of potential site locations (with divers when feasible), and site delineation and evaluation (period, depth, areal extent of deposits, etc.)”

This suggestion was made on the basis that these two phases in fieldwork are usually separate, and it thus makes sense to separate them in this context.

Planning and logistics

Under the theme of ‘planning and logistics’, several different aspects are discussed including the financial costs of research and survey procedure, diver safety, and the limits of the discipline as it currently stands. Benjamin (2010a) notes that technology has allowed scuba diving to investigate early prehistoric sites at shallow depths, however deeper sites (up to 100 m) remain an issue for archaeological fieldwork and deeper investigations necessitate the use of remote sensing and ROVs. While the use of remote sensing has seen greater academic attention in submerged landscape archaeology since the publication of the 2010 JICA Forum, the issue of cost of remote sensing techniques and their ultimate benefit is an ongoing discussion. Ford and Halligan (2010) raise this point to argue that in some cases submerged landscapes may require remote sensing investigation, and the initial outlay provides a less time-consuming search in the long term. Additionally, they point out that partnerships between the aggregate industry and similar organisations may allow for access to expensive, high-resolution data with little additional cost incurred. Flemming (2010) warns that if too much is expected from survey operations, and little is delivered in return, the extensive cost is likely to deter funding and prompt stagnation of the discipline. The solution, Flemming (2010) suggests, is to include a “fail-safe” component in conjunction with a “hopeful” component in projects.

The discussion of personnel suitable to work on submerged landscape archaeology forms an important discussion point of Benjamin’s (2010b) evaluation of the Danish Model. Personnel should be familiar with the area in which they are working, or undergo an extensive familiarisation process to become familiar with the specific material culture they are working on. This is also to ensure that all divers on the project are capable of identifying artefacts confidently and relatively independently, given the constraints of working under water. Sport divers are described as a valuable asset to a field project, given their expert knowledge of local dive sites, conditions, and offshore geology. While their contribution is valuable, on the basis of safety and suitable archaeological practice, Benjamin (2010b) advises that a specialist must lead the fieldwork.

Accessing existing maps

In the model outlined by Fischer (1993) and that of Benjamin (2010b), the use of existing maps to enhance survey strategies and characterise the seabed is advised, although Benjamin (2010b) notes the possible variation in accuracy and reliability. Flemming (2010) observes that there are "petabytes of seabed data obtained for economic and military purposes" which could assist in research of submerged prehistory.

Ethnography

In this case, Ford and Halligan (2010) also encourage "cautious optimism", citing the potential inaccuracies that may enter an archaeological study with inappropriate analogies. In some cases, ethnographic data from more recent populations is applied to archaeological questions involving populations from thousands of years ago. It must be kept in mind that the cultural behaviours of these populations are not necessarily continuous. However, as seen in the Danish Model, there may also be consistency in patterns of behaviour spanning millennia, and these can be successfully applied to the identification of prospective landforms for submerged landscape archaeology.

Coastal survey as parallel

While Benjamin (2010b) emphasises the importance of understanding the environment on land, adjacent to submerged areas, Ford and Halligan (2010) write that the "analogy of inland groups of the same period may not be particularly informative". They also identified the need for caution in using the behaviour of coastal groups from more recent time periods to guide parameters for older sites.

Remote sensing

The use of remote sensing in submerged landscape archaeology is an important factor to characterise seabeds and establish refined survey areas, however, there remains a debate as to whether diver observation or remote sensing should be prioritised. Although remote sensing may allow for the establishment of appropriate dive targets in a timely manner (Ford and Halligan 2010), this is not to say that inexpensive methods cannot also be substituted to contribute to archaeological research, including consumer-grade fish-finders (Benjamin 2010a). Faught (2010) writes optimistically of the development of remote sensing applications in submerged landscape archaeology, indicating the considerable potential for the use of ROVs in deeper water environments, and highlighting the important data that can be obtained for assessing large areas to reconstruct high potential site locations. Ford and Halligan (2010) describe the significance of developing technical approaches to the shallow water environment as well, given the high-resolution mapping that can be obtained through LiDAR.

Georeferencing data

Benjamin (2010b) writes that GPS was used in Danish fieldwork, but this remained poorly defined in the guide for international application of the survey model, and included this phase in the re-evaluation.

Chance finds

Flemming (2010) writes that “research design” must accept the role of chance, and maximise the likelihood of rapid detection and action. In this response, the role of fishers, sports divers, dredgers, and pipe-layers, as people regularly lifting archaeology by chance, is emphasised.

Industry collaboration

Faught (2010) notes greater cooperation between industry and archaeology present in Europe than was apparent in America. Ford and Halligan (2010) also provide a comment on this theme based on the state of research in America, writing that “archaeology is one part of a larger effort to construct, extract, or manage another resource”, with the examples of pipelines, wind turbines, and dredge materials. Ford and Halligan’s (2010) stance is also supportive of building inter-disciplinary partnerships.

Modelling

The ‘modelling’ research theme addresses the points made across the 2010 JICA Forum about the development of models for submerged landscape archaeology, and archaeology at a more general level. Benjamin (2010b) notes the capacity for models incorporating an understanding of settlement distribution, ecologically productive locations, and targeted raw material for lithic production. GIS-based predictive modelling is alluded to, however with the advice that they should be used if the data and means are available. Currently, numerous open-source GIS programs exist (for example, QGIS, gvSIG), thus cost and means are likely no longer an issue assuming technical proficiency, however data remains a significant challenge. Open-source data (including bathymetry and other environmental variables) are widely available to archaeologists, though they may not be available at an appropriate resolution for the outcomes of the project. The issue of scale is also addressed in Flemming (2010), who writes that although the successful Danish example can clearly be developed for international practice, recalibration to suit varying scales or time and space, with different cultural conditions, remains key to its ongoing success.

Faught (2010) advocates for terrestrial analogue modelling, emphasising the importance of regional familiarisation not only for practical benefit but also to provide ways to test hypotheses of site preservation based on the onshore record, and assess continuity into the offshore environment. This preference towards established data is echoed by Hale (2010), which advises against the tendency of archaeologists to "re-invent the wheel to suit the local conditions", and argues that the best of previously developed and tested models is a more logical approach to the issue of site discovery. This consideration is applied across this thesis in the development of an Australian Model.

Preservation

The preservation theme was given several 'sub-themes', including sea-level change, sedimentary and geological processes, tides, wave energy, currents, and storm and cyclone impacts. Benjamin (2010b) describes the evaluation of preservation in Fischer's initial model as a matter of 'intuitive modelling', in which years of expertise in archaeology allowed for seamless and automatic elimination of problematic areas. However, the process of identifying less prospective areas forms a significant part of the Danish Model adapted for international practice, particularly in situations where research teams are less familiar with the regional archaeology and geology. The depth to age ratio, similar to Fischer (1993; 1995), is also emphasised as an important part of understanding preservation. Optimal features are summarised by Benjamin (2010b) as involving micro- to meso-tidal protected environments, with little exposure to storm events, and sedimentation rates that allow for protection of the submerged site.

These factors are all met by the Danish example, reiterated by Flemming's (2010) description of the circumstances in the Baltic as "ideal on almost every count." However, Flemming (2010) writes that there is also a need to understand site preservation across a variety of different environments, and that in less favourable environments a prospective 'micro-niche' can usually be identified. While seeking out high potential areas is important, there is also a need to test models rigorously in presumed low potential areas.

Sea-level change

Ford and Halligan (2010), compared to other responses, focus more extensively of the impact and nature of sea-level rise. First, they identify a theoretical aspect of the nature of 'submerged' and 'exposed' landscapes, as representations of waterline positions at an instant in time. These may be further complicated in areas with large tidal ranges. They also argue that older sites, in association with the increased depth, will require different methods to those set out in Benjamin (2010b).

Sedimentary and geological processes

Benjamin (2010b) encourages studies with a focus on Holocene sedimentation and erosion, given their potentially high impact on the archaeological record. However, seemingly contrary to this, the importance of noting ‘unfavourable’ deposits is also described, based on the fact that 80% of the Danish seabed is categorised as “mud and sand”. Eroding land surfaces are also given credit in this evaluation of the Danish Model, based on examples of erosion of land surfaces leading to increased visibility of archaeological material. Masters (2010) also provides some insight to the ‘unfavourable’ conditions, and argues that a truly international search strategy requires a consideration of coast types beyond the ideal conditions.

Tides

There is little mention of the specifics of tides throughout the 2010 JICA Forum, with the exception of one mention by Benjamin (2010b) in the Scottish case study as an application of the Danish Model. The extensive (> 5 m) tidal swings of the region are noted as a significant challenge, requiring a holistic approach given the difference between this area and the locations in which the Danish Model was developed (Hardy et al. 2016).

Wave energy

Similar to the issue of tides, little discussion is provided on the impact of waves on submerged sites. Masters (2010) notes that the west coasts of the Americas would initially appear unsuitable targets for submerged landscape archaeology, yet some sheltered areas can be found and indicate potential despite the high energy coastlines.

Archaeological material

This category describes the material studied in submerged landscape archaeology at a general level, and the observations reported in the 2010 JICA Forum. In the case study application in Scotland, the Mesolithic record’s characteristic traits are highlighted in an evaluation of depositional criteria that will allow for their preservation (suggested to be lagoons or deep bays). Faught (2010) notes the prevalence of material dating to the mid-Holocene onwards on a global scale, while on the other hand Flemming (2010) discusses the issue that sites of any age may be located further from the palaeoshorelines, and their “ecological determinants” then become similar to those that would be expected in a terrestrial site. This idea connects to the concept of coastal surveys and the use of inland archaeological sites as conceptual models for offshore material.

Interpretation of material

Although little information was obtained broadly from these papers regarding archaeological interpretation, given that it is a survey model and does not deal with theoretical approaches to processing and interpreting data, this was still alluded to by Flemming (2010). Flemming (2010) advocated for landscape approaches in understanding archaeological material in its depositional context and plotted alongside other material culture.

Post-fieldwork

While the Danish Model was not intended to provide guidance to post-survey and post-fieldwork procedure in its original format or in the re-evaluation, Ford and Halligan (2010) identify this as a weakness in the model, and they argue that a conservation plan and budget are essentials to any investigation that intends to recover archaeological material.

Heritage management

In Benjamin (2010b) the importance of awareness of submerged landscape archaeology, both in the broader public and the archaeological community, is highlighted to guide its protection. Masters (2010) provides an example from southern California, noting that exposure of material on the seabed has left material vulnerable to collection by sports divers, and that greater reporting of sites and engagement with the wider diving community is needed to combat this issue.

Summary

This review of the themes identified in the 2010 JICA Forum underpin the comparative portion of this thesis, allowing for a methodological discussion across established modes of practice, and an emerging example from northwestern Australia. The results of this assessment indicate several components that should be factored into an Australian Model. The first is the significance of material to provide an analogy for offshore material, including inland sites and ethnographic examples. Additionally, the role and limitations of remote sensing emerged as a topic for discussion in the 2010 JICA Forum. The importance of geomorphological assessments of preservation potential is also significant, and indicates an emphasis on understanding site formation processes. The management of submerged landscape archaeology is also discussed, with consideration for the broader public as well as other archaeologists.

5.3 A review of the 'Israeli Model'

The review of the Israeli Model here is presented in three parts: the first is a review of the model text per Galili et al. (2019b), the second builds on this review through the reuse and adaptation of existing data through map digitisation (to enable reconstruction of the palaeocoastline), and the third aspect provides an additional fieldwork element to assess previously discovered stone features off the Carmel Coast. Over the course of this aspect of the research, regular field assessments were conducted to several submerged prehistoric sites along the Carmel Coast, in addition to Epipalaeolithic sites inland, to further investigate the capacity for preservation of earlier prehistoric material offshore. While an in-depth analysis was possible for responses to the Danish Model and its re-evaluation due to the 2010 JICA Forum, no parallel exists yet for the Israeli Model, however a detailed and critical review of its viewpoints is discussed below.

5.3.1 Galili et al. 2019

The Israeli Model, proposed by Galili et al. (2019), acts as a research model. This incorporates phases dealing with locating sites, and then research priorities and management of submerged prehistoric sites. Underwater archaeology began in Israel in 1960, and was initially focused on shipwrecks and harbours. The first submerged prehistoric finds were reported in 1965, by the Underwater Exploration Society of Israel, on the Neolithic site of Tel Hreiz. By the 1980s, a research program to survey and excavate submerged prehistoric settlements was established by Ehud Galili on behalf of the University of Haifa and later on behalf of the Israel Antiquities Authority, including underwater surveys and excavations (Galili 1985, 2004). The Israeli Model is outlined by Galili et al. (2019b). It is described as a "model of submerged prehistoric investigation", for "general, multi-disciplinary investigation aimed at locating submerged sites for the purpose of mapping, researching, monitoring, managing and rescuing." Galili et al. (2019b) note the possible applications internationally of this model.

The sections of this model include:

A) Site Location and Survival
B) Search Methods and Site Detection
C) Procurement of Archaeological Data
D) Typology of Submerged Sites
E) Reconstructing sea level and coastal changes
F) Coastal adaptations and site abandonment

G) Cultural resource management of submerged sites

The first phase of the Israeli Model describes site location and survival. According to the Israeli Model, depth-dependent survival is demonstrated along the Carmel Coast, and suggests that the most productive survey strategies should target depths of −1 to −15 m. The Israeli Model suggests that chances of finding sites in deeper water are considerably lower than sites in shallow water. This is suggested to be because the deeper shelf spent less time as dry land and reduces the chances of occupation. It is also argued that the remains of Epipalaeolithic sites are more ephemeral than permanent Neolithic settlements. The Carmel Coast also shows substrate dependent preservation, in which high sand cover protects the sites from erosion. However, the thicker the sand, the lower potential of exposure and discovery. A rocky, exposed sea floor could cause sites to erode rapidly without the protective sand layer. Additionally, many submerged prehistoric features located are sub-surface site features, placing them in a more protective location during the destructive process of inundation. Predictive modelling and terrestrial analogy is also considered in this model, where it is suggested that effective modelling and analogy must consider subsistence requirements. On the Carmel Coast, the Neolithic settlements subsisted on agriculture, thus sites are usually located on a palaeosol surface, and then protected by several metres of sand. The sand is periodically removed, particularly during winter storms, which allows for archaeologists to survey these chance exposures and plan for future survey and excavation opportunities.

Galili et al. (2019b) then proceed to outline suitable search methods to detect sites. In an evaluation of remote sensing methods, the model "recommends choosing the most suitable technology for the job, bearing in mind that often the same work can be successfully undertaken using simple, readily available, low-cost equipment." In this way, the Israeli Model emphasises sustainable research programs by identifying affordable and available solutions to conduct survey work. The Israeli Model identifies variations in survey purpose: searches intended to locate new submerged sites for research, rescue surveys in which erosion has disturbed the seabed, and rescue surveys in known areas. In the case of rescue scenarios, the site features and the archaeological data are endangered and can be lost. Thus, site features (structures and installations) should be documented, while artefacts, human burials and finds that may be lost, should be documented in situ and then retrieved. The search methods procedure suggests that background information should be collected, followed by aerial photographic survey. Year-round diving surveys following storms is emphasised as an approach suitable to this environment, in addition to coastline walking surveys. Jet-probes and sediment sampling are also suggested to test areas offshore. As a final point of search methods, Galili et al. (2019b) write that importance must be placed on verifying the anthropogenic nature of sites, given the potential for highly symmetrical natural features to be incorrectly interpreted as archaeological features. This should be done by searching for anthropogenic indicators such as flint artifacts, bones, charcoal and other indicative materials.

In terms of excavation protocol, these are addressed in section C of the Israeli Model, and again the strategy of allowing the sea to remove overlying sediments is emphasised and preferred, although this is not always possible, and projects have been undertaken where time had to be spent excavating several metres of sand to reach the palaeosol layer. The Israeli Model provides guidance for the excavation of shallow water features, shafts and water wells, and in situ human burials, which require slightly adapted techniques from one another. Additional guidance is provided for the initial processing of archaeological material following collection through excavation methods.

Decades of research in Israel have allowed for the development of a typology of underwater prehistoric sites corresponding with time periods and the nature of sites. In section D, Galili et al. (2019b) outline the current understanding of submerged archaeology off the Carmel Coast. Scattered Middle Palaeolithic to Epipalaeolithic artefacts have been found, and embedded in palaeosol deposits, but no specific Epipalaeolithic (or earlier) occupation sites have been found. Similarly, there is no early PPN material found offshore currently. The earliest occupation corresponds with PPNC Atlit-Yam, and then a series of late PN/early Chalcolithic settlements. Chalcolithic to Early Bronze Age remains are scant, however Chalcolithic examples are recorded at both Atlit, Hishuley Carmel, and Kfar Samir (Galili et al. 2019b). The Carmel Head stone pile site, surveyed as part of this thesis research, was identified as potentially prehistoric based on sea-level projection, where the stone piles would have been on dry land at 7 ka. Establishing a more secure date for the Carmel Head features and identifying their nature are important outcomes of the current research.

The Israeli submerged prehistoric sites have also informed the current understanding of Holocene sea-level rise and coastal change in the region, described in section E. Living floors are used as sea level indicators, marking the uppermost possible sea level at time of habitation. The submerged wells of the Neolithic sites are a unique example of archaeological material informing studies of sea-level change. They can provide the uppermost and lowermost sea level at time of usage. The Israeli Model also outlines methods to reconstruct the palaeocoastline and topography. The model emphasises the need to address local and global sea-level curves, and ways to factor in tectonic activity by examining natural features which are associated with present sea-level elevations. Erosion and sedimentation are also indicated as crucial factors to consider in reconstructions of past coastlines. The digitisation of the northern Carmel coast bathymetric maps conducted in this thesis aimed at creating a sequence of data to enable reconstruction of the palaeocoastline.

Another key research theme of the Israeli Model is the study of coastal adaptation and site abandonment. This is described in section F, and notes the ideas raised by Weissenberger and Chouinard (2015) including resilience, adaptive strategies, and the vulnerability to sea-level change in modern coastal communities, with various technical, administrative, and social adaptations applied. Galili et al. (2019b) note the relatively harsh environment of the Carmel Coast during the

PPNC and the development of permanent settlements. The settlement of Atlit-Yam shows that as sea-level rose, the site was eventually abandoned, and PN sites are found to the east of the deeper PPNC settlement. These sites were also eventually abandoned, with presumably less intensive occupation on the coast following the PN. The location of the sites and their depth (the older the site is, the further offshore and deeper, with the later sites are closer to the coast in shallower water) demonstrate the abandonment of sites due to sea-level rise and the shifting inland of sites as a result of postglacial sea-level rise (Galili et al. 2005; 2019b).

Galili et al. (2019b) also place the Israeli Model in context of cultural heritage management, and legislation in Israel. The Law of Antiquities 1978 in Israel protects the submerged settlements, and any excavation or other work that would disturb the seabed requires a permit from the Israel Antiquities Authority (IAA). The Israeli model advises that building activity on or in proximity to the submerged prehistoric settlements should be prohibited, and that rescue excavations should be undertaken where necessary to prevent the loss of material. Additionally, for offshore projects to depths down to −120 m, Galili et al. (2019b) explain that impact and assessment surveys should be conducted, including surface and sub-bottom surveys. If anthropogenic material is located, these areas should be avoided, and project plans changed in accordance with these finds. On shallow shelf construction work, the Israeli Model considers depths of up to −20 m and suggests that this area could have been occupied by late PPN and PN peoples. It is the observation of this model that frequent surveys by divers and remote sensing should be carried out in these shallow areas, where the probability of encountering submerged prehistoric settlement is considerably higher than in the deeper offshore areas. A combination of sub-bottom profiler work, core sampling, and trial trenches is also recommended. For deep shelf construction work (−50 to −120 m), the model proposes that archaeologists assess potential based on available data, and that sediment samples from the seabed should be checked for artefacts. Galili et al. (2019b) highlight the success of regular monitoring of sand coverage and erosion to evaluate sites and their condition, where survey and excavations may be planned according. The Israeli Model also emphasises the involvement of the public, and generating public awareness of submerged prehistoric material. The model advises collaboration with diving clubs and amateur divers, as well as military divers and industrial divers.

5.4 The case study of the Carmel Head stone pile site: The Israeli Model in practice

The submerged Carmel Head stone pile site were first identified during the 1980s and was briefly reported (Galili et al. 2019b). The site was relocated and surveyed as part of this PhD thesis to provide a case study of the Israeli Model in practical terms. In this case, the Israeli Model is viewed as an approach to identify and evaluate archaeological material under water. A series of stone pile features were identified on the submerged, rocky plateau of the Carmel Head (also referred to as

Carmel Nose) (Galili et al. 2019b). The stone features measure 3–4 m in diameter, and stand 0.7 m high (Fig. 18). In addition to the stone piles, concentrations of boulders were recorded in shallower water (3 m depth) on the south-east area of the Carmel Head submerged plateau. It was suspected that these stone features may be anthropogenic, and potentially prehistoric in origin given that they are located at depths of −5 to −9 m which corresponds with a date preceding 7 ka, and given that the rocky plateau where the stone piles are located was dry during the Neolithic period.

Preliminary observation in the field suggested that some of the stones appear to be local limestone, rather than the imported stones that would be expected of ballast piles from ships. While it has been assumed that prehistoric communities in the Southern Levant were less interested in rocky coastal environments, the Carmel Head may potentially indicate a different aspect of prehistoric human interaction with the sea that has yet to be recorded in this region. As part of this thesis, diver-based survey was conducted to locate and map some of the stone features, with 3D photogrammetric models to enhance the recording process. The divers searched for associated anthropogenic artifacts typical to a prehistoric site (flint artifacts, fragments of bones and charcoal), yet no such finds were located.

Further surveys and research of additional stone piles and stone boulders off the Carmel Head may securely date these features and clarify their function. The analysis of the Carmel Head stone features serves as a directly comparable example of material culture that might be located on the continental shelf of Australia, where stone features on hard rocky seabed are anticipated as a resilient example of submerged material in the region. In the case of the Carmel Head, the stone piles appear to be more consistent with ballast piles known elsewhere along the coastline, however it is important that reports of submerged anthropogenic material are verified.

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Figure 18: An example of the Carmel Head stone piles (Photograph: E. Galili, from Galili et al. 2019b)

5.4.1 Map digitisation

To acquire a higher level of familiarity with the offshore environments of the Carmel Coast, a series of maps based on marine geophysical data were digitised for ongoing use in research of the submerged settlements. This provided an opportunity for familiarisation with the local geology of the area. Adler (1985) and Galili (1985) conducted studies of the shallow continental shelf of the northern Carmel Coast between Haifa and Atlit, aimed at reconstructing the palaeoenvironment in association with human habitation. Adler (1985) conducted a sub-bottom profiler survey using a 3.5 kHz system mounted on a 6 m vessel, with a focus on mapping the submerged kurkar ridges and troughs between them. The survey mapped the sub-surface and buried palaeolandscape, identified palaeosol deposits, and evaluated the thickness of these deposits and the thickness of the overlying sand. These buried palaeosols may potentially contain remains of yet unexposed and undiscovered submerged settlements. In addition, Adler (1985) and Galili (1985) conducted jet drillings to adjust the sub-bottom profiler records and sample the buried palaeosols. To transfer the maps, which were drawn in the 1980s into a digital format, each map was georeferenced using the Georeferencing tools in ArcMap, and then vectorised using the ArcScan extension which allows for drawn maps to be converted from a raster image to a vector image, from which shapefiles can be obtained. In this case, a polyline file was used to represent depth contours in a bathymetry map, and to represent thickness of palaeosol deposits in the isopach maps. Once these polylines are obtained, the Topo to Raster tool was used to convert these maps into a Digital Elevation Model (DEM) (e.g. Fig. 17). The aim of this process was firstly to provide a way for the maps to be maintained in a readily available digital format, and secondly to identify a method to interpolate the higher resolution bathymetry and isopach maps with open-source lower resolution options to provide a sequence of bathymetry for the future Carmel Head study, and the wider area of the Carmel Coast. All openly available bathymetric options for this northern area of the coast (Carmel Head) remain too coarse to operationalise against the higher resolution bathymetry (Fig. 19) successfully, so this could not be completed. However, the map digitisation process demonstrates the potential to include previous survey maps, including those that may only be accessed in print, for future survey work.

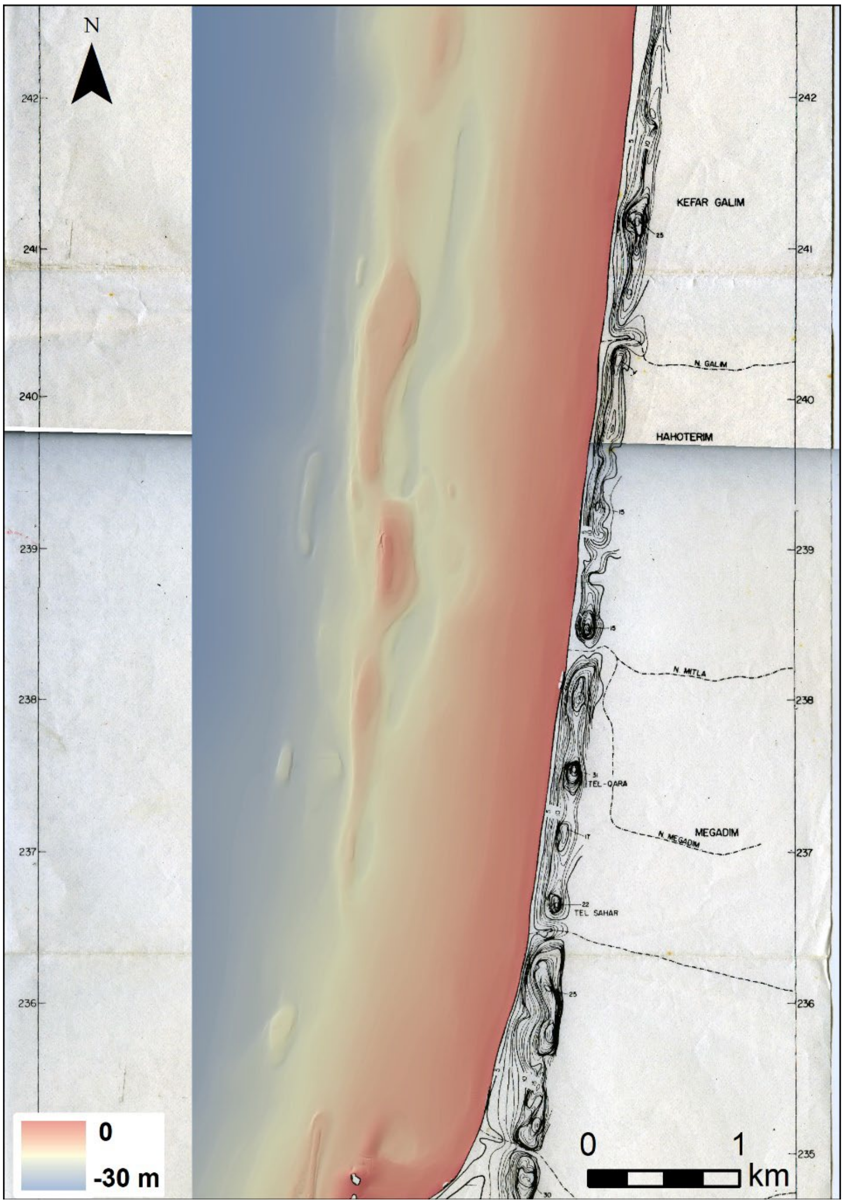

Figure 19: Digitised bathymetry of the Carmel Coast. (Underlying data acquired by Adler 1985, processed in ArcGIS by C. Wiseman).

5.4.2 Carmel Head underwater survey

While the Carmel Head has been recorded by Ehud Galili in the past, additional surveys were undertaken to map these features as a potential analogous feature with submerged material that might be identified in an Australian context. Underwater survey operations were undertaken on 2nd May 2019 on snorkel dives, followed by diver survey on 25th July 2019 (Fig. 20). The first snorkel survey was conducted to establish features that were visible in shallow depths (−1 to −4 m), including features previously identified. The snorkel team located two elongated stone concentrations, a large boulder concentration, and a concentration of small stones. The features identified on this survey mostly correspond with shallower depths due to the nature of a snorkel survey, as well as visibility (approximately 3 m). All observed features were mapped according to the embedded geotags from

GoPro images. The preliminary survey allowed for the confirmation of the locations of previously identified features, and to evaluate their current condition. It also allowed for confirmation about the extent of the area where the stone piles are found at the Carmel Head, to inform priorities for diving survey including sampling of the boulders. A more intensive survey effort was carried out on the 25th July 2019, as a scuba diver-based survey to allow for geological samples to be taken from stone piles at greater depths, in addition to detailed photography of the stone piles. The maximum depth of this survey was 8 m. Two stone piles were sampled, referred to as Location 1 and Location 2. Each of the stone piles was photographed, and a 3D model of Location 1 was produced using Agisoft Metashape (see Appendix 1).

Figure 20: Diver (C. Wiseman) at stone pile Location 2 (Image: E. Galili).

Most of the stones from Location 1 were sampled at least once, using a chisel and hammer, for a total of 13 samples (Fig. 21). A sample was taken at Location 2 from 7 stones in the stone pile. A sample was also taken of the seafloor surface geology at Location 1 to compare with the stone pile samples. In cavities and shallow places near the stone piles, the divers removed the thin layer of sand by fanning and collected small items that may be artifacts associated with anthropogenic activity. Each rock sample was processed and recorded, and preliminary rock types were identified (see Appendix 1). The results from Location 1 show that the stone pile is mostly composed of basalts with one instance of a plutonic rock that could not be identified further. Location 2 demonstrates greater variety in the stones, with numerous possible points of origin. The analysis of these two stone piles from the Carmel Nose indicates that they are composed of imported, non-local stones. All the small items collected by the divers were identified as natural products formed by erosion of the limestone seabed and no anthropogenic artifact was detected in association with the stone piles. Given the lack of prehistoric anthropogenic material and the presence of imported stones, the hypothesis of ballast piles from ships in antiquity is suggested for these two studied features, rather than confirmation of a submerged prehistoric settlement. Similar ballast piles have been found at Caesarea, and elsewhere along the coast of Israel (Boyce et al. 2009). However, numerous stone features exist on the Carmel Head, including concentrations of large boulders and numerous additional stone piles, and their provenance and possible date must also be assessed to provide an accurate assessment of the dates of material at the Carmel Head. Although the two specific features examined here are not prehistoric, there may still be submerged prehistoric material at the submerged, rocky landscape of the Carmel Head, and the procedure discussed provides a case study for the survey and recording of stone features suspected to be of anthropogenic origin and potentially prehistoric.

Figure 21: Stone pile Location 1 at Carmel Head site (Image: E. Galili).

5.5 Other international modes of practice

While the Danish Model and Israeli Model are the primary focus of this thesis, there are other discussions of submerged landscape archaeology methodologies to be considered. However, generally, these have not facilitated the same level of site discovery as in the Danish and Israeli example. In many of these examples a greater understanding of the submerged landscape was achieved, although in some cases no submerged archaeological material was recorded. These frameworks are considered here, and compared alongside the Australian Model in Chapter 7. It should be noted that this section focuses specifically on publications that have outlined and discussed methodology, rather than publications focused on addressing archaeological research questions. Many of the examples discussed in Chapter 2 have contributed to the development of these methodologies, however I have elected to focus this section on explicit discussions and evaluations of methods and methodology. This is primarily due to the fact that not all published material on submerged landscape archaeology discusses the reasoning and rationale applied to the methods selected, and to include the methods from all submerged landscape studies is also beyond the scope of this research.

5.5.1 North America

In North America, there are many different predictive models and methodologies for submerged landscape archaeology. While all these models contribute to valuable discussions of how to locate and protect material, only some of these models have been tested and contributed to the identification of archaeological material. In several North American models, a greater emphasis is placed on sedimentary signatures of submerged archaeological sites, and their connection to landforms that may be located through remote sensing. These examples indicate significant factors for consideration in an Australian Model.

As an example of procedure for submerged landscape archaeology, Gagliano et al. (1982:115) outlined a framework for the identification of submerged landscape sites as follows:

> "1. Synthesize geophysical and geological data from OCS geological hazard and archaeological surveys, from the literature and other sources.
>
> 2. Identify areas with well-defined, submerged, relict landforms and thin marine sediment cover.
>
> 3. Identify relict landforms geologically within time span of human occupation of region.
>
> 4. Identify areas of high probability for prehistoric site occurrence.
>
> 5. Conduct tight-grid geophysical survey designed for optimum scale and resolution to define archaeological deposits. Collect an array of physical samples in conjunction with survey.
>
> 6. Analyze geophysical data and physical samples for site indicators and test discovered sites using large volume box core samples."

Gagliano et al. (1982) relies on the identification of sites by their sedimentary signature. This is not included in most frameworks, and remains one of the key works on the sedimentary composition of submerged landscape archaeology. This framework also notes the importance of identifying landforms which are geologically contemporaneous with human occupation of an area, and emphasises the importance of landscape formation. Additionally, the significance of thin sediment cover is noted, to aid in the identification of material. Probability modelling and geophysical survey are also noted as tools to assist in the process of narrowing down an archaeological site.

While Gagliano et al. (1982) outlines a procedure for identifying sites based on their sedimentary composition, Faught (2014:38) describes a procedure that has been demonstrated in Florida. According to Faught, these principles can be applied elsewhere, and the recommendations include:

> "(1) modelling for sites by the identification of relevant antecedent landforms, culture groups and sea-level history; (2) remote sensing using different kinds of underwater acoustic devices and identification target genres; and (3) coring, or dredging, and (4) geologic analysis of sediments to test for the presence or absence of evidence for human activities."

The framework proposed by Faught (2014) indicates that particular landforms associated with material culture are deemed "relevant", such as rocky areas that could be associated with quarrying. While remote sensing is then prioritised to determine areas that are prospective, the importance of testing for archaeological material through coring and dredging is emphasised. This technique has been successful in locating submerged sites, unlike many others.

Some models in North America are focused on the coastal migration hypotheses, and investigations of submerged landscapes are therefore targeted to specific time periods. The model set out by Westley et al. (2011) focuses on Newfoundland, and compares this with archaeological research in Ireland, selected as both areas had lowered RSL at their earliest colonisation. Westley et al. (2011) outline the importance of sea level and the identification of suitable sea-level curves as a crucial first step to begin the process of mapping coastal evolution. In this framework, 3D modelling is highlighted as a valuable resource for understanding submerged landscapes and targeting particular landforms for archaeological interest (Fig. 22).

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Figure 22: A generalised diagram of the procedure undertaken by the Submerged Landscape Archaeology Network in work at Newfoundland and off the coast of Ireland (Westley et al. 2011:132).

McLaren et al. (2020) also highlight the use of sea-level curves as a first point in analysis, and also rely on the use of elevation models to identify areas of interest. The use of predictive modelling can be seen in this framework as well and is used to understand site selection in a particular area. This model is designed to identify material that dates to a specific time period, to answer specific questions of coastal migration, and thus importance is placed on material dating to the late Pleistocene in the regional terrestrial archaeological record to predict for material offshore, in a way that is not necessarily seen in the Westley et al. (2011) framework despite its relevance to addressing questions of earliest occupation of certain areas.

At Lake Huron, O'Shea (2021) developed the micro-regional approach for submerged landscape archaeology. The approach shows similarity to the Vita-Finzi et al. (1970) model of site catchment analysis, in which a designated area is analysed thoroughly to establish resource foci and possible human movement and activity across an area. The approach can include the use of predictive models, such as those described by other North American frameworks. The micro-regional approach recognises a "nested set of activities" common to the process of submerged landscape survey, described by O'Shea (2021) as beginning with detailed mapping of the seabed, then progressing to remote sensing and coring, followed by direct observation by divers. As noted by O'Shea (2021), the micro-regional approach operates alongside this mode of practice, but by narrowing the area of search, the time and effort dedicated to a project may dedicate more detailed results. However, there are particular considerations to establish micro-regions for survey. The size of a micro-region, the number of micro-regions to be addressed, and locating the micro-regions are all considerations for this approach.

While several frameworks have been established for archaeological research in North America, there is ongoing discussion about the suitability of approach for varying preservation conditions. Additionally, further research is required to refine the sedimentary criteria established by Gagliano et al (1982) for submerged archaeological material.

5.5.2 Europe

Despite Europe's prominence in leading submerged landscape archaeology, few examples of reflection on procedure and mode of practice can be found aside from the Danish Model. However, two key examples are discussed here, and demonstrate issues that are relevant globally: the importance of intertidal archaeology within submerged landscape research, and cooperation with industry to map and study submerged landscapes.

Bates et al. (2013:28) describe the use of a 'seamless' approach for shallow marine archaeology in Scotland. While this approach is designed with the intertidal zone in mind, many of the features outlined in this case study are relevant to areas further offshore. They propose the following as guidelines:

"1. Reconstruction of the changing rate of sea-level transgression through time;

2. Identification of erosional or depositional features related to sea-level transgression;

3. Reconstruction of the palaeo-landscape at key time slices;

4. Definition of the period in which human activity may have taken place within the landscape;

5. Definition of likely locations for human activity within the landscape at key time slices;

6. Identification of locations favourable to archaeological preservation;

7. Identification and assessment of potential archaeological sites."

Targeted modelling of the landscape in accordance with archaeological research questions is highlighted in this mode of practice through the reconstruction of landscape at particular points in time, in addition to establishing the period and relevant geological features associated with human occupation. While the intertidal zone is often considered 'not quite marine' and 'not quite terrestrial' in archaeological research, with implications for modes of practice, this represents an example where the intertidal zone is considered for its own significance in answering archaeological questions, with a challenging preservation environment.

In a vastly different example and further offshore, Vos et al. (2015) outline the procedure undertaken in the archaeological work of the expansion of Yangtze harbour in the Port of Rotterdam (Fig. 23). This mode of practice represents a scenario that is markedly different to many of those studied, in that it was undertaken as part of an industrial process. In this case, once palaeolandscape mapping was undertaken, areas were selected for detailed investigation (including maps of archaeological potential), and then increased sampling for archaeological material. Georeferencing of material is emphasised in this process, largely owing to the importance of mapping this submerged environment alongside the development of the harbour.

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Figure 23: Diagram of the staged approach undertaken in the archaeological prospection during the development of Yangtze harbour (Vos et al. 2015:9).

5.5 Towards an 'Australian Model'

The model presented by this thesis represents an effort to characterise methodology for submerged landscapes broadly. However, there has been previous research to develop a methodology for the identification of sites in Murujuga (the Dampier Archipelago). The multi-staged approach presented by Veth et al. (2020) outlines the procedure developed by the Deep History of Sea Country project in Murujuga (the Dampier Archipelago), including a terrestrial analogue model to predict sites based on examples known on land. This section reviews the mode of practice developed specifically for the DHSC project, to provide context to methodological approaches specific to Australian submerged landscapes, and to allow for a discussion of the testing of this framework in the field campaigns conducted by DHSC (Chapter 6).

Murujuga is an archaeologically rich location, with over 2500 known sites to draw information from in the pursuit of submerged site discovery. The majority of these sites are rock art sites, however they are also interspersed with artefact scatters, stone structures, shell middens, and quarry areas. Across the islands, these site types tend to be focused on the coast, in interior valleys, and in associated uplands. Two-thirds of the sites occur on rhyodacite and basalt substrates, while the others are constrained to sedimentary deposits (Veth et al. 2020). The extensive petroglyphs of Murujuga, as the most prevalent element of material culture, were investigated for preservation potential by both Dortch (2002) and Veth et al. (2020). It remains unclear as to whether rock art sites will preserve well under water, however in the case of Murujuga, erosion of rock art on land appears to be slow, and this may assist in preservation (Pillans and Fifield 2013).

Veth et al. (2020) developed a hierarchical approach to assess known sites, and their geological and environmental associations. From this, Veth et al. (2020) advocate for a regional-scale assessment of known topographic features of the submerged landscape to identify contexts for site survival. While terrestrial analogue modelling has been described as a potentially fraught methodology given its capacity to generalise inappropriately in the study of past societies, in this case it offers a way to narrow a large search area to test hypotheses of site preservation. On land, previously recorded sites demonstrate a high level of spatial patterning, and assuming a level of continuity into the offshore environment, sites located under water may also demonstrate similar patterning, or offer a different perspective to the current understanding of site patterning based on inland examples.

The habitation of the Dampier Archipelago may date back as far as 30 ka based on dates from Murujuga Rockshelter on the Burrup Peninsula (McDonald et al. 2018), however dates from archaeological sites in the islands of Murujuga indicate habitation as far back as 10 ka. Comparisons of possible depositional environments in this area are divided into hard (crystalline) rock and soft (sedimentary) rock contexts (Fig. 24). This assists in determining the procedure to investigate the material.

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Figure 24: A representation of the approach undertaken by the DHSC project per Veth et al. (2020), including distinctions between hard rock and soft rock contexts.

Direct sampling (or ‘ground-truthing’) is then used to correlate onshore and offshore depositional contexts, and to then develop a greater understanding of how these sites formed and what changes are evident based on their different preservation characteristics. This remains a crucial step in most approaches to submerged landscape archaeology, but particularly in this case where the remote sensing technologies used (LiDAR and sidescan sonar) can identify small (<1 m) features, however these could easily be confused for natural features. Veth et al. (2020) highlight that the preservation of archaeology in soft rock contexts will be much more dependent on erosion and deposition of sediment. The predicted results of this framework, in accordance with known material culture of Murujuga, include macro-scale sites including rock shelters, stone arrangements, house structures (McDonald and Berry 2017), and fish traps (Kreij 2018). These features are all described by Veth et al. (2020) as durable and more likely to withstand the impacts of sea-level rise, and also importantly, more likely to be identified in the process of remote sensing to narrow the search area for submerged sites across the archipelago.

Veth et al. (2020) identify a selection of features deemed most likely to preserve in Murujuga. This includes middens in cemented dunes and beachrock deposits, quarried outcrops, stone structures, standing stones, lag deposits on the outer island landscape and in the intertidal zone, and small overhangs/rock shelters with preserved material. The multi-stage approach developed by Veth et al. (2020) represents the only example created so far for submerged landscape archaeology in Australia. The present thesis discusses, in detail, the fieldwork conducted in Murujuga in conjunction with this thesis to evaluate the testing of the Veth et al. (2020) approach, and facilitates a comparison of this emerging research strategy alongside the examples of the Israeli Model, Danish Model, and other models which have been developed over several decades of research and field observations.

5.6 Conclusion

This chapter sets out the main models and modes of practice for comparison with an emerging Australian Model, reinforced the criteria set out by Veth et al. (2020) and verified in the field by Benjamin et al. (2020) in conjunction with this thesis research. From the 2010 JICA Forum, several themes within submerged landscape archaeology can be explored by treating the papers as a dataset, and a greater level of detail from the literature may be obtained. The Israeli Model was tested in this project through the Carmel Head stone pile survey, and serves as a parallel to potential stone features that could be found under water in Australia. Other modes of practice have been proposed beyond Denmark and Israel, and these are evaluated and also inform the procedure proposed for an Australian Model. The findings of this desk-based study are compared and discussed in Chapter 7, to establish how they have informed the various phases of an Australian Model.

6.0 IDENTIFYING SUBMERGED SITES IN MURUJUGA

6.1 Introduction

This chapter presents an assessment of the work undertaken in Murujuga (the Dampier Archipelago), Western Australia[2]. In this project, the first two subtidal Indigenous sites were located in Australian waters. This research effort represents the development of an iterative framework and a suite of techniques for locating submerged archaeological material, and this process is important to consider in the pursuit of developing an Australian Model for the continent. The sites from Murujuga serve as an encouraging 'proof of concept', and indicate the immense potential for sites elsewhere off the Australian coastline. The mode of practice first proposed by Veth et al. (2020), and then tested in Murujuga (Benjamin et al. 2020), is evaluated as a critical case study in the progress of submerged landscape archaeology in Australia.

6.2 Background to the Study Area

Murujuga, meaning 'hip-bone sticking out', also known as the Dampier Archipelago, is a series of 42 islands located off the northwestern coast of Australia (Fig. 25). The Indigenous peoples of Murujuga are the Ngarluma, Yindjibarndi, Mardhudenera, Wong-Goo-Tt-Oo, and Yaburara, represented in management of the land and sea by the Murujuga Aboriginal Corporation (MAC). The first two underwater ancient Aboriginal sites in Australia were found in this archipelago. It is also known for its vast numbers of petroglyphs, with estimates of up to 2 million motifs across the islands. Murujuga forms part of the Pilbara region of Western Australia, and deep-time sequences are known from

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Hacker, J.: 5% Research design, 5% Data collection and analysis, 5% Writing and editing
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McCarthy, J.: 5% Data collection and analysis
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Baggaley, P.: 5% Research design
Collins, C.: 5% Data collection and analysis
Ulm, S.: 5% Research design, 5% Data collection and analysis, 5% Writing and editing
McDonald, J.: 5% Research design, 5% Data collection and analysis, 5% Writing and editing
Benjamin, J.: 10% Research design, 5% Data collection and analysis, 5% Writing and editing

some archaeological sites in this region. This background sets out the environmental, geological, and chronological background to the region, and how this informed the methods used to locate sites.

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Figure 25: Orientation map of Murujuga (the Dampier Archipelago), and its regional context in northwestern Australia (Benjamin et al. 2020). 1) Cape Bruguieres; 2) Gidley Island; 3) Flying Foam Passage; 4) Dolphin Island; 5) Angel Island; 6) Legendre Island; 7) Malus Island; 8) Gidley Island; 9) Enderby Island.

The earliest archaeological work in Murujuga was driven by the development of the port on the Burrup Peninsula in the 1960s. Initial works were carried out by the Western Australian Museum as industrial development pressure increased. The first large-scale survey was conducted by (Vinnicombe 1987a, 1987b), as a salvage recording effort, which covered stone structures, middens, petroglyphs, and quarry sites. Over 2500 sites were registered in Murujuga by 2006 (McDonald and Veth 2009). Most of these sites were recorded as part of surveys preceding industry development across the Burrup Peninsula, however additional research has been conducted across the islands and peninsula and shows the range of sites over Murujuga. Several assessments have described Murujuga as a continuous archaeological landscape (Lorblanchet 1992; Vinnicombe 2002; McDonald and Veth 2011), indicating the importance to now consider the underwater environment as part of this extensive landscape.

The archipelago's vast archaeological record was assessed for National Heritage Listing, and shows that over 60% of the 2,534 sites analysed are rock art engraving sites. Many of these sites are also associated with artefact scatters, and stone structures (including lines, standing stones, and terraces). The density of the petroglyphs is estimated at around 26 per km^2. Alongside the Deep History of Sea Country project, the Murujuga: Dynamics of the Dreaming project recorded numerous archaeological sites across the islands (McDonald 2015; McDonald and Berry 2017). Over 12,000 rock art motifs were recorded, in addition to 761 grinding patches, and 295 stone features. The latter project has helped to address the issue of an archaeological record for Murujuga that is heavily influenced by industry, and provides additional insight to the outer islands which are not as well-surveyed as the Burrup Peninsula and islands located closer to the mainland.

6.2.1 Environmental background

Prior to deglaciation following the LGM, the coast of Murujuga was located 160 km away from its present configuration, and the islands formed a series of upland ranges (Fig. 26). The landscape was altered drastically by sea-level rise, and by 12 ka, the coastline was 30 km from the Dampier

Ranges, the previous formation of the archipelago (Ward et al. 2015; McDonald and Berry 2017; Ward and Veth 2017). At 10 ka, the valleys surrounding the Dampier Ranges were inundated, and separated the higher points of the landscape. Mermaid Sound began to form at 8 ka, while Enderby and Rosemary Island separated from the mainland (Fig. 26). Sea level continued to rise in Murujuga, reaching a highstand of 2 m at 7 ka, before stabilising at the present levels at 2 ka.

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Figure 26: A reconstruction of sea-level change in Murujuga (McDonald et al. 2018:369).

Murujuga is in the semi-arid Pilbara region. The area is prone to cyclones, and large swells associated with these weather events. Between 1980 and 2007, 36 tropical cyclones crossed the Pilbara coastline (Benjamin et al. 2020). In 2019, a major Category 4 tropical cyclone, Cyclone Veronica, passed over the area. This allowed the opportunity to assess the influence of cyclones on archaeological material on coastlines, by comparing features before and after a cyclone event to assess its impact. Tidal range in the archipelago is approximately 4 m, with low wave energy from the sheltering of the larger islands (Semeniuk 1993).

6.2.2 Geological background

Murujuga is mainly comprised of intrusive igneous granophyre and gabbro geology, with basement geology laid down in the Precambrian and Early Archaean periods (ie older than 2800 Ma) (Hickman 1983; Jones 2004). Dolerite dykes cut the Precambrian geology as the youngest igneous rocks in the region (Jones 2004). Several of the islands include basalt and sandstone corresponding to the Proterozoic Fortescue Group (Hickman 1983). The intrusive 'Gidley Granophyre' forms the most prevalent rock throughout the Burrup Peninsula, as well as Dolphin Island, Angel Island, East Lewis Island, and Enderby Island (Fig. 27). The intrusions are presumed to date to 2700–2400 Ma (Kojan 1994). Dolerite sills are found on Enderby Island, East Lewis Island, and Rosemary Island, intruding the Fortescue Group formations.

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Figure 27: Geological map of Murujuga, outlining primary geological formations on the islands (McDonald and Berry 2017:26).

Aeolian calcarenites can be found in the outer islands, such as Legendre Island, as remnants of Pleistocene dune features (Kojan 1994). The submerged geology in the archipelago is formed of limestone and overlies the Precambrian basement geology (Semeniuk et al. 1982). Pleistocene to Holocene aged deposits of gravel, silt, sand, and clay cover the nearshore areas of the mainland peninsula and Pilbara coastline (Semeniuk 1993). These deposits signify the fluctuations in position of the shoreline and ongoing alluvial sheet-flood depositions (Jones 2004). Bioclastic carbonate sands accumulated in the past 6000 years in sheltered, inshore areas. Sheltered, low energy areas in this region are also often composed of silty mangrove environments. Mangroves are also located in the rocky and sandy areas of the Burrup Peninsula and the archipelago (Semeniuk and Wurm 1987).

Gidley granophyre is well-known in the archipelago as an optimal surface for rock art. Although gabbro and dolerite were also selected, granophyre appears to be preferred given its silica-rich texture which allows for detailed engravings (Donaldson 2011). Granophyre and the intrusive igneous rocks located throughout the archipelago also appear to be preferred for tool-making and the construction of stone structures. Granophyre also weathers very slowly, as evaluated by Pillans and Fifield (2013) who concluded that petroglyphs carved deeper than 10 mm into the rock would be visible for 30,000–50,000 years. The submerged geology is composed of igneous rocks, similar to the terrestrial gelology, and overlaid by Pleistocene coastal sedimentary sequences and mid-to-late Holocene sediments. The area is relatively sediment-starved, with minimal fluvial sediment. On this basis, remote sensing techniques that focus on the surface of the seabed were used, and sub-bottom profiler was deemed less useful in this context.

6.2.3 Chronology: The late Pleistocene to mid Holocene of the Pilbara

The archaeology of the Pilbara fits within a broader discussion of occupation and migration across the Australian continent. The date of settlement and colonisation for Australia is currently based on the oldest dates from Madjedbebe rock shelter in the Northern Territory, approximately 60 ka (Clarkson et al. 2017). On this basis, at the time that Australia was first settled, sea level was −85 m (Lewis et al. 2013). In the Pilbara, Boodie Cave on Barrow Island was dated to 50 ka at its earliest layers, while at Yurlu Kankala on the mainland, occupation was dated back to 47 ka (Morse et al. 2014; Ward et al. 2017). This demonstrates an extensive habitation of the Pilbara region, and although Murujuga was presumably occupied at a similar time, the earliest dates have been obtained from Murujuga Rockshelter at 23 ka (McDonald et al. 2018). McDonald and Berry (2017) propose that the absence of Pleistocene evidence in Murujuga is due to previous archaeological work focusing on shell middens and shelters that post-date Holocene sea-level rise.

These late Pleistocene coastal occupation dates are reinforced by two collapsed rock shelters, Noala Cave and Hayne's Cave (dated 31,270–8,330 BP) on the Montebello Islands (Veth et al. 2014). Pleistocene faunal assemblages for the island rock shelters illustrate broad-spectrum exploitation of mammals and reptiles from dunefields, sand plains, and rocky plateaux (Veth et al. 2017). Shellfish use is also observed at 31 ka, and across time the dietary use of shellfish as well as fish and marine reptiles develops following 12 ka (Veth 2007). Comparatively, marine resource use on Barrow Island begins after 17 ka where *Terebralia* remains were identified (Manne and Veth 2015). The lithic assemblages of the Montebello Islands demonstrate connectivity with the adjacent hinterland, through the long-distance travel of groups or through exchange networks (Manne and Veth 2015). The trend in non-local lithics is also observed in Boodie Cave at Barrow Island (Ward et al. 2017). Prior to the LGM, Veth et al. (2017) distinguish the use of marine resources as prevailingly utilitarian with minimal evidence for dietary use. While these areas are located 100 km apart, similar resource use and trends are assumed based on the finds at Murujuga Rockshelter and these relatively adjacent sites.

During the peak of the highly arid LGM, in the arid zone of Northwestern Australia, depositional hiatuses were identified in numerous rock shelter sites, interpreted as drastic changes in group mobility or abandonment of the region altogether (Williams et al. 2013; Slack et al. 2018). The Pilbara may have acted as a refuge during the LGM (see Veth 1989; Veth 1993; Hiscock and Wallis 2005), and the 'Dampier Ranges' served as 'cryptic refugia' (where humans continued to exploit scattered pockets of an area, per Smith 2013). Sea levels were at their lowest point over the course of human occupation of Australia (−130 m), and the coast would have been 160 km away (Lewis et al. 2013). Rock art in Murujuga associated with this phase generally appears to represent large terrestrial fauna, and is interpreted as an indicator of the environment and subsistence practices (see Fig. 28; Mulvaney 2013).

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Figure 28: Major rock art phases and corresponding changes in landscape (McDonald 2015:129).

Following the colder, arid conditions of the LGM, at 18 ka, the climate warmed and sea level began to rise rapidly (Yokoyama et al. 2001). The loss of territory over time created increased territorial pressure on the groups living in the northwest of the continent, and smaller, highly mobile population groups emerged (Lorblanchet 1992). By the end of the Pleistocene and the transition to the Holocene (11.7–8 ka), mobility seems to decrease but territorial pressure remains high (Table 2). There is a shift towards the dietary use of marine resources following marine transgression, including turtle and crocodile predation according to sites at Barrow Island and the Montebello Islands (Manne and Veth 2015:118).

The Chronology of the Pilbara, NW Australia		
Time period	**Date**	**Archaeological context**
First settlement and colonization	50,000–22,000 BP	Establishment of regional broad-based economy
Last Glacial Maximum (LGM)	22,000–18,000 BP	Occupational hiatus in sites, necessity to seek refuge
Late Pleistocene	18,000–11,700 BP	Small, mobile population groups; social pressure through territoriality
Pleistocene-Holocene transition	11,700–8000 BP	Larger groups and decreased mobility, territorial pressure increases
Mid Holocene	8000–6500 BP	Increased coastal resource use, stone structures in larger habitation sites
Mid-Late Holocene	6500–4000 BP	Marine A – use of marine and mangrove resources
Late Holocene	4000 BP to present	Marine B – use of marine resources, switch to *Anadara*, watercraft

Table 2: Chronology table of the Pilbara region in Northwestern Australia showing relevant time periods, approximate dates, and associated archaeological features (after McDonald 2015; McDonald and Berry 2017).

As sea-level rise continued and additional marine resources were introduced, intensive coastal resource use is recorded at sites in the northwest and Murujuga in the mid-Holocene (8–6.5 ka) (Bradshaw 1995). Examples of sites associated with this period include Wadjuru Pool and Rosemary 8, both sites located on Rosemary Island in the archipelago (see Fig. 29 for stone structure at

Rosemary 8). Both sites appear to have adopted mangrove-focused subsistence strategies amidst other complex behaviours, including changes in the production of rock art, increased shellfish exploitation, seed grinding, changes in stone artefact procurement, and the construction of stone structures (Bradshaw 1995; McDonald and Veth 2009; McDonald and Berry 2017). Towards the end of the mid-Holocene period, the outer islands of the archipelago such as Enderby Island and Rosemary Island became separated from the mainland and appear to have been abandoned (ca. 7 ka, Ward et al. 2013).

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Figure 29: Stone features from Rosemary Island in Murujuga (McDonald and Berry 2017:34).

The mid-Holocene is also a crucial chronological point in the 'intensification' debate, which is particularly relevant to coastal sites in Australia, such as those found in Murujuga. Lourandos (1983) examined the cultural shift in Australia from the highly mobile, small population groups of the late Pleistocene to early Holocene, to the observed increased occupation duration and range of exploited resources of the mid-Holocene, and deduced that increasing population levels may have contributed to this move towards increased production and productivity. For coastal areas, this often comes with an assumption with increased coastal resource use and reduced mobility. The 'intensification' theory responded to static views of the Australian archaeological record which implied passiveness in hunter-gatherer societies in responding to environmental and ecological change, and sought to emphasise factors such as social organisation and demography (Lourandos and Ross 1994). Although responding to a concern that Indigenous Australian archaeological material was often interpreted as relatively unchanging, the premise of a rapid, evolutionary intensification process from the mid-Holocene also assumes a relatively long period of uniform history prior, and becomes problematic for the very idea that Lourandos sought to challenge. Other aspects of critique include Lourandos' assumption of equivalent site formation processes and preservation across time and space, the exclusion of ecological and technological change as factors, and the risk of homogenising Indigenous Australian history to a generic, continental narrative (Hiscock 1986; Holdaway et al. 2008; Ulm 2013). For Murujuga, increased marine and coastal resource use corresponds with the mid-late Holocene, however is predominantly described in the literature as an adaptive feature of a society whose environment was transformed profoundly by sea-level rise (McDonald 2015).

The 'coastal time lag' hypothesis proposed by Beaton (1985) is directly challenged by the archaeological record of Murujuga. Based on excavations in the far north of Queensland, Beaton (1985) asserts that the ecological disruption wrought by sea-level rise prevented sustained occupation of coastlines until the late Holocene. Other areas in Australia were analysed and Beaton

(1985) concluded that the 'lag' in coastal settlement was identifiable across the continent. Coastal sites across Australia dating to the late Pleistocene-early Holocene illustrate that this does not appear to be the case on a continental scale, and the coastal Pilbara provides a key example of this where marine resource use dates significantly prior to the stabilisation of sea levels (Veth et al. 2014). For example, in Murujuga, a combination of marine and mangrove resources is noted to correspond with the mid-late Holocene (6.5–4 ka). The 'coastal time lag' hypothesis can be refuted, given considerably earlier dates for engagement with coastal resources across the continent.

During the late Holocene in Murujuga (ca. 4 ka), mangrove environments declined, and shell midden sites in Murujuga show an inclination to rocky shore, mudflat, and sandy beach shellfish (Vinnicombe 1987; Bradshaw 1995). McDonald and Berry (2017) predict that the late Holocene saw the introduction of watercraft in Murujuga, as resource exploitation on the outer islands recommenced. Several early visits by European settlers to Murujuga note the use of watercraft to travel between islands, reported as Aboriginal people paddling with their hands astride buoyant mangrove logs (King 1827). The long-term use of watercraft cannot be confirmed, however it is certainly a consideration in the late Holocene record of Murujuga. The chronology of Murujuga and the Pilbara region demonstrates a long history of coastal occupation and resource use, and thus it is possible that the now-submerged coastal margins of this area were inhabited at periods of lower sea level. This approach does assume some continuity in land use (see Veth et al. 2020), but it also necessary to identify submerged sites to test this hypothesis of continuity. Murujuga's extensive history of human habitation focused on coastal resources, and dense archaeological record, all demonstrate aspects that are conducive to the deposition of archaeological material in environments now offshore.

6.2.4 Previous underwater survey results

Prior to the efforts of the DHSC project, Dortch (2002) was the only previous survey undertaken in Murujuga aimed at the identification of submerged archaeological remains. While accompanying biology researchers on fieldwork, Dortch (2002) established seven dive stations at depths between −10 and −20 m, which were deemed prospective for the preservation of petroglyphs based on granophyre outcrops (Fig. 30). Similarly to the methods undertaken by the DHSC project, Dortch (2002) reviewed aerial photographs that showed the location of granophyre outcrops as a starting point.

Petroglyphs were the focus of this first research project, however Dortch (2002) also noted the potential for indurated material to preserve underwater, based on an example on land at Enderby Island where stone artefacts and mollusc shells were found in an indurated deposit. Over the course of this survey, no archaeological evidence was located. However, Dortch (2002) outlined some recommendations for further survey in this area, and identified that there were rock surfaces that were free of marine growth for further assessment of rock art and quarrying potential.

Dortch (2002) stated that "the possibility of identifying rock engravings or other prehistoric sites on the archipelago's sea floor does not merit the enormous monetary costs of a fully-equipped, sea-going expedition". This essentially describes the DHSC project and arguably the possibility of identifying sites does indeed merit the costs associated, however the point of cost as a hurdle is an important factor. The often costly nature of submerged landscape research should not be under-estimated as an issue for the future of the discipline, and efforts must often be made to identify financially feasible options.

Instead, Dortch advised shore-based diver searches, which could be easily conducted from the Burrup Peninsula. This is described as requiring a boat handler and two divers on a hookah system, and the success of this approach was noted at Lake Jasper, the first submerged lacustrine Indigenous archaeology in Australia (Dortch and Godfrey 1990). Dortch (2002) also described the importance of community engagement, and the likelihood of accidental discovery by sports fishers given the recreational interests in the area. Of significance to this research, as well, is Dortch's claim of a local story that suggests that sports divers identified rock engravings in a sea cave off Enderby Island. This story remains unconfirmed, however accidental finds and community engagement are a significant aspect of submerged landscape archaeology.

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Figure 30: Map of Dortch (2002:38) dive stations, each marked by an 'X'.

6.3 Methods

In Murujuga, a multi-scalar approach was applied, using a variety of charting, remote sensing, as well as aerial and marine geophysical survey methods to reconstruct submerged environments and establish how these environments may have looked in the past. Alongside this approach, a baseline study of the archaeological record of the Pilbara was undertaken to establish a high-level predictive model (Benjamin 2010; McDonald 2015; McDonald and Berry 2017; Veth et al. 2020). The predictive model allowed for the identification of targets of archaeological potential, and this informed the areas chosen for diver-based survey. In this project, several remote sensing techniques were applied to derive individual target locations, and to consider these in their landscape context for archaeological prospection.

The potential and probability of locating an archaeological site is addressed often in submerged landscape archaeology literature, with models for site location, preservation, and identification applied across the Middle East, Europe, and North America (Fischer 1993; Fischer 1995a; Faught 2004; Gaffney et al. 2007; Gaili et al. 2019). For projects involving a large-scale study area, predictive modelling (either by qualitative or quantitative means) become especially important to determine priority areas for further survey. Statistical, quantitative predictive models may contribute meaningful results to survey strategy, assuming relevant data is available, and refine high-potential areas. With the increased use of GIS in archaeology, and developments in agent-based modelling, this variety of predictive model has also become more common (Cook Hale and Garrison 2017; Gaffney et al. 2017; Braje et al. 2019; Monteleone 2019; Wren et al. 2020). In the case of this project, the Veth et al. (2020) qualitative model infers possible archaeological features, and their preservation characteristics as understood by terrestrial analogy. It is clear that a detailed knowledge of local geomorphology is needed to establish site formation in underwater environments, and to reconstruct past landscapes to refine targets for archaeological survey.

6.3.1 Reviewing satellite imagery and maps

The first phase of the project collected existing data and maps of the study area. In 2015, the European Space Agency launched Sentinel-2a, followed by Sentinel-2b in 2017. These satellites are in the same sun-synchronous polar orbit, located at 180° to each other. These satellites provide open access imagery, with a resolution of 10 m at the blue, green, and red NIR spectral bands. Open access data from Sentinel-2a and -2b provided a significant improvement on the resolution of other previous open-source data, such as Landsat 8, and thus offers an effective resource to analyse shallow, coastal, and intertidal areas across the world. Sentinel-2 has a 290 km field of view and five-day return time which allows greater opportunity to capture high-water clarity conditions.

In addition to satellite imagery, nautical charts were consulted to identify features and structures that were located at greater depth than the Sentinel imagery might show, and also to confirm observations made in satellite imagery. Nautical charts tend to represent single depth soundings, and in many cases may act as a starting point to identify submerged landforms with archaeological potential. The nautical chart offered additional guidance for survey planning for airborne and marine geophysical survey, based on optimal water depths. Additionally, the DHSC project used nautical charts and satellite imagery to locate shoals that could be igneous outcrops on the seabed.

6.3.2 Airborne lidar

Based on priority areas derived from the satellite imagery and mapping phase, a bathymetric Light Detection and Ranging Instrument (LiDAR) was used to create high-density point clouds of features of the sea floor. This phase of the project was conducted in association with Airborne Research Australia. Two LiDAR systems were mounted on a Diamond Aircraft HK36TTC-ECO Dimona motorglider-based aircraft: a Riegl Q680i-S topographic LiDAR system, and a Riegl VQ-820-G topo-bathymetric LiDAR. The Riegl Q680i-S laser pulse repetition rate was set to 400 kHz or 300 kHz, and the Riegl VQ-820-G set to 284 kHz or 522 kHz. The LiDAR wavelength of the Q680i-S is 1064 nm, and 532 for the VQ-820-G. To ensure eye-safety for the VQ-820 scanner, flight altitude was 600 m, which recorded swaths of 490 m for topographic lidar and 600 m for topo-bathymetric LiDAR. Lines were spaced at 200–300 m, and the seabed mostly mapped to −10 m. The two LiDAR systems were paired with a Novatel SPAN IMU/GPS reference system, along with a Canon Eo5 5D Mk4 DSLR which took RGB-images every 3 seconds. For data processing, Riegl Software, Airborne Research Australia's in-house software, LAStools, and Globalmapper Version 20 were used. Digital terrain models were then generated at 0.5 m resolution. The LiDAR data produced high-resolution topography, and assists in informing the shape and structure of archaeological objects above water, which can then be integrated with remote sensing techniques used in deeper water (MBES and sidescan sonar).

6.3.3 Sidescan sonar survey

In areas with little sedimentation, and with the acquisition of suitably high-resolution imagery, sidescan sonar may provide an optimal method for remote sensing of areas conducive to the preservation of submerged archaeological sites. O'Shea et al. (2014) demonstrate the capacity for geophysical mapping of a prehistoric hunting drive in Lake Huron, North America, using a scanning sonar, which allows for the detailed mapping of the extent of the site. Sidescan sonar was also used in mapping the submerged prehistoric settlement of Pavlopetri, Greece (Missiaen et al. 2017). In Murujuga, the targets of the sidescan sonar survey include upstanding features such as standing stones or other stone structures. Three seasons of sidescan sonar survey were conducted in Murujuga over 2018. The aim of this phase of the project was to build on the previous aerial surveys and desk-based research to create a systematic approach to characterising submerged environments for archaeological potential. This then allowed for the development of diver survey targets.

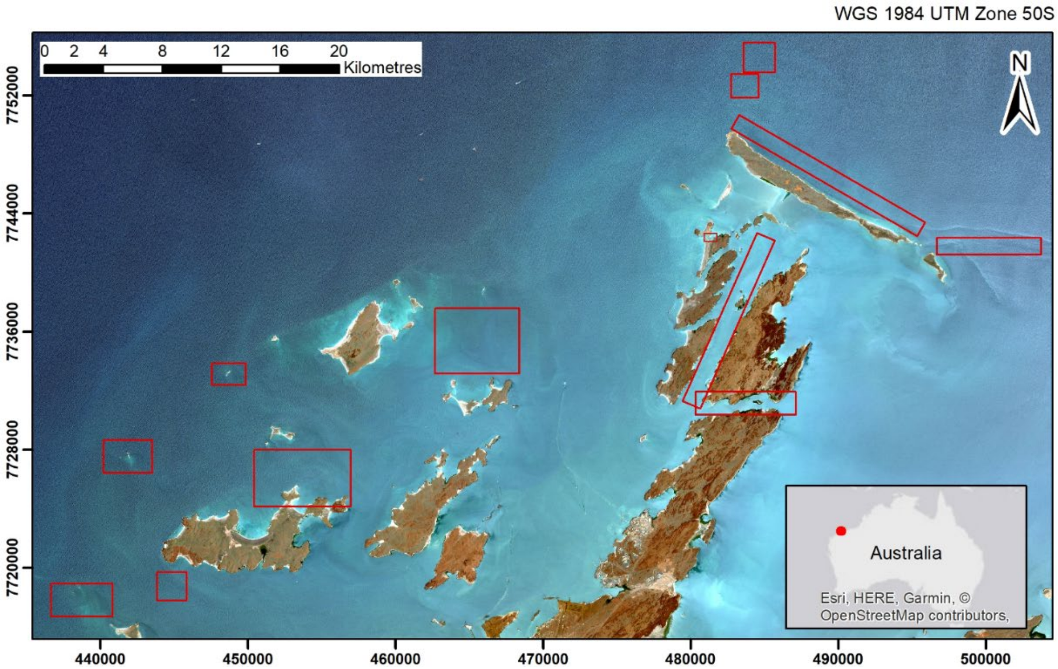

Figure 31: Approximate area covered by sidescan sonar survey.

Sidescan sonar data were collected and processed in the ellipsoid WGS84, in UTM Zone 50S (Fig. 31). All survey lines were plotted in Hypack 2016a navigation software, using a line spacing of 50 m. While it is recognised that English Heritage guidance (English Heritage 2013) suggests a maximum line spacing of 30 m with alternate lines running in the opposite direction, the minimum line spacing was reduced to 50 m for the purpose of reconnaissance of large areas that otherwise could not be covered in the time available. Line spacing of 30 m was used for areas of higher archaeological potential identified in the previous phases of the project. Line spacing was thus adjusted based on the time constraints and priorities of the survey, with 200 m used for areas previously unrecorded and requiring preliminary reconnaissance, with the potential to increase overlap by using 150 m, 100 m, or 50 m line spacing. The priority areas deemed of interest for geophysical survey included north of Legendre Island, Madeleine Shoals, Flying Foam Passage, Searipple Passage, east of Rosemary Island, the area to the north of Enderby Island and south of Goodwyn Island, south of Enderby Island, Northwest Reef, Bare Rock, and Roly Rock (Fig. 31). Vessel speed averaged 3–5 knots for optimal data collection, and all geophysical equipment was mounted on and towed from the vessel. For navigation, a Garmin 72 GPS (3 m accuracy) was interfaced with Hypack 2016a, with instrument towpoints set in relation to the location of the GPS.

An EdgeTech 4125P sidescan sonar system with 600 kHz (Low frequency) and 1600 kHz (High frequency) towfish was deployed for this survey. The 4125 has an observed range at low frequency of 125 m, and a high frequency range of 35 m. Based on this, and the minimum line spacing of 200 m, 125% coverage of the study areas was acquired with 20% overlap of each line as a minimum coverage and overlap. Cable out values were changed throughout the survey depending on water depth, in accordance with English Heritage Guidance Notes (English Heritage 2013). The towfish was kept high in the water column for the duration of the survey given the potential for submerged hazards including coral bommies and rock outcrops.

Sidescan sonar data processing was conducted in SonarWiz 7, accounting for varying gains, corrections to slant range, and bottom tracking. A systematic methodology was also developed to identify targets, and is applied in the assessment of each individual line (see Appendix 2). Both frequencies were used in data processing to review the survey areas. Low frequency data were prioritized at reconnaissance areas to determine overall characteristics of these areas, while high frequency data overlaid allowed for higher resolution of priority areas while maintaining full coverage of each location. In sidescan imagery, hard returns represented high-amplitude backscatter objects, including boulders, or patch coral reefs. Low-amplitude backscatter articles produce soft returns, including clays and muds. High returns are depicted in a sharper, light coloration, while low amplitudes are shown as a darker image or potential shadow. Mosaics of each gridded survey location were created at a resolution of 15 cm. This allows for the export of mosaics for use in GIS alongside LiDAR imagery and satellite images to further inform target regions.

6.3.4 Drop-camera

A Spot X Squid-Cast drop-camera was towed alongside the sidescan sonar, providing a live video feed to the personnel onboard the vessel through an iPad, in order to characterise the seabed as seen in the sidescan sonar data. This footage was especially useful in ground-truthing shallow areas recorded via sidescan sonar, where shallow depths may have introduced some distortion to the data. This phase is also an important phase between diver-based observations, and informed prioritisation of research targets with sidescan sonar.

6.3.5 MBES

A sidescan sonar survey along Flying Foam Passage identified numerous features of interest, however, the depth of this area was beyond the capacity for effective mapping with LiDAR. Multibeam echosounder (MBES) survey was undertaken to allow for a DEM of the areas of interest in Flying Foam Passage, with the assistance of EGS Survey who facilitated data collection and access. A high-resolution Kongsberg dual head EM2040 (1°x1° beamwidth at 300 kHz) was used. A dual head MBES provided greater survey efficiency and a higher rate of data capture. A standard single head system provides 3–4 times coverage in shallow water (30–40 m swath width in 10 m water depth), as opposed to the 5–6 times water depth coverage provided by a dual head system.

6.3.6 Aerial drone survey

Two small remotely piloted aircraft (RPA or UAV) were used during surveys at Cape Bruguieres and at the Dolphin Island Intertidal lithic scatter to map the shallow and nearshore environment. At Cape Bruguieres, a DJI Phantom 4 Pro and DJI Mavic 2 (20-megapixel cameras) were used with Drone Deploy to map the site during various stages of tidal change, including the Lowest Astronomical Tide of the year (LAT) on October 2, 2019, between 6.00am and 7.00am local time. The drones allowed for 3D and 2D reconstructions of the channel, at a resolution of 1 cm per pixel. From these surveys, it was confirmed that Cape Bruguieres Channel remains entirely submerged, even during low tides. The survey also allowed us to verify the tidal regime for this site. The Australian Hydrographic Office has 3 secondary ports near Cape Bruguieres, including Cape Legendre (7 km north), Withnell Bay (14 km south), and Mawby Island (17 km southwest). At these three areas, the tidal predictions are 0.10 m, 0.14 m, and 0.15 m above LAT, and the lowest calculated tides for the year. Satellite altimetry data were used to determine if the observed water levels match the predicted levels at the three secondary ports. The gridded sea-level anomaly (GSLA) data were accessed through the AODN portal (Australian Ocean Data Network 2020), and a grid cell located 10 km east of Cape Bruguieres showed a 0.1 m negative sea level anomaly. This suggests that on a regional scale, observational water levels were at or slightly lower than the predicted level.

6.3.7 Community engagement

Informal and formal discussions were held with the local Aboriginal and other community members in the Pilbara. Formal meetings included Council of Elders meetings with Murujuga Aboriginal Corporation, as well as informal discussions with recreational divers and fishers, as well as commercial boat operators and heritage professionals. These conversations with people familiar and knowledgeable about the environments and archaeology Murujuga impacted the survey strategy. All work undertaken was conducted in collaboration with the Murujuga Aboriginal Corporation, the representative organisation for the archipelago. The community engagement strategies assisted to prioritise the survey areas selected, and acknowledged the community of Murujuga as experts of the area. Cape Bruguieres became a priority area after a local report of stone arrangements found onshore. A cave at Goodwyn Island was also recommended to the field team as a possible target area, and the depressions found throughout Flying Foam Passage are renowned local fishing places. This collaboration with community led to the successful identification of the sites at Cape Bruguieres and Flying Foam Passage. These discussions are not disembodied from the remote sensing process, but instead form a central aspect of the project that informed priority areas for further survey.

6.3.8 Diver survey

Capacity-building and training activities were first undertaken by the DHSC project's scientific divers, based on European examples. The team members participated in the geophysical and diver-based excavation of a submerged Mesolithic shell midden in Denmark, providing an international component to increase the divers' knowledge and understanding of submerged archaeological material (Astrup et al. 2021). Additional work was required to impart this knowledge to the environments of Murujuga, where the dive team participated in land-based surveys of Enderby, Goodwyn, and Dolphin Island to ensure that each member of the team could confidently and independently identify lithic material as understood in the Pilbara region. This was important given the difference in lithic material dealt with in the European context (Mesolithic flint tools), and the artefacts of Murujuga manufactured from granophyre. Additionally, this familiarisation process also assisted the divers in identifying material under water in Murujuga, which was often covered by fine silt and marine growth.

Based on the targets previously established in the remote sensing phases, divers were deployed to investigate each priority area. Survey lines were initially mapped in ArcMap as a grid, based on aerial imagery and LiDAR, and the vessel's navigation then used to locate these in the field. The number of survey lines varied depending on the survey area, and in addition to the 'grid' creation process, many dives were also used as preliminary reconnaissance dives to confirm features observed in remote sensing and establish further validity as a target area. On each dive, the dive team carried a camera, and a marker float with a GPS to log the divers' location. The camera and GPS were then set to the same time, so that individual artefact locations could be derived based on the timestamps on the camera and GPS. A 100 m leaded line was used for recording and diver orientation, with the line attached to weights and buoys.

6.3.9 Artefact recording and analysis

At Cape Bruguieres, while 269 lithic artefacts were recorded in the field, 46 artefacts were collected (Fig. 32). While at Flying Foam Passage, a single lithic was identified in a submerged freshwater spring. Each artefact retrieved was recorded with its location, dive number of the project, and date of collection. Given that the preservation of the marine growth on the artefacts was not a priority, the artefacts were not kept in water to sustain the marine growth. Detailed lithic recording was undertaken by project partners at the University of Western Australia and led by Jo McDonald, with additional recording undertaken by Jerem Leach.

From the Cape Bruguieres assemblage, all 46 lithic artefacts were photographed, and examples of the CB assemblage in addition to the single find from the submerged spring at Flying Foam Passage selected for 3D photogrammetry, as well as scale drawing. Neutron tomography was also applied to selected lithics using the synchrotron at the ANSTO DINGO beam facility in Sydney, Australia. This allowed for the ‘removal’ of surface marine growth by digital means to reveal the artefacts more clearly.

6.4 Results

The waters and islands of the archipelago covers approximately 1200 km^2, thus a detailed survey of the seabed of the entire area would be both cost-prohibitive, time-consuming, and impractical. In the approach developed, satellite imagery and nautical charts are used to create a regional picture of the archipelago’s submerged landscapes. Specific areas were then targeted with LiDAR, sidescan sonar, and MBES surveys. Once specific features were identified from the high-resolution remote sensing, these were assessed by drop-camera and diver observations. This iterative approach identified several prospective locations with high potential for archaeological material. In this section, the geomorphology of each feature is described, in addition to palaeoenvironmental interpretation, archaeological context, and the use of integrating multiple remote sensing datasets for feature interpretation. It must be noted that the focus of this approach is locating sites, and does not address issues such as land use.

6.4.1 Cape Bruguieres

At Cape Bruguieres Channel, 269 lithic artefacts were identified on the seabed. The channel separates the small island of Cape Bruguieres in the north, and North Gidley Island in the south (Fig. 32). Pleistocene aeolianite borders the channel, along with granophyre outcrops, and sand banks and spits created by the mobile sand that shifts through the channel. The channel floor is relatively flat, with a maximum depth of −2.6 m. Through the drone operations of the DHSC project it was confirmed that Cape Bruguieres Channel does not dry out, even in especially low tides. The lowest points of the channel are submerged at all tides except for the sill dividing the west and east of the channel area, which is partially exposed at low tide. The lack of sedimentary bedforms in the channel indicate that it is relatively sediment starved. In the remote sensing, LiDAR elevation records the sill feature and bathymetry of the channel, while sidescan sonar does not show this feature. While very small, light returns at the Dolphin Intertidal site (described in this chapter) could possibly show small crystalline rock, this is not the case at Cape Bruguieres despite the known presence of artefacts, as there are also small corals that return similarly bright, reflective acoustic signatures.

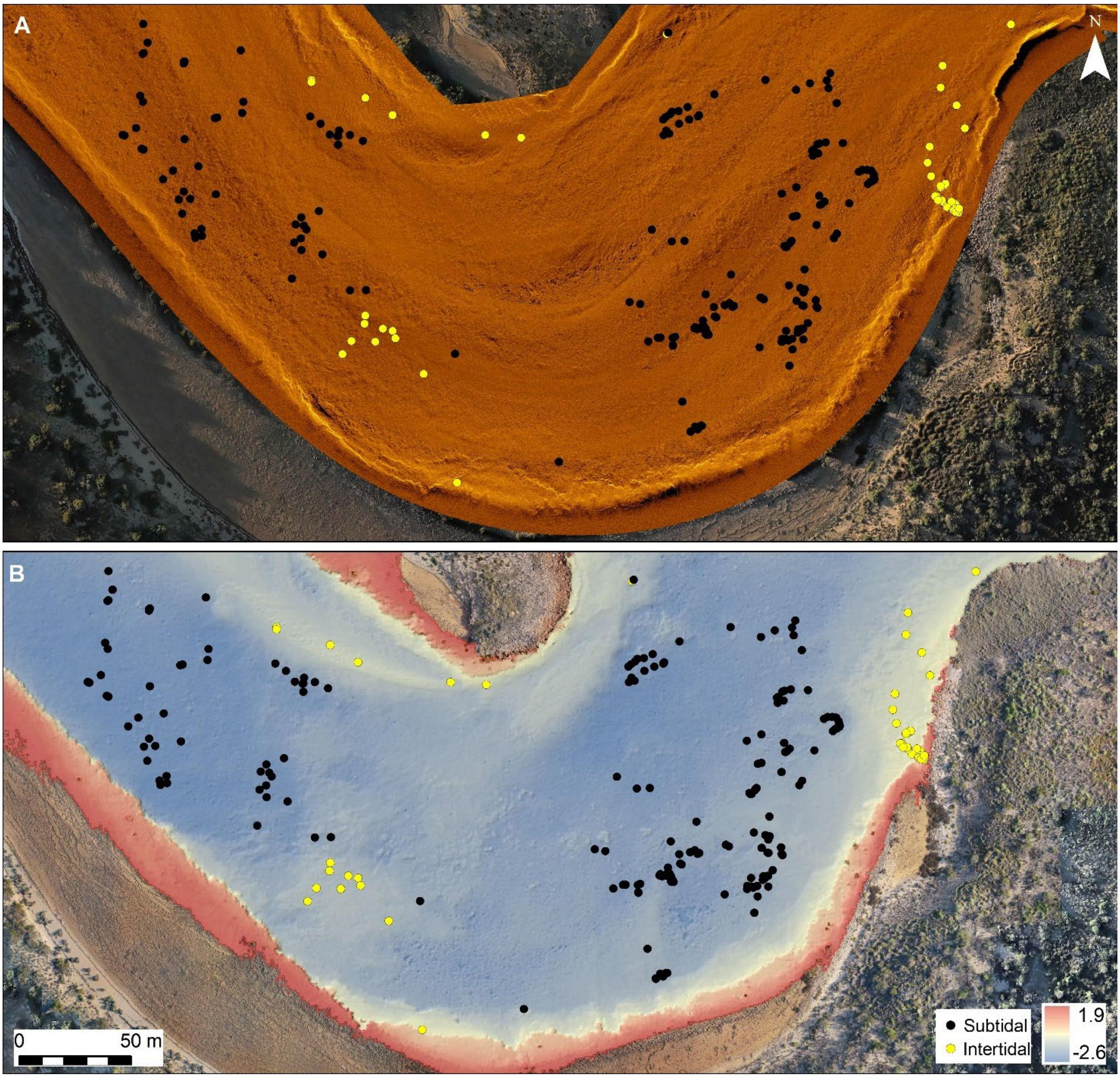

Figure 32: The Cape Bruguieres Channel site, shown in sidescan sonar imagery (A), and overlaid with bathymetry (B) and find spots.

The floor of the channel is a Pleistocene marine limestone and aeolianite mantled by a thin veneer of mobile sediments, including silty sand and sand mixed with shell and coral debris. Patchy corals can also be found in the deeper parts of the channel. A beachrock terrace dating to the mid to late Holocene (1791–2141 cal BP, see Benjamin et al. 2020 for details of calibration) is located on the southern shore of the channel, according to a radiocarbon date from shell cemented into the beachrock. The southern beach and dune system originated from mobile sand and were formed in the late Holocene. In association with the Pleistocene land surface, divers located 269 lithic artefacts below mean low water level. The material is not interpreted as contemporaneous with the deposits on the terrace on the southern shore. The underwater assemblage is located with the channel as a terrestrial landscape at a lower sea level, with an inundation date of approximately 7 ka acting as a minimum date for artefact deposition. Three hypotheses were established for the deposition of the underwater artefacts. The first hypothesis is that the material is in situ, and associated with a former land surface. The second hypothesis suggests that the material was transported from an archaeological site on the shoreline to the submerged environment. The third hypothesis suggests the presence of a lag deposit, in which heavier material deposited on a Holocene sand dune remains following the erosion of finer sediment. It should be noted that there is no rounding or edge-damage consistent with fluvial transport, or rolling by waves. There is also no spatial patterning in the archaeological material consistent with the action of tidal currents or waves. These factors instead indicate that the material is associated with a formerly terrestrial surface. As for the lag deposit hypothesis, there is no geomorphological evidence for remnants of a beach ridge complex or its erosion. It should also be noted that there is a sand spit to the west of the site, and given the lack of modern sediment deposition, the current is too strong for the accumulation of beach ridge sediments, which is required for the first step of the lag hypothesis. Therefore, it seems most likely, at this point in time, that the artefacts are found in situ on a former land surface.

The impacts of cyclone activity were mapped based on the onshore archaeological material (Benjamin et al. 2020), with very little movement of stone features on the southern terrace following Cyclone Veronica in 2019. Similar stability is assumed for material underwater, particularly as the underwater lithic assemblage demonstrates no rolling or edge damage, which would be expected from artefacts that were swept in or eroded into the channel.

6.4.2 Flying Foam Passage

Flying Foam Passage runs between two islands, and forms a sheltered passage in the archipelago. LiDAR was used to assess the terrestrial, intertidal, and shallow sub-tidal areas of the passage, with multibeam used to capture deeper areas beyond the range of LiDAR (Fig. 33). This provides a mostly continuous DEM for the area, and its surrounding islands. On the bordering islands of Gidley and Angel Island, quarries, rock art panels, lithic scatters, and standing stones have been found and indicate a continuous archaeological record across the landscape. Additionally, Flying Foam Passage is located near the Dolphin Island intertidal lithic scatter site (reported in Dortch et al. 2019), indicating the potential for further offshore archaeological material.

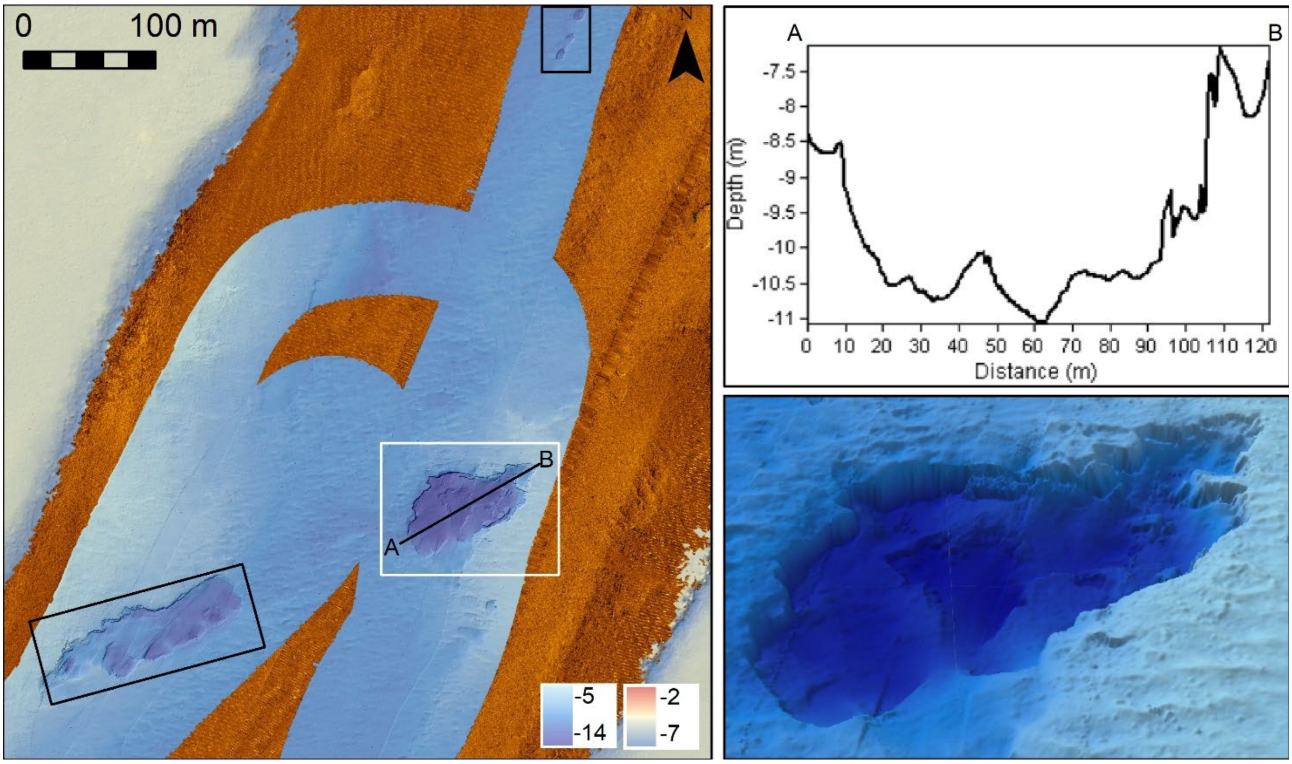

Figure 33: Flying Foam Passage submerged freshwater spring shown in multibeam bathymetry, adjacent to the Dolphin Intertidal lithic scatter site. The submerged spring was first identified in sidescan sonar, and then revisited with multibeam to enhance the mapping of the feature.

The passage area was initially interpreted as a significant drainage line. However, the sidescan sonar imagery showed numerous complex features along the passage floor, rather than evidence consistent with a drainage line. For example, a large depression in the centre of the channel was located, with multibeam data then acquired to offer a bathymetric model of the area and confirm its morphology. Other shadow features in the sidescan sonar were also confirmed as smaller seafloor depressions, but similar to the large, central depression first identified. Each of these depressions is 3 m deep, 80 m long, and 40 m wide, with a flat seafloor and sharp walls. The depressions appear to be formed within limestone rather than igneous geology, and are not the result of scouring. Of the largest depression, sidewalls were deeply notched, which is common in the intertidal zone of limestone coastal environments. These notches in a submerged, karstic depression indicate that they likely formed in a non-marine setting. Non-marine notches are described by Shtober-Zisu et al. (2015), and Simms (2002), who observe that the notch formation can occur through dry epikarstic processes, and also in limestone dominated lacustrine areas (respectively). The lack of evidence for palaeochannels flowing through the passage suggests that the notches are more likely to have been created by the presence of standing water, either as a spring or ephemeral billabong. These make the depressions of Flying Foam Passage a likely attractive area for human habitation until the inundation of the passage at 8.5 ka. Divers found the floor of the depressions scattered with cobble to boulder sized material, covered in significant marine growth and concretions. This made the process of identifying rock type or possible cultural material challenging. However, a single confirmed lithic artefact acts as an encouraging find in this target area, located at −14 m (Fig. 34). The tool is a cutting tool made of rhyodacite, located on the floor of the largest sea floor depression and amongst similarly sized stones. The origins of this particular artefact remain unclear, however, fluvial transport and erosion from adjacent sites on land does not account for its present location, as there is no rolling evident on the artefact and it would have to have been moved across a wide reef flat, then into the passage, then into the depression.

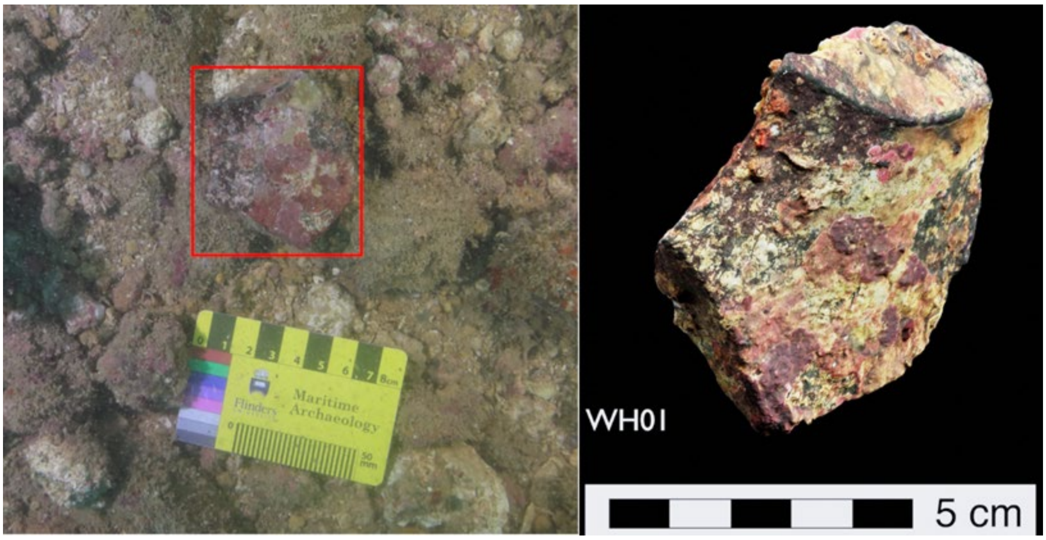

Figure 34: Submerged stone tool located at −14 m in the Flying Foam Passage freshwater spring.

A succession of three features north of the main karstic depression was identified, however, when these anomalies were first identified in survey, their similarity and presence on the starboard side in the direction of survey suggested it was more likely to be one circular depression, with an echoed data error. The multibeam dataset then elaborated on this, and showed that this features were not an echo but additional karstic depressions of 6 m width and 2 m depth. These morphologically similar karstic depressions remain highly prospective for archaeological survey.

6.4.3 Dolphin Island

The Dolphin Island intertidal lithic scatter remained a focus of the remote sensing, with questions as to whether it extends to the subtidal zone. This site fits the characterisation of a lag deposit, in which tidal processes and other physical processes shift finer sediment and leave coarser, heavier material behind (in this case, stone tools). Veth et al. (2020) raised the possibility of submerged lag deposits of lithics, and they are deemed a highly prospective site type which could survive inundation and the potentially damaging impacts of the intertidal zone. This area was first surveyed by remote sensing, then reinforced by walkover and diver surveys at low tide. In the remote sensing, while the LiDAR depicts the area quite clearly, individual lithic artefacts cannot be seen (Fig. 35). Sidescan sonar was able to map the area, however it also become ineffective in shallow depths as the shallowness may create distortion in the data. Nonetheless, crystalline rock with bright returns could be identified, but these features are small (<10 cm), and thus it is unlikely to identify lithic scatters by sidescan sonar alone (Astrup et al. 2021). A drainage line can be clearly seen at the deeper part of the intertidal lithic scatter, in addition to small, bright returns. These returns are likely indicative of gravel to cobble sized crystalline rock. Although not possible to differentiate artefacts from natural cobbles, the sidescan sonar data was used here to characterise a known intertidal site, and create the possibility of identifying similar site types at greater depths.

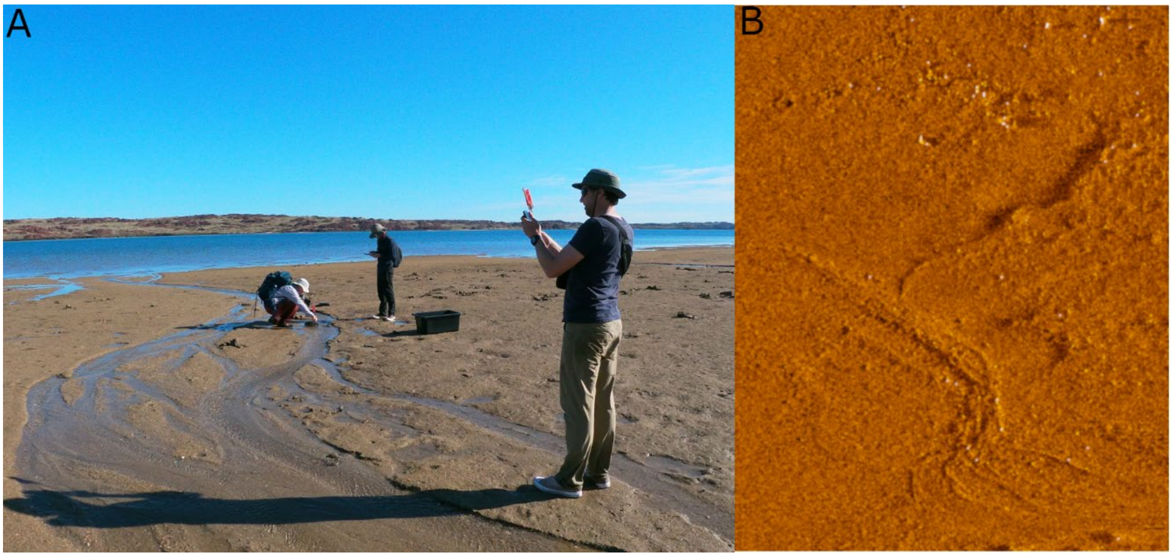

Figure 35: Dolphin Intertidal site shown in photograph (A) and sidescan sonar (B).

6.4.4 North Enderby-Goodwyn

The North Enderby-Goodwyn study area covers the submerged land bridge between Goodwyn Island in the north, and Enderby Island and its surrounding waters to the south. The feature resembles a causeway that once connected Goodwyn and Enderby Island at periods of lower sea level. The area is made of mobile sand to the west, and transitions to a silty seabed with visible pockmarks in the acoustic imagery. In the centre of the study area, there is an elevated sand bank. The area was a sheltered embayment in the early Holocene, providing access to coastal resources, and a likely favourable area for human habitation (Fig. 36).

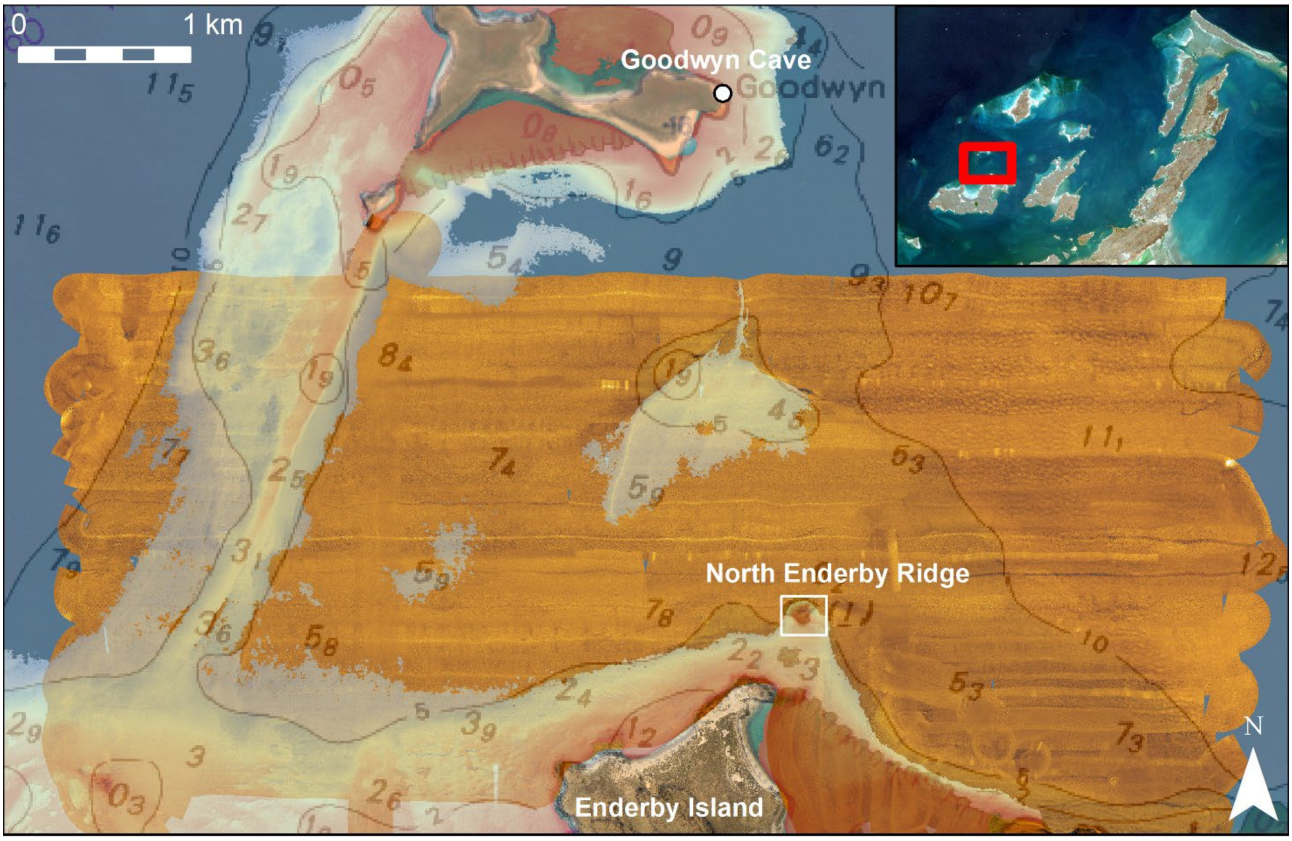

Figure 36: The North Enderby Island and Goodwyn Island survey area, note the causeway feature between islands.

Goodwyn Island is covered by lithic scatters and evidence of habitation, and at the northeastern corner of the island, a large intertidal cave was surveyed for submerged archaeology potential. The cave is 10 m at the entrance, then extends 10 m horizontally. The floor of the cave is 2 m below MLWS, and the ceiling is 2–3 m above MHWS. The floor extends under overhangs which are covered by oysters, in addition to fossil oysters above this level which could represent the mid-Holocene highstand. The age of the cave must then be older than the fossil oyster deposits, possibly late Pleistocene. The cave is the largest known shelter in the vicinity of Enderby, Rosemary, and East Lewis Islands. Smaller caves are also found at Goodwyn Island, and these too could have served as favourable habitation areas. Despite this, no worked lithic material or other archaeological evidence was located in the intertidal Goodwyn cave, however, numerous crystalline rocks were found at the entrance to the cave and mostly rolled. The origins of this crystalline material is unclear, as the closest outcrop is 2 km to the western side of Goodwyn Island and no mechanism is apparent for transporting this material to the cave.

The 'causeway' feature was first identified in the nautical chart, and reinforced by satellite imagery, however it can be seen across LiDAR and sidescan sonar as well. Sidescan sonar provides less detail on the relief of the causeway area, but this is then supplemented by LiDAR bathymetry. The area was then surveyed using a drop-camera to confirm seabed composition, as assessed with sidescan sonar. While the causeway is clearly visible in the LiDAR, deeper targets around this area could not be obtained due to the limits of LiDAR. The surrounding area was then mapped with sidescan sonar, allowing for greater coverage of the area north of Enderby Island.

6.4.5 North Enderby Ridge

To the east of the ‘causeway’ feature north of Enderby Island, an underwater rhyodacite outcrop, covered in algae and sessile invertebrates was identified. The outcrop is 200 m north of Enderby Island, with a maximum depth of −6 m. This feature was observed across nautical charts, satellite imagery, sidescan sonar, and LiDAR (Fig. 37), and generally indicates the presence of a rock outcrop, however diving was required to verify this outcrop as a rock feature rather than reef. Similar rock outcrops are found across Murujuga, and this example from north of Enderby Island could perhaps have provided a source for lithic material or art production. No archaeological material was located in this area, and diving this site is challenging due to a strong tidal current.

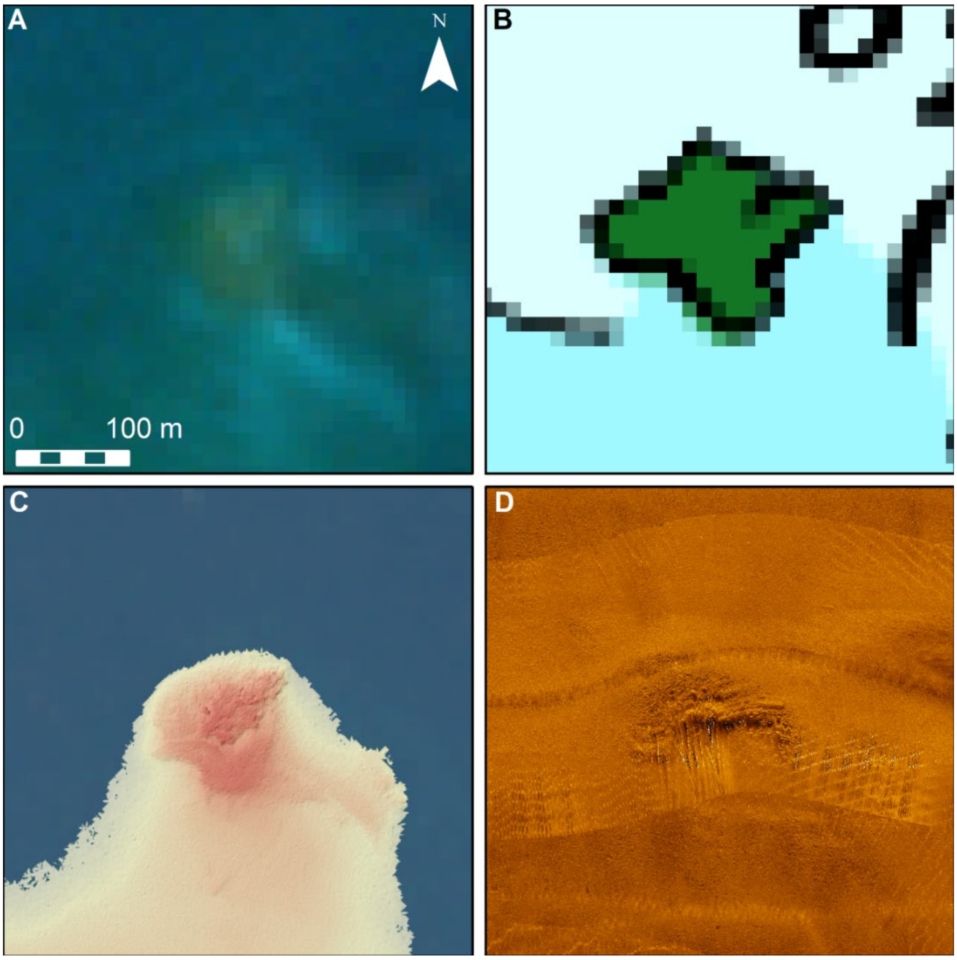

Figure 37: North Enderby Ridge feature as seen in A) satellite imagery, B) nautical chart , C) LiDAR , and D) sidescan sonar.

6.4.6 Mermaid Mound

To the south of Enderby Island, an elevated mound was identified in a bathymetry dataset collected by Pilbara Ports. This feature is found at −16 m, with an upstanding relief of 4 m (Fig. 38). Given the similar morphology of this feature to shell middens found on land, this feature was deemed prospective. Diver survey shows that the feature is a rock outcrop, made up of large boulders which are generally covered in marine growth, although some more exposed areas were also found. The area is located alongside a palaeochannel, and thus this area remains a prospective target given the potential for lithic material in association with a freshwater environment prior to inundation.

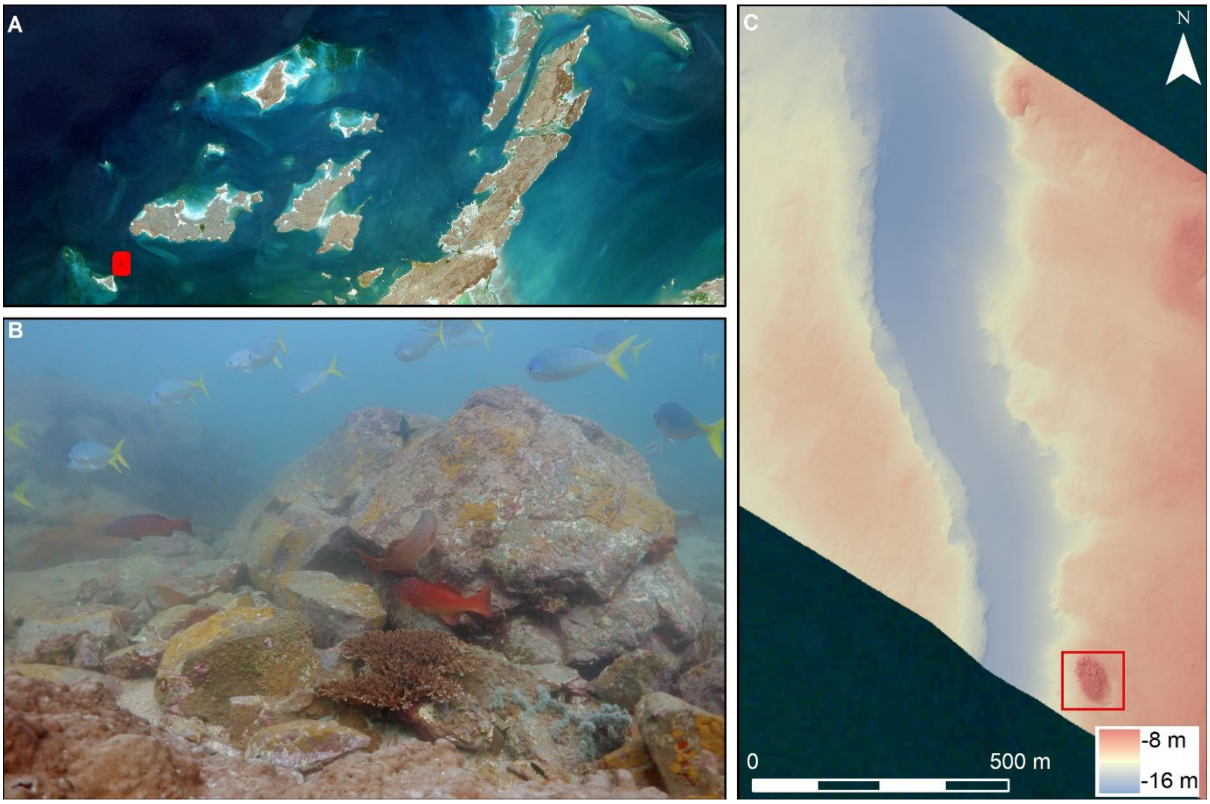

Figure 38: Mermaid Mound target site, with A) location, B) rock outcrop, and C) location of rock outcrop in relation to palaeochannel.

6.4.7 Roly Rock, Bare Rock, and Northwest Reef

Roly Rock, Bare Rock and Northwest Reef, form part of the former coastline at 7 ka. Due to the high potential nature of quarry sites for the archipelago, it was deemed a priority to map these rocky outcrops, and assess their extent under water. The rocky seabed includes large boulders and cobble size clasts, which extend down to −15 m. This was first observed in sidescan sonar survey and then verified by drop-camera (Fig. 39). These rocks are not covered in marine growth, and may also be periodically covered by mobile sand. Rocks at depths of −5 m and shallower appear to be rounded and abraded, however, sharp edges have been retained on rock surfaces at depth and this may indicate greater protection at depth. At periods of lower sea level, rocky formations including Roly

Rock were possible sources for lithic material, with the nearest equivalent 5 km to the east at Enderby Island. Considering Roly Rock's proximity to a coastline dating to 7 ka, the potential for these areas as quarried sites is significant, and they are an important target.

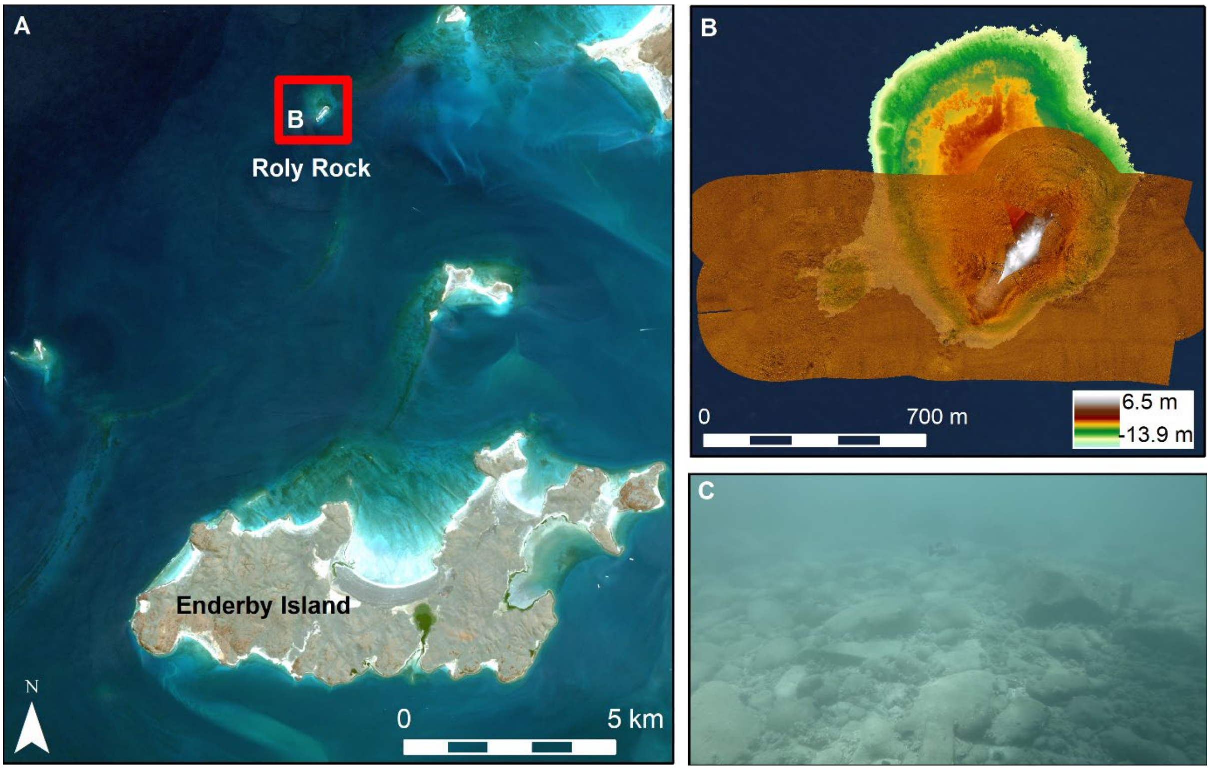

Figure 39: Roly Rock target site, A) in context in the archipeago, B) with use of LiDAR bathymetry and sidescan sonar, and C) footage collected via drop-camera.

At Bare Rock, semi-circular rock features were visible in the sidescan sonar data (Fig 40). These stone features are small-scale and although they may represent errors in data, however, they have occurred in lines where little movement and distortion is apparent. These features may serve as future targets for archaeological survey, although were not included in the DHSC diving surveys as targets given the need to prioritise diving on a select number of sites following the discovery of the Cape Bruguieres channel site. Following additional surveys at Cape Bruguieres, it became apparent that these stone circle features at Bare Rock strongly resembled features found on land at Cape Bruguieres, and these remain highly prospective targets.

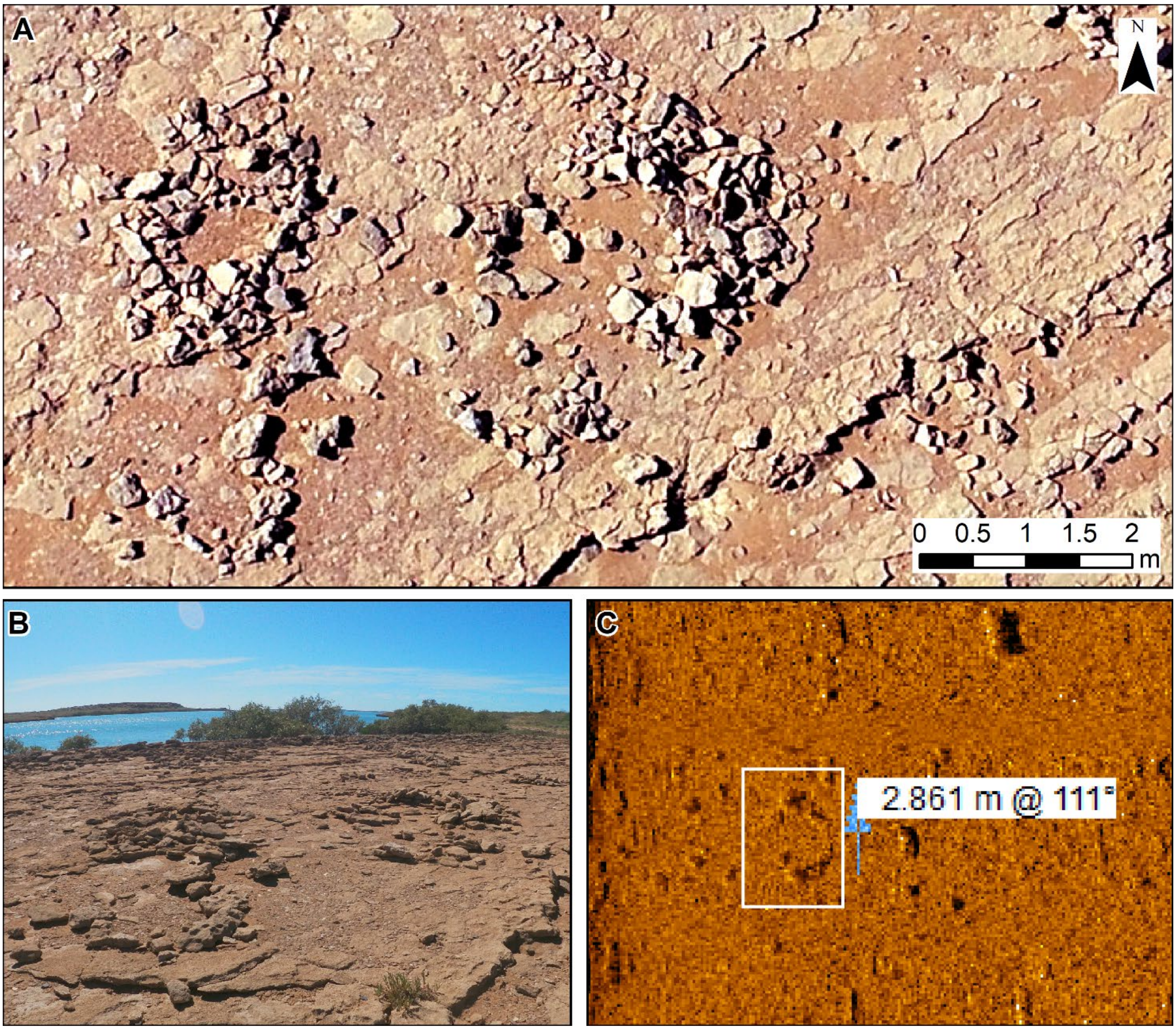

Figure 40: Stone circle features shown at Cape Bruguieres in aerial imagery (A), and in context (B), alongside the features found at Bare Rock (C).

At Northwest Reef, in addition to the rock outcrop features also seen at Bare Rock and Roly Rock, a possible palaeochannel was identified in the sidescan sonar data (Fig. 41). Given the highly prospective nature of palaeochannels in submerged landscape archaeology, this palaeochannel and its surrounds remain highly prospective for ongoing research in Murujuga.

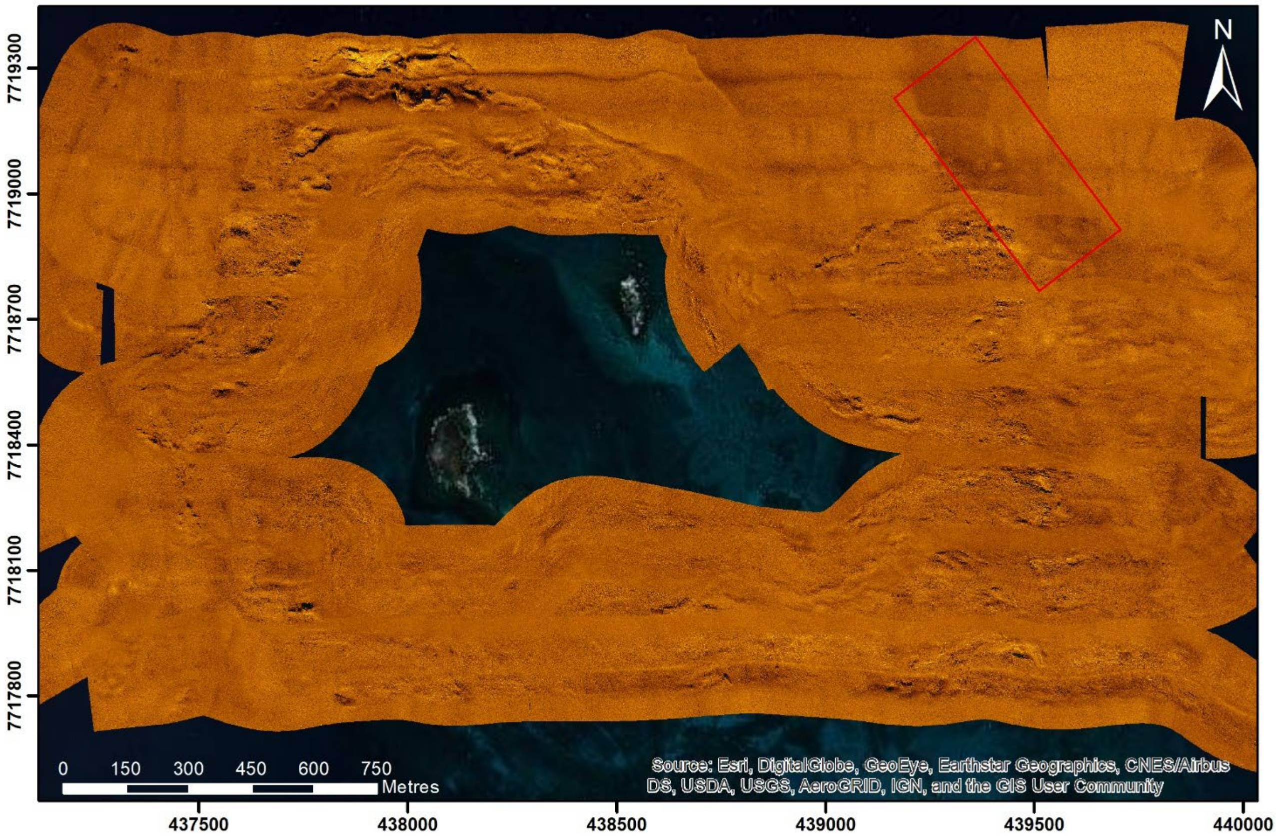

Figure 41: Palaeochannel outlined in red at Northwest Reef.

6.4.8 Madeleine Shoals and Legendre Island

Both Madeleine Shoals and Legendre Island were deemed priority areas to analyse relict coastlines dating to the terminal Pleistocene (Fig. 42). Legendre Island is an atypical example of the geology of the area, with abundant limestone. Both areas are especially susceptible to erosion, particularly on the northern side of Legendre Island. Despite this, they are important areas to have reviewed to assess areas that are less likely to include preserved archaeological material.

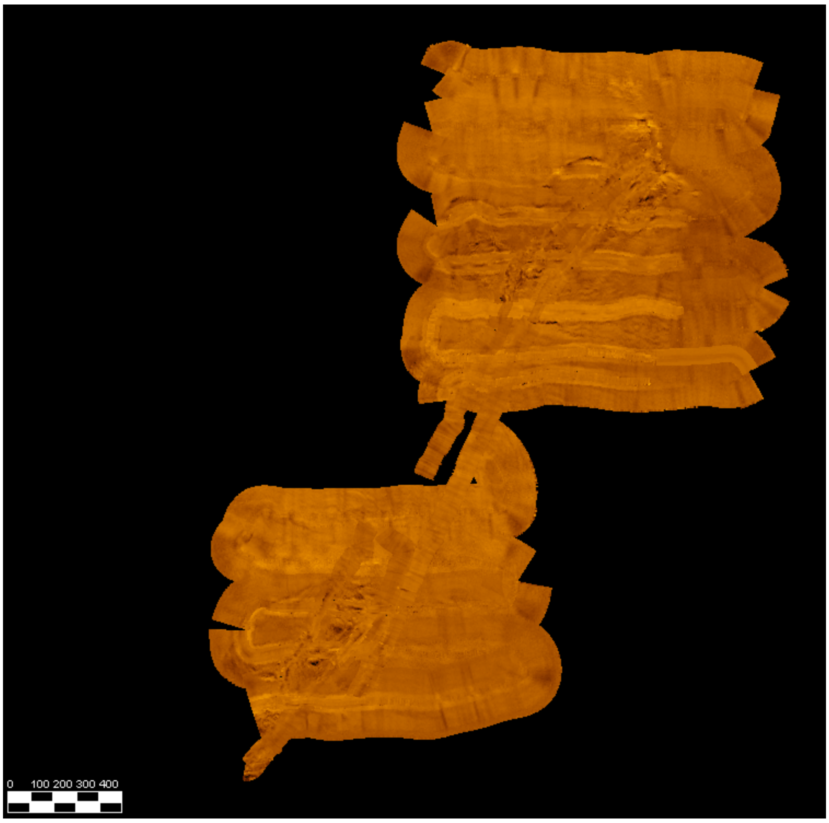

Figure 42: Sidescan sonar data showing the Madeleine Shoals study area.

6.5 Discussion

6.5.1 Evaluating the Veth et al. (2020) model

The predictive criteria outlined by Veth et al. (2020) balanced a combination of preservation potential and occupation potential. Sheltered and low energy environments were selected over exposed areas subject to erosive processes. Additional geomorphological assessments allowed for an understanding of possible resource foci in the landscape. Terrestrial analogy provides a baseline to assess the submerged landscape for similar features, however, it is also offers a testable hypothesis as to whether terrestrial continuity exists in the archaeological record. Predictive criteria for Murujuga have also been suggested by McDonald (2015), which notes the importance of freshwater as a resource in the area and the increased likelihood of identifying rock engravings adjacent to freshwater features.

The material culture outlined by Veth et al. (2020) as most likely to survive inundation in Murujuga includes: 1) middens and artefacts in cemented dunes and beach rock; 2) quarried rock outcrops and associated lithic material; 4) standing stones; 5) lag deposits; and 6) rock overhangs that could be used as rock shelters. These features are considered based on whether possible examples were located, how these features may be located through remote sensing, and then how this may be relevant in developing further guidance and best practice in Australia.

6.5.2 Middens

While it could be possible to detect midden deposits through remote sensing, assuming upstanding relief, this did not occur in the case of the work conducted in Murujuga. On land, middens in this area are typically found as scatters, linear features, and also as mounds. Late Holocene mounds (based on those located on the West Intercourse Islands of Murujuga) may be >5 m in height, and these would make for likely targets underwater. However, *Terebralia* middens associated with the early Holocene do not tend to be mounded, although it may still be possible to locate indurated features adjacent to freshwater features (such as those found on Rosemary Island, see McDonald and Berry 2017). In this research, a feature consistent with the interpretation of a possible midden was located at Mermaid Mound, but this target area was eventually determined to be a rock outcrop, and thus the overlap in how these features appear in remote sensing datasets must be considered.

Previous work to assess the preservation potential of middens was conducted by Nutley (2005), who observed the gradual destruction of a midden deposit by a river. Although this research demonstrates important factors about the issue of erosion for midden material, the erosion of a river bank and the erosion of a coastline are influenced by different processes and further research in required to fully understand midden preservation in the Australian context. Underwater midden preservation is a major theme for further research in both the Australian context and internationally, and this theme will be discussed further in Chapter 7.

6.5.3 Quarries

In Murujuga, quarry sites identified on land may be associated with piles of large boulders, with extraction pits, flakes, and debris. Some single boulders may also show evidence of quarrying. Areas that are conducive to quarrying are readily identified in both sidescan sonar and LiDAR, however, these require further testing by drop-camera, divers, or snorkelers to confirm the presence of actual quarried material. In this case, the remote sensing assists in providing high priority targets for diver survey. An intertidal quarry site was identified to the north of Cape Bruguieres Island (see Fig. 43), and this could indicate the potential for quarried material to preserve further offshore in subtidal environments as well. At Roly Rock, it is possible that evidence of quarrying may have preserved, in addition to the likelihood that debitage may preserve amongst the larger boulders and crystalline rock. From the remote sensing conducted, additional diver targets could be identified based on the integration of sidescan sonar, LiDAR, and drop-camera survey. Other rocky outcrops, including North Enderby Ridge, remain similarly prospective for this reason. On many of the underwater rocky outcrops, marine growth prevents an accurate assessment of the rock surface (for quarrying evidence as well as engraving evidence), however the Roly Rock area is less overgrown than the North Enderby Ridge which could increase the likelihood of locating quarried material.

Figure 43: Surveying the intertidal quarry site to the northwest of Cape Bruguieres (Image: J. Benjamin).

6.5.4 Stone arrangements

Stone arrangements in Murujuga may include linear features, rounded arrangements, arrangements that may have been associated with the construction of shelters (see Rosemary 8, McDonald and Berry 2017), standing stones, and stone-built fish traps. Arrangements that are prominent against the seabed and surrounding geology are more likely to be identified via remote sensing methods, while standing stones (which may be <10 cm in diameter) are predicted to be harder to identify in remote sensing. Larger standing stones could be identified of 20 cm or larger via sidescan sonar, however the reflective properties of standing stones could also be confused with natural features such as corals or natural rock. Circular stone features were identified at Cape Bruguieres, and similar features were located in the sidescan sonar data however these remain untested and could also be a data error in the geophysical data.

Fish traps associated with modern sea level and the present tidal regime are located throughout Murujuga (see example in Fig. 44), and their proximity to sea level indicates they are at least late Holocene in age. These prominent, stone-wall features represent a resilient aspect of material culture in Indigenous Australia, and could also act as a useful indication of relative sea level in the past in the event that a subtidal example was located. The potential for fish trap and stone feature preservation in the underwater environment is evaluated through international case studies in Chapter 7.

Figure 44: Stone-built fish trap located to the south of Enderby Island (Image: J. Benjamin).

6.5.5 Lag deposits

The prediction of Veth et al. (2020) that lag deposits of lithic artefacts form a prospective element of material culture was demonstrated by the Dolphin Intertidal site (Dortch et al. 2019). In the criteria set out by Veth et al. (2020), lag deposits are presumed to preserve on shallow declination shorelines in protected passages, which describes the environment of Flying Foam Passage and could indicate that there is potential for other intertidal lithic scatters throughout this area. Although the geomorphology of Dolphin Intertidal is consistent with a lag deposit feature, the same cannot be said of the subtidal lithic scatter found at Cape Bruguieres. The processes required for sediment to collect prior to erosion (the first elements of a lag deposit) are not evident at Cape Bruguieres, and thus this site is believed to be in situ on a former land surface. The potential of lag deposits of lithic scatters in coastal, intertidal, and subtidal environments remains a significant factor, and should be evaluated when lithic scatter sites are encountered based on the area's geomorphology.

6.5.6 Overhangs and seabed depressions

The second site identified by the DHSC team is the Flying Foam Passage submerged freshwater spring, with a single lithic artefact identified at a depth of −14 m. This indicates the preservation potential of these features, which can be identified with high-resolution sonar or consumer-grade echosounders. The integration of the multibeam and sidescan sonar datasets indicates that these freshwater features may appear significantly different across datasets, and thus a preliminary identification should be ideally followed by an assessment of the bathymetry of the feature. Past freshwater sources were identified as prospective areas for site location by McDonald (2015). Although predictive models should not rely on environmentally deterministic criteria alone, this indicates the potential for a combination of freshwater sources, sources of raw material for lithic technology, and productive coastal environments to be considered when predicting areas of potential habitation in offshore environments.

Rock overhangs were also identified in the sidescan sonar imagery, and these could be significant as options for shelters at times of past sea level. A similar strategy was used to identify features at Port Hacking (Nutley et al. 2014), however no archaeological material was located in this survey. Nonetheless, the shelter offered by rock overhangs and the subsequently more protected environment demonstrates that a level of preservation of archaeological material could be expected.

6.6 Conclusion

From the remote sensing and diver survey work conducted, several methodological insights can be identified. Terrestrial analogy is determined as particularly effective in guiding priority survey areas for submerged landscape archaeology, however it is important to note the potential to introduce bias from the reliance on terrestrial material that may not translate to material under water. In Murujuga, this was especially effective at Cape Bruguieres, where archaeological material was located onshore, at the water's edge, and then followed into the marine environment. However, despite the effectiveness of this approach at Cape Bruguieres Channel, the same procedure was conducted at Dolphin Island Intertidal and North Enderby Ridge, with no archaeology presently recorded below MLWS at these study areas. While the North Enderby Island area indicates vast evidence of quarrying and archaeological material, this has yet to be located in the subtidal environment, however, sand cover and reef cover may have contributed to the lack of results in this location. Nonetheless, in the creation of a set of predictive criteria for Murujuga, terrestrial analogy proved relatively effective.

Post-depositional processes in underwater environments are a significant factor in the preservation of submerged landscapes. In this case, remote sensing, ground-truthing, and geological sampling assisted in understanding the formation of the landscape and its change over time, and an in-depth understanding of regional geomorphology remains crucial to all submerged landscape archaeology research. Local knowledge should also be prioritised, as local fishers provided important assistance in the identification of the submerged freshwater spring feature in Flying Foam Passage, as well as Goodwyn Cave. The spring features, also referred to as 'wonky holes' in northern Australia (Stieglitz 2005) are easily recognised in both high-resolution geophysical survey instruments and in consumer-grade sonars. These areas may serve as important targets across the northern coast of the continent.

While LiDAR provided exceptional coverage and detail of shallow environments, sidescan sonar offers a relatively cost-effective technique to map features at greater depth including rocky overhangs and rock outcrops. These can then be followed by more time-consuming survey methods such as multibeam to acquire detailed bathymetry of the feature of interest. Increased collaboration with industry in Australia may also assist in acquiring high-resolution data, given that many offshore projects collect seabed data regularly, as occurred at Flying Foam Passage.

The methods developed by this project assisted in the identification of several high priority survey targets, and the confirmation of the first two in situ sub-tidal Aboriginal archaeological sites. This approach begins at a large scale with a suite of remote sensing, eventually narrowing areas given the geomorphological and archaeological context, and then progressing to observation in the field by divers. The cultural and environmental factors of the archipelago have been considered throughout the survey design, including the rich onshore archaeological record, and the coastline characterised by igneous rock formations and large tidal ranges. Further work is needed to understand the impacts of cyclone activity. Although further work is required to develop the digital and acoustic signatures of hunter-gatherer archaeology under water, these results demonstrate that this material preserves and can be identified through a systematic approach.

7.0 ESTABLISHING AN 'AUSTRALIAN MODEL' FOR SUBMERGED LANDSCAPE ARCHAEOLOGY

7.1 Introduction

This chapter will consider the development of an original Australian Model for submerged landscape archaeology. As the study of Australian submerged landscape archaeology begins to grow and the focus shifts now from potential to prediction (of where next) a national model (or mode of practice) to develop probability for site encounter would be useful for researchers, heritage practitioners, managers and regulators and policy makers. Is it possible to generate a mode of practice specific to Australian archaeology with consideration for international parallels? If so, this may have significance for refining the methodological approaches to locating sites. With the criteria for the stepped Australian Model, there are additional factors to consider in its implementation. Firstly, the context of submerged landscape archaeology in Australia is revisited. The types of archaeological material that can be expected in the submerged Australian record is reviewed, based on existing features on the Australian coast and international examples, and how best to record these sites in accordance with international practice. The legislation of submerged landscape archaeology in Australia is also reviewed. The potential for regional-scale iterations of this Australian Model will be addressed in the following chapter.

7.2 Systematic literature review: submerged landscapes and Australian maritime archaeology

The representation of submerged landscape archaeology in Australia is firstly reviewed in a thematic content analysis, and the criteria of the model are then described and reviewed alongside the international examples researched in this thesis. The rationale of specific components of the model is discussed, in addition to potential considerations for its implementation.

To understand the ways in which Australian archaeology has approached submerged landscape archaeology, both the journal of *Australian Archaeology* (from 1974 to 2019) and the *Bulletin of the Australian Institute for Maritime Archaeology* (hereafter, *AIMA Bulletin* and newsletters, spanning 1982 to 2019) were selected to create a corpus of representative literature to assess the research priorities and potential biases inherent to these sub-disciplines. These two journals were selected to represent the primary areas for publication of archaeology, both maritime and terrestrial, in Australia. While this material is found in other journals as well, and future research could expand this literature search to the broader literature, the intention of this review is to establish the views around submerged landscapes specific to Australian archaeology, and thus the key journals for the topic are reviewed. This is conducted to address an important question: why is a baseline mode of practice needed?

For this review, Publish or Perish 6 was used to firstly systematically search the *AIMA Bulletin* and *Australian Archaeology* based on a series of search terms (Table 3). Additional literature was added based on manual searches that the search tool did not acquire.

Publish or Perish Search Results		
Search Term	AIMA	Australian Archaeology
Submerged landscape	3	4
Submerged prehistory	0	0
Submerged prehistoric	0	2
Submerged Indigenous	1	0

Table 3: The results of searches using Publish or Perish to identify articles that discuss submerged landscape archaeology in Australia.

In addition to the publications located through the Publish or Perish search, the AIMA Newsletters are made available online, and these were checked manually for mentions of submerged landscape archaeology. Six total mentions were found. It should be noted that the search only includes digitised *AIMA Bulletin* editions, which includes 2001 onwards, and I was able access newsletters from 2007 to the present. Nothing was found in the *Australasian Journal of Maritime Archaeology (AJMA)*, the recently renamed version of the *AIMA Bulletin*, and no mention was found in Special Publications. Anything located manually was found by reading each of the issues and reading articles that I presumed might have some mention of submerged landscape archaeology. Most mentions of submerged landscapes are from international case studies, and submerged landscape archaeology in Australia is scarcely mentioned in the *AIMA Bulletin* or newsletters. In *Australian Archaeology*, while there are numerous discussions of coastal settlements, shell middens, and marine resource use in Indigenous archaeology, discussion of submerged landscapes is limited. Five journal articles (but six results due to the same article using both search terms) were found through automated searches, and following a manual check of digitised journals dating back to 1974, 10 further articles were added to the core literature based on their relevance for any mention of submerged landscape archaeology.

The fact that there is little mention of submerged landscape archaeology is important and further terms could be searched and investigated to address what tends to be published in both journals comparatively, however the key concern of this thesis is what has been written and published in these journals about submerged landscapes so far, and what that information conveys. For this purpose, a qualitative assessment of themes in Australian archaeology and submerged landscapes was conducted, using the method described previously in the review of the 2010 JICA Forum. As in the previous review, each article was reviewed as part of a 'dataset' of literature, and reviewed for several themes in submerged landscape archaeology (Table 4). Each section of text associated with the theme is logged as a single 'reference' to that theme (in NVivo, coded to a particular node).

Glossary of themes reviewed	
Theme	**Description and protocol for recording**
A) Archaeological potential	Highlights the potential for submerged landscape archaeology to preserve and contribute to archaeological questions
A1) Submerged quarry potential	Indicates potential for submerged quarry sites to preserve
B) Coastal archaeology	Discusses coastal archaeology with acknowledgement of submerged landscapes
B1) Past coastal environments	Refers specifically to past coastal configurations and inundated areas
C) Confirmed sites	Intertidal/freshwater submerged archaeological site confirmed
C1) Artefact redeposition	Submerged archaeological site confirmed, but artefact redeposition noted
C2) In situ material	Submerged archaeological site confirmed, determined to be in situ
C3) Post-depositional processes	Submerged site confirmed with discussion of post-depositional processes
C4) Freshwater contexts	Discusses impact of freshwater environment on archaeology
D) Dating	Establishes the date of confirmed submerged material
E) Excavation	Discusses potential for excavation of submerged landscapes
F) Human dispersal	Demonstrates importance for submerged landscapes in understanding human dispersal
G) Impact of sea-level change	The role of sea-level change on the archaeological record is noted
G1) Depth to age ratio	The association of depth and age ranges of submerged environments is highlighted
H) Implication of existence of submerged remains	Implies existence of submerged material but does not highlight preservation or discovery potential
I) Indigenous knowledge	Indicates role of Indigenous knowledge in understanding past coastal environments

J) Interdisciplinary	Describes submerged landscape archaeology as interdisciplinary
K) International example	Describes international examples of submerged landscape archaeology
L) Lack of visibility	The lack of visibility of submerged material is described as an issue
M) Landscape evolution	Changes in coastal and inland landscapes are described
N) Legislation and management	Role of legislation in protecting submerged landscapes discussed
O) Marine resource exploitation	Importance of marine resources to coastal populations discussed
P) No finds located	Survey conducted to find submerged landscape archaeology, but no material found
Q) Seafaring and watercraft	Highlights the association of seafaring and watercraft with submerged environments
R) Settlement of Sahul	Notes the importance of submerged environments to understanding settlement of Sahul
S) Site destruction assumed	Describes habitation potential of submerged landscapes, but assumes all sites were destroyed
T) Survey methods	Discusses potential or actual survey methods for submerged landscapes
T1) Aerial imagery	Describes use of aerial imagery for submerged landscape archaeology
T2) Industry involvement	Notes the importance of industry collaboration for submerged landscapes
T3) Funding and resources	Discusses funding for submerged landscape archaeology
T4) Possibility of chance discovery	Emphasises potential for chance finds
T5) Predictive models	Emphasises role of predictive modelling
T6) Survey rationale	Outlines rationale of submerged landscape survey
T7) Technical and logistical issues	Discusses logistical issues of submerged landscape survey
T8) Terrestrial analogy	Indicates potential for terrestrial archaeology to inform offshore research

Table 4: The themes reviewed and their definitions for this content analysis.

Firstly, to address the results from *AIMA Bulletin*, several observations can be made based on the most frequently mentioned themes (Table 5). Some of the most frequently discussed themes in the *AIMA Bulletin* include the archaeological potential of submerged landscape archaeology, international examples, and seafaring and watercraft in association with submerged Indigenous archaeology. With eight references in text to archaeological potential, despite few articles having been published in the *AIMA Bulletin* that mention submerged landscape archaeology, what is written tends to be relatively optimistic about the potential to locate submerged archaeological sites. However, this may seem at odds with the other frequent mention of international examples, which perhaps reinforces the discussion around archaeological potential, but also perhaps negatively indicates a general association that such sites do not preserve or cannot be found in Australia. It portrays an image of submerged landscape archaeology as something that is found only internationally, but does not exist in Australia. The other key theme is seafaring and watercraft, which may align with AIMA's tendency to focus on the research of watercraft. In summary, despite the fact that the potential for submerged landscape archaeology is acknowledged, there's more significant discussion of international contexts rather than in Australia, and when Indigenous Australia and coastal adaptation is mentioned, it is often in the context of watercraft.

References in *AIMA Bulletin* from 1982 to 2018	
Theme	**References to theme**
Archaeological potential	8
International example	7
Seafaring and watercraft	6
Legislation and management	5
Landscape evolution	5
Indigenous knowledge	4
Impact of sea-level change	4
Technical and logistical issues	3
Settlement of Sahul	3
Terrestrial analogy	2
Predictive models	2
Industry involvement	2
No finds located	2

Lack of visibility	2
Implied existence of submerged potential	2
Dating	2
Freshwater contexts	2
Artefact redeposition	2
Funding and resources	1
Survey methods	1
Site destruction assumed	1
Marine resource use	1
Interdisciplinary	1
Confirmed sites	1
Past coastal environments	1

Table 5: References to research themes in the AIMA Newsletters and *AIMA Bulletin* ranging from 1982 to 2018.

The emerging areas of focus in relation to submerged landscapes in *Australian Archaeology* include the impact of sea-level change on past Indigenous communities, implied likelihood that submerged material exists, post-depositional processes of coastal material, and the destruction of inundated sites (Table 6). The prevailing perspective that is indicated by *Australian Archaeology* is that although extensive coastal archaeological sites exist, and may well have existed on now-drowned landmasses, the likelihood of their preservation is low, with several allusions to the outright destruction of sites despite the potential for site preservation remaining relatively untested.

References in *Australian Archaeology* from 1974 to 2019	
Theme	**References to theme**
Impact of sea-level change	8
Implication of existence of submerged remains	7
Post-depositional processes	6
Site destruction assumed	6
Coastal archaeology	6

Survey methods	6
Artefact redeposition	4
Confirmed sites	4
Past coastal environments	4
Industry involvement	3
Seafaring and watercraft	3
No finds located	3
Human dispersal	3
In situ material	3
Archaeological potential	3
Terrestrial analogy	2
Marine resource exploitation	2
Lack of visibility	2
Dating	2
Freshwater contexts	2
Technical and logistical issues	1
Possibility of chance discovery	1
Funding and resources	1
Aerial imagery	1
Settlement of Sahul	1
Landscape evolution	1
Interdisciplinary	1
Depth to age ratio	1
Excavation	1
Submerged quarry potential	1

Table 6: References to research themes in *Australian Archaeology* from issues dating 1974 to 2019.

From this brief assessment of submerged landscape archaeology in two key Australian journals dealing with maritime archaeology and Australian archaeology, some inferences may be made as to how submerged landscape archaeology in Australia has been approached prior to the announcement of the first submerged ancient Aboriginal sites. Despite noteworthy exceptions and encouraging indications for offshore material, such as Lake Jasper which was published in *Australian Archaeology* (Dortch and Godfrey 1990), the overarching assumption presented to readers of publications in *Australian Archaeology* is that the environmental conditions surrounding a submerged site could easily destroy it. While *AIMA Bulletin* seems more positive, a level of bias towards historic ships and watercraft seems to have created interest specifically in the possibility of submerged watercraft.

The maritime archaeology community in Australia has predominantly retained an interest in watercraft, and this is reflected in the data. On the other hand, terrestrial archaeologists often present the sea as a boundary, or as something unchanging, or as a force that destroyed archaeology on the past coastlines. This leaves submerged landscape archaeology in a difficult middle ground, but may optimistically serve to bridge a gap between sub-disciplines, and indicates the scope for conversation and collaboration to better understand submerged landscapes. This gap in both sub-disciplines requires ongoing research of submerged landscapes, which can be informed from material internationally.

7.3 Potential site types

Based on the discussion of land use and site selection by past societies, post-depositional processes, and the factors influencing a site's visibility and discovery, a list of possible sites that could be identified on the Australian continental shelf is developed with a comparison to international examples of the material type (or similar features). A similar strategy is employed by Nutley (2005), however, Nutley (2005) primarily relies on Australian terrestrial examples, whereas this discussion compares known international underwater examples with a discussion of potential material to be found in Australian waters. This section outlines the likelihood of the material's preservation, the context in which these features are known to preserve based on international submerged landscapes, and potential methods to identify them.

The site types are categorised by broader themes in archaeology, the first being the distinction between open air sites and cave sites for submerged landscapes. Resource procurement and stone arrangements are also discussed. Although both categories are technically open-air sites, they are considered separately from the open air versus cave site distinction to convey the archaeological contribution of these sites more accurately.

7.3.1 Open-air sites

Two examples of open-air sites are reviewed for submerged landscape archaeology potential in Australia: lithic scatters and shell middens. These features are found throughout the coastal archaeological record in Australia, however, their preservation in underwater environments remains contentious. Despite the ongoing debates surrounding the preservation potential of open-air sites in submerged landscapes, there are international parallels that hint to the conditions required for the preservation of submerged lithic scatters and shell middens.

Lithic scatters

Although submerged prehistoric sites have the potential to preserve organic materials significantly better than terrestrial sites, lithic materials, known for their durability on land, often degrade in the marine environment (Cook Hale 2018). These artefacts are often vulnerable to abrasion, and may also be shifted during inundation. Lithic artefacts yield important data for submerged landscape archaeology, including insight to mobility and subsistence, and other culturally driven choices impacting raw material selection and use (Binford 1980; Purdy and Clark 1987). In some cases, there is difficulty in verifying the anthropogenic qualities of corroded artefacts, to accept them as artefacts rather than 'geofacts', or unworked stone, as a natural stone formation that is difficult to discern from artefacts (Lubinski et al. 2014). To confirm an object's status as an artefact, a stone should demonstrate evidence of human modification, or that it is made of imported material that had to be transported by humans rather than natural processes.

In the Australian context, lithics make up the currently known subtidal Indigenous archaeological sites. At Cape Bruguieres Channel, >260 lithics were located across the subtidal and intertidal zone, with various levels of marine growth. At Flying Foam Passage, a single lithic artefact was identified in a submerged freshwater spring. For the most part, lithics in the intertidal zone in Murujuga are not encompassed by marine growth, and this facilitates their identification and confirmation as lithic artefacts. Subtidal artefacts, however, may be covered substantially by marine growth. Removal of this material was avoided to prevent damage to the artefacts, however, it does complicate their analysis visually. Neutron tomography was used in this case to digitally 'remove' the marine growth covering the artefact, to gain a clearer sense of the artefact's surface and shape (Benjamin et al. 2020). Developing an understanding of the natural processes of stone weathering, chemical corrosion, and marine growth contributes to the potential to identify and improve interpretation of submerged material. There are features that can be identified that increase the likelihood of a stone object as an artefact. The shape of the object should resemble artefacts known in either intertidal or terrestrial deposits. This is more challenging with fragments of artefacts, however, the same principle applies. Weathering processes and heat fracturing can fragment rock in a way that may mimic human modification, and this should be taken into account based on the region.

Shell middens

Shell middens are recognised as an important archaeological indication of marine resource use across the world (Erlandson 2001; Bailey and Milner 2002; Roksandic 2014; Allely et al. 2021). Most middens are associated with the mid-Holocene onwards, from around 7 to 6 ka, and it remains unclear if this is due to demographic change and cultural shift, or due to likelihood that older shell middens were located on coastlines which have since been submerged (Bailey and Flemming 2008). Natural shell beds or other accumulations of shell by other species could be mistaken for anthropogenic shell middens, however, several criteria exist to distinguish cultural shell accumulations from these other features. According to Hughes and Sullivan (1974), middens contain charcoal, blackened shells, artefacts, and hearth stones, which are absent from marine shell beds. Middens are also roughly stratified, whereas shell beds tend to be well-stratified. Middens contain shells that are of edible size and species, while shell beds contain a combination of edible and nonedible species. Middens are also likely to contain the bones of other species used for food, while natural shell beds do not. Rosendahl et al. (2007) emphasised that shell deposits may be deemed anthropogenic based on the presence of artefacts and charcoal, burnt shell, consistency in shell size, in addition to the presence of non-molluscan faunal remains. Attenbrow (1992) cautioned that natural shell beds may also contain charcoal, and also noted that although terrestrial faunal remains and artefacts may demonstrate the presence of a shell midden, their absence does not necessarily indicate that a feature is a natural shell deposit. To further complicate matters, other species including fur seals, gulls, and megapode birds (all of which are found in Australian coastal environments) may create midden-like deposits that show considerable similarity to cultural shell deposits (Horton 1978; Jones and Allen 1978; Bailey 1993). However, the use of criteria described above, with some consideration for other species of a region, will still likely allow for an accurate assessment of a shell deposit as a shell midden or other shell formation.

The prevalence of shell middens in coastal environments around Australia suggests that they may also have existed on coastlines which were submerged by sea-level rise (Cann et al. 1991; McNiven 1992; Bailey et al. 1994; Clune and Harrison 2009). Globally, there are two examples of submerged shell middens that have been recorded in detail and excavated, located at Hjarnø, Denmark (Fig. 45), and Econfina Channel, off the coast of Florida (Astrup et al. 2021; Cook Hale et al. 2021). Although these are the best-studied examples of submerged middens, it is likely that many more existed in areas across the world that have since been submerged, and many are likely to have preserved. Shell middens can be identified by remote sensing to an extent, as demonstrated by the use of sub-bottom profiler to map a submerged shell midden by Astrup et al. (2020). Diver-based observation is important to verifying sites located through remote sensing, and especially in the case of shell middens where this is crucial to determine that the shell midden is not a natural feature. Among the challenges of the identification of submerged shell middens is how to distinguish these features from natural accumulations of shell under water, which could form through wave activity and mimic the appearance of an anthropogenic midden.

In North America, Gagliano et al. (1982) sampled shell middens alongside non-anthropogenic landforms to determine how archaeological deposits could be identified at a sedimentary level. Gagliano et al. (1982) note that non-anthropogenic landforms tend to be well-sorted, and that poorly sorted material is more likely to be indicative of anthropogenic deposits. In the research of the Hjarnø and Econfina Channel midden sites, there is a focus on site taphonomy and formation processes (Astrup et al. 2021; Cook Hale et al. 2021). These studies use a suite of techniques to establish the anthropogenic origin of the submerged middens based on geological characteristics, and have established principles that indicate the likelihood that a shell midden is an anthropogenic feature and not a nature accumulation of shell under water. Both middens are located in very different ocean basins and environments, however they provide an ideal opportunity to gain insight to the preservation characteristics of shell middens at a site scale.

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Figure 45: The section of part of the submerged shell midden at Hjarnø, with artefacts visible in both the shell layer and underlying dark gyttja layer (Astrup et al. 2021).

The shell midden located off the island of Hjarnø, Denmark, was deposited on a subaerial beach terrace made up of glacial till deposits (Skriver et al. 2017). The materials of the midden are poorly sorted, which is consistent with glacial till and anthropogenic origin, but not likely to be associated with non-anthropogenic contexts such as shoreface deposits and tidal deposits (Cook Hale et al. 2021). Additionally, an indication of the midden's terrestrial origin is the lack of foraminifera or other inclusions that would suggest deposition in a brackish or marine environment. The zooarchaeological material can also be compared with the terrestrial middens to confirm consistency between the different site types (Astrup et al. 2020). This depositional environment is different to Econfina Channel, as the inclusions in the midden demonstrate deposition in an intertidal environment, especially based on the presence of foraminifera through the stratigraphic profile of the midden. Cook Hale et al. (2021) describe this as due to exposure to marine water during deposition, but note that the midden was not deposited in a fully saltwater environment. Submerged shell middens indicate the potential for micromorphological and geological techniques to enhance the archaeological understanding of their deposition, and ultimately, their preservation.

7.3.2 Cave sites and rock shelters

Caves and rock shelters have long been a focus of archaeological research. The interiors of caves are in darkness and isolated from their external environment, whereas cave mouths and rock overhangs have some association with the outside environment and are partially illuminated. The protection afforded by the cave or rock shelter is dependent on the configuration, size, and orientation of the feature. Caves and rock shelters may form through a variety of means, with cave sites more frequently associated with karstic processes and the dissolution of limestone. Sandstone caves are well-known across Australia. Rock shelters may also form by fluvial undercutting of the bedrock walls. The depositional and post-depositional processes of caves can affect the preservation of archaeological material. The displacement of bones, lithics, and other anthropogenic material may occur through erosion by wind or water. Given the protective element of cave sites and rock shelters, they often preserve material that is missing from open-air sites. Ongoing studies of depositional processes and sophisticated analytical techniques allow for greater insight to activities, subsistence, and behaviours of the past inhabitants of caves. Binford (1998) addressed ethnographic uses of rock shelters, and emphasised short-term exploitation of these sites versus long-term habitation. This may include as a refuge, for storage, sources of material resources, and ritual locations. Galanidou (2000) describes a “modular pattern” of use in rock shelters, including arrangement of activities, demarcation of areas for different families, use of space for sleeping, and the construction of depressions and hearths. Rock shelters may exist in coastal, lacustrine, glacial, aeolian settings, and are found across all environments. Rock shelters specifically are impacted by different processes than a more protected cave site, and may preserve less frequently due to their exposure.

Rock shelters

Submerged natural features may be significant to the study of submerged landscapes, such as rock outcrops which could be used as rock shelters. Caves and rock shelters served as important locations for past societies, and may also be associated with rock art (as demonstrated by Cosquer Cave). They are also high potential targets for the prospection of submerged archaeology, given the possibility for rock shelters to provide a considerable level of protection to archaeological material. Identifying rock outcrops has served as a main theme in survey design in past attempts to locate submerged landscapes in Australian archaeology (Flemming 1982; Nutley et al. 2016), however no submerged rock shelters with confirmed human habitation have been located in Australia to date.

Rock overhangs and outcrops were also deemed prospective in work at Murujuga, and a cave at Goodwyn Island was surveyed over the course of this project. The Goodwyn Cave site yielded one stone that was too rolled to confirm as an artefact, however, this cave is subject to very abruptly changing levels of sand cover, and it is possible that archaeological material is beneath the extensive sand cover. The likelihood of rock shelters (and any archaeological material within) surviving sea-level rise is due to whether they are impacted by currents, storms, and winds, and subsequently scoured with any evidence of human occupation eroded.

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Figure 46: Divers in the Hoyo Negro cave, where human remains and late Pleistocene fossils were recorded (Hoyo Negro 2018).

Internationally, there are numerous examples of underwater cave sites (Campbell 2017). In the Hoyo Negro cave on the Yucatan Peninsula, human remains dating to 13 ka were recovered, along with late Pleistocene fossils (Collins et al. 2015; Fig. 46). To the west of Sardinia, submerged Neolithic burials were found at −8.5 m in an underwater cave (Antonioli et al. 1996). A more prospective example is also found in Italy, where the coastal Mesolithic rock shelter of Riparo Blanc indicates a reliance on marine molluscs and fish, and although this shelter is located above sea level, a lower cavity of the cave system can only be entered underwater and would have been dry during the Mesolithic (Castagnino Berlinghieri et al. 2020). This area has yet to be formally recorded. This suggests that rock shelters are a site type that seem prospective in conceptual models of preservation, but due to logistics can be challenging to analyse and verify past human occupation.

Rock art

Some attempts have been made to locate submerged rock art in Australia (Dortch 2002; Benjamin et al. 2020), however rock art has yet to be located in subtidal environments. In Murujuga, engravings on igneous rock may survive up to 30,000 years on land, and thus it is possible that these could preserve underwater, but likely in areas where both erosion and marine growth have had little impact on the rock surface (Pillans and Fifield 2013). Elsewhere in Australia, engravings on softer rock types such as sandstone are less likely to survive, and organic material for painting is also not likely to endure sea-level rise. Nutley (2005) suggests that stone that has absorbed red ochre could retain this pigmentation, but may also then discolour from minerals under water. Rock art involving pecking or engraving may withstand sea-level rise better than painted motifs. The environment of the rock art may also play a factor in its ultimate preservation, and caves and rock shelters may shield rock art from the impacts of sea-level rise. This is the case in the only presently known example of submerged Pleistocene rock art, located in Cosquer Cave, off the southern coast of France.

Cosquer Cave is accessed through an opening at −37 m, which leads upwards to a partially inundated chamber. The cave was cut off by rising seas following deglaciation. It has been visited by divers since 1984, but only formally recorded in 1991. The cave has yielded a vast collection of rock art, including portrayals of animal figures (including marine species), negative handprints, and other symbolic representations (Fig. 47). The cave is dated between 29 and 17.5 ka (Billard et al. 2020). Cosquer Cave presents an example of conditions that allow for the preservation of rock art, and while the art itself is not submerged, it represents a cave site that was only occupied during periods of lower sea level.

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Figure 47: Rock art located in Cosquer Cave (Billard et al. 2020:265).

7.3.3 Resource procurement

Fish traps

Fish traps are an important indication of coastal adaptation in the archaeological record, serving as an efficient way to catch fish throughout human history. Fish traps in coastal Australia are made from stone walls, or made with organic bark and fibres. These fish traps are prevalent along the northern coast of Australia (Rowland and Ulm 2011; Kreij et al. 2018). Nutley (2005) stated that stone fish traps were the most likely archaeological feature to survive inundation, except in high energy environments where it is possible for these stone structures to be dismantled over time. Despite this, the analogy of the Tel Hreiz seawall (Galili et al. 2019a) perhaps indicates a greater level of durability of this type of feature than has previously been presumed, particularly in the case of the vast fish traps associated with Queensland (Kreij et al. 2018).

While stone fish traps are assumed to be resilient even in harsh conditions, there are some conditions that could allow for the preservation of fish traps made from organic materials. The preservation of organic material in underwater environments has been demonstrated by several studies in the Baltic, and may yield greater preservation of organic material that is not otherwise found on land. In Sweden, fish traps and weirs have been found dating 9 ka to 8.5 ka, and forming some of the oldest known wooden fish traps (Nilsson et al. 2020). Woven fish weirs date to later periods in Denmark, and these are recorded at 17 sites across the Mesolithic and Neolithic (Fischer 1997), ranging from Kalø Vig (8 ka) to Ølby Lyng (5 ka) (Fig. 48). The Mesolithic structures are simpler structures made from hazel wood, while the Neolithic examples use several types of wood and a more tightly woven pattern. In the Baltic, these features were mostly subject to rapid, but low energy inundation. It is possible that otherwise, fish traps and weirs made from organic material may survive if buried in sediments or peat prior to inundation. Stone fish traps remain a more likely element of material culture to survive, however the possibility for preservation of fish traps made from organic material, especially in conditions analogous to the Baltic, should not be ignored.

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Figure 48: Remains of a fish weir at Haväng, Sweden, with hazelwood strips forming a panel (Nilsson et al. 2020:85).

Quarry sites

Though the endurance of lithic artefacts may be called into question, quarries are projected to be highly resistant, and an important element of resource procurement for the archaeological record. Quarry sites may also produce large quantities of diagnostic debris which may be more recognisable to diving archaeologists. Nonetheless, evidence of quarrying may be eroded in high-energy environments, especially over the course of gradual inundation. Rock outcrops are highly visible in remote sensing, and may be identified in shallow environments using low resolution methods such as nautical charts and open access satellite imagery, or mapped in greater detail through sidescan sonar and drop-camera surveys. Diver survey is then required to distinguish whether it is quarried or unquarried rock.

Quarries have been found in coastal environments and in the intertidal zone in Australia, however not below MLWS. Elsewhere, several quarried outcrops were found in Apalachee Bay in Florida, and the focus on rock outcrops in this area has been used as a model of site potential, in which outcrops are deemed a highly prospective formation where additional archaeological material including stone artefacts may then be located (Faught 2004; Faught 2014). In all cases, the preservation of evidence of quarrying relies heavily on a lack of corrosion, and a lack of marine growth that could otherwise obfuscate a quarried surface. In areas where such outcrops can be identified, they remain useful targets to focus submerged landscape archaeology research. Additionally, quarries may be included in predictive, GIS-based models, based on geological maps that depict the rock type used for lithic manufacture by past societies. The importance of understanding regional geomorphology and archaeology is seen in this case as well.

Lithic artefacts and submerged quarries remain archaeological features that are predicted to survive in potentially severe conditions, and currently, lithic artefacts are the feature that has been identified in the subtidal environment in Australia. Further prospection on the continental shelf can take insight primarily from submerged prehistory analyses in Florida, which have prioritised quarry sites, and pursued methods beyond visual inspection to gain further insight to lithic artefacts. These are applicable in the Australian context, and may generate useful results.

7.3.4 Stone features and arrangements

Stone features are considered a durable form of material culture, and likely to withstand the impact of marine transgression. They are also a feature that is well-recorded in the international submerged archaeological record. The success of sonar for identifying anthropogenic stone features was demonstrated at Lake Huron in North America, in the mapping of a hunting drive using scanning sonar which was then ground-truthed by divers (O'Shea et al. 2014). Similar stone features are expected in the submerged Australian record. Stone features are located across coastal environments in Australia, and may point to a highly prospective form of archaeology. In the studies conducted at Murujuga, standing stones, linear stone features, and stone circles were all deemed highly prospective elements of the regional archaeology. No stone features were identified under water, however, a possible stone circle identified in the sidescan sonar data shows some similarity to stone circles found on land. Given the success of remote sensing to identify submerged stone features in North America, a similar approach was used in Murujuga, however, no stone features were confirmed from the sidescan sonar survey.

As another example, the Carmel Coast of Israel demonstrates a variety of stone features in submerged settlements, and various depths at which they have preserved. At the submerged village of Atlit-Yam, stone foundations of buildings are abundant, in addition to a megalithic ritual structure (Fig. 49). These features are located at around −15 m, while later Pottery Neolithic sites include similar stone structures in shallower depths of −5 m. At Tel Hreiz, a stone wall was located, measuring >100 m long at −3 m, which would have acted as a coastal defence against rising sea level, as sea levels encroached by up to 4 mm per year with an increased impact on the inhabitants of the village (Galili et al. 2019b). This stone wall structure bears some similarity to stone fish traps in northern Australia, however, they are functionally different structures in the intent behind their creation, and in the size of the boulders used for construction. The coastal defence at Tel Hreiz was constructed from large (up to 1 m) boulders with the intention of shielding the village, and withstanding destructive winter storms, while stone fish traps are built to withstand the inundation and retreat of tides.

This image has been removed due to copyright restriction.

Figure 49: The megalithic structure at Atlit-Yam, shown a) following excavation, and b) reconstructing the potential role of the structure (Galili et al. 2020:455).

7.4 An Australian Model for submerged landscape archaeology

A model or methodology for identification of submerged archaeological potential, probability and research priority areas can be useful in Australia, as it has been in other parts of the world. However, it is not without its challenges. Other national models have originated from small countries, which make up comparatively small regions on a continental scale. Therefore, it is worth considering that a national model to consider the practice of submerged archaeology, as a discipline, would be comparable to a larger European/Mediterranean model, or a North American model, which would consider the many different landscapes, seas and oceans, and cultural and natural variability. This has previously been attempted in the re-evaluation of the Danish Model outlined by Benjamin (2010b). Thus, describing a national mode of practice in Australia it is more useful to consider a continental-scale model, with regionally distinct practices and environmental considerations in each of the broader regions. Nonetheless, it is still useful to try to solve the problems associated with data gaps (in the archaeological record) and heritage management considerations (including jurisdictional and practical elements required by practitioners) in submerged landscape archaeology. Further refinement or regional adaptation is necessary, and this proposed mode of practice here is not meant to suggest that a simplified, general model is itself sufficient. However, it may be a useful starting point.

Given the gaps in submerged landscape archaeology in Australia, this broad model represents a starting point, which is a culmination of the process undertaken in Murujuga, alongside a review of existing modes of practice to derive a process specific to the Australian context. It is stressed that the model or methodology can be considered first at a high level, in theoretical and practical terms, before then being further refined to consider regional (or local) natural and cultural variables including landscape characteristics and cultural adaptations or preferences.

7.4.1 Phase 1: Preliminary reconnaissance and feasibility assessment

In the first phase of the model, the overall feasibility for submerged landscape research should be assessed, and the overall likelihood that material has preserved should be established. This is, essentially, to address whether there is any archaeology that has the possibility to preserve, and if it has, how to best approach surveying the area. At this stage, existing sea level and geological data should be used to assess the area's overall likelihood for material to preserve offshore, and the depth at which it may preserve. Globally, a substantial part of submerged landscape archaeology is located in −10 m or shallower, however this may not reflect archaeological preservation but it may indicate logistical considerations for locating sites. In areas with the capacity for the preservation of organic material, including Denmark and Israel, a combination of protective sedimentation and low tidal energy is observed. If preservation potential is deemed likely and areas can be targeted based on depth-time ratio, the researcher should proceed to the second phase. In areas where extensive erosion is likely to have taken place, or to the contrary, extreme sedimentation that prevents access to any preserved material, the likelihood of identifying material is reduced.

This phase has parallels with several international models, including the use of aerial imagery proposed by Galili et al. (2019b) and the synthesis of existing geological data proposed by Gagliano et al. (1982). The latter places particular emphasis on establishing whether the geological units deemed prospective align with known times of human habitation in the region. This phase most closely aligns with Benjamin (2010b) and the re-evaluation of the Danish Model, which emphasises the importance of understanding a region and acquiring data before research is carried out. The key distinction between the Danish Model and this Australian Model is that a preliminary phase is implemented first to evaluate the feasibility of material preserving at all, before continuing to detailed desk-based research. In many cases, these might be combined. This is seen in the international examples, as this phase is often not explicitly outlined in these examples. However, I have chosen to make this a separate phase to emphasise the importance of early feasibility assessments that are well-rounded and informed before additional research is conducted. This allows for time and resources to be dedicated towards highly prospective regions, and issues of minimal preservation or searching for material in an unsuitable area may be countered early in the survey process.

7.4.2 Phase 2: Detailed desk-based study

At the second stage of the model, an investigation of the prospective region should be conducted, including the collection of existing data such as nautical charts, satellite imagery, aerial imagery, and industry-collected geophysical and geotechnical datasets. Areas with relict landforms that are geologically within the time span of human occupation, having been identified in phase 1, should be maintained as prospective regions (a criterion based on Gagliano et al. 1982). The onshore archaeological record should be characterised, to provide an analogy for material offshore (Veth et al. 2020). This allows for topographic and bathymetric features to be mapped which may be conducive to archaeological material. This includes features associated with habitation sites, as well as protective features that may allow for preservation.

Following preliminary ideas of regional archaeology and site preservation, existing map data and geological data should be collected and evaluated for potential. This can include satellite imagery, as well as nautical charts and geological maps. Sentinel-2a and -2b currently provide high-resolution and open access data which may be used to delineate shallow features, while nautical charts may demonstrate features at greater depths which are of importance to archaeologists. The geomorphology of an area should be considered throughout this process, and consultation and discussion with experts in a region’s geomorphology should be sought out.

While many of the international frameworks examined would commence a project with this step, by allowing a preliminary desk-based study phase first, regions may be prioritised more easily based on their status as highly or less prospective. This allows for a greater sense of preservation potential before in-depth research and regional assessments are carried out, and provides a better understanding of known material to then search for unknown material.

7.4.3 Phase 3: Meetings and permissions

The third phase of this Australian Model indicates the importance of community engagement. Local divers and fishers can offer insight to an area that researchers would not necessarily have, and there is the potential for chance finds. This is also seen in Fischer's (1993; 1995a) Danish Model, and in the Israeli Model (Galili et al. 2019b), and re-emphasised by Benjamin (2010b). Although in some contexts the application of ethnography may be inappropriate, there is the potential for ethnography to assist in identifying elements of the archaeological record that could preserve under water. Meetings should be carried out with the community, including Traditional Owners, sports divers and fishers, and marine industry in both formal and informal settings. Issues of cultural safety for the proposed work should also be dealt with at this time, in addition to legislative matters such as permits. These aspects are standard practice for Australian archaeology (and archaeology globally) and are no exception here.

There has been extensive work investigating community-based approaches in Australian Indigenous archaeology (Clarke 2002; Greer et al. 2002; Greer 2014; Mitchell et al. 2013; Ross et al. 2013). Greer et al. (2002) observe a transition in Australian archaeology from 'getting consent' to carry out archaeological work, to consultation and increased involvement of Indigenous communities. This is reflected in their survey and excavation of midden sites in Cape York. Buhrich et al. (2019) sets out a 'working alongside' approach, in which communities and researchers identify mutually beneficial projects. Buhrich et al. (2019) also note that Indigenous protocols were incorporated to the fieldwork, including smoking ceremonies and land management practices including burning. These examples illustrate a shift in Australian Indigenous archaeology that includes Indigenous people in the process of archaeology rather than simply acquiring permission for research. This level of community engagement should also be carried over to submerged landscape archaeology, and is reinforced by this phase of this Australian Model.

7.4.4 Phase 4: Develop preliminary predictive criteria

In the same way that the desk-based study phase is separated into two phases, predictive modelling is addressed in two phases here as well. Firstly, predictive criteria should be developed based on the outcomes of the detailed desk-based study outlined in Phase 2, including geological material, cultural trends in site patterns on land, and known resource foci in the coastal landscape. Once these preliminary criteria have been established, areas may be selected for remote sensing to reflect these prioritised elements based on preliminary predictive criteria. The preliminary phase may require GIS-based predictive modelling, or instead may be conducted similarly to the topographic fishing site model (Fischer 1993; 1995) where suitable topographic features are identified using nautical charts based on the terrestrial record. Other preliminary predictive criteria may include substrate-dependent or depth-dependent preservation potential, as evidenced by the Israeli Model in the targeting of clay palaeosol at specific locations and depths (Galili et al. 2019b). The predictive criteria here should be developed to determine areas suitable for remote sensing, with additional predictive modelling to follow prior to direct observation.

At a general level, areas that are more sheltered, particularly by barrier features, as well as low energy environments, and areas with a balance of sedimentation (enough to protect material but not prohibit site discovery, with known erosion rates) are all factors to consider at this phase. This allows for the identification of areas that are conducive to occupation and preservation, and areas that are less likely. A 'traffic light' system can be used here to establish preservation potential as low, medium, or high.

7.4.5 Phase 5: Select areas for remote sensing

Target areas for additional remote sensing can be established at this phase. Priority areas within the study region for further investigation may be selected based on community engagement, prospective features visible in known mapping, and topographic/bathymetric features conducive to site preservation characteristics at a general level, in addition to logistically feasible and accessible points for fieldwork. The size of a study area is likely to vary, however smaller study areas will allow for time and effort to produce high-resolution data, while a larger area will generate less detailed information but may yield greater results for reconnaissance, especially in areas where little previous mapping has been undertaken. For smaller areas, the micro-regional approach suggested by O'Shea (2021) may be used to deliver highly detailed results of a smaller area, and involves a focus on sampling landscapes to compare with terrestrial occurrences.

This phase aligns closely with a similar phase in the Danish Model, both in the Fischer (1993) iteration and in Benjamin (2010b). In the Danish Model, locations are plotted according to topographic predictive criteria, and following the analysis of maps and aerial imagery. Locations are then selected based on preliminary criteria for preservation. While the development of predictive criteria on a preliminary basis is generally assumed for most of the other frameworks, it is explicitly stated here to evaluate the ways in which targets have been selected for further investigation.

7.4.6 Phase 6: Remote sensing

With priority areas selected, remote sensing procedures can be undertaken. Depending on the budget of any given project, this phase may vary. As a general principle, the highest resolution data should be sought out, and options may include LiDAR, sidescan sonar, sub-bottom profiler, multibeam, drone survey, ROV, or drop-camera. In some cases, this phase be omitted in favour of direct testing by divers, particularly in cases where extensive remote sensing has already taken place or the investigation has been prompted by chance finds. Additionally, more cost-effective measures may be undertaken to map an area, such as an echosounder on a small vessel.

Each of the frameworks analysed for this thesis describes some form of remote sensing, ranging from the use of boat echosounders (Fischer 1995b) through to 3D modelling of submerged environments (Westley et al. 2011). The emerging lesson from the evaluation of these modes of practice is that remote sensing should involve the use of an instrument of sufficient resolution for the scale of the area to be surveyed, and the scale of the possible archaeological material to be recorded. Instruments and systems should be selected in accordance with the understanding of sedimentation and stratigraphy for the area based on the detailed desk-based study phase. In some areas, sub-bottom profiler data may yield useful insight to the landscape evolution of an area, however, in others with sparse sedimentation, this may not be as useful compared to sidescan sonar or multibeam bathymetry.

7.4.7 Phase 7: Predictive modelling

Based on the selection of criteria given general principles of preservation, alongside additional remote sensing, predictive modelling may be used to identify high potential areas as opposed to areas that are of low potential for the preservation of submerged archaeological material. While GIS-based approaches and agent-based modelling is common for examples of this phase, this is not always necessary, and similar outcomes can be achieved through an understanding of topographic features associated with known sites that is then compared against nautical charts or other bathymetric data. Landforms and features of interest are then selected based on the predictive modelling.

This phase allows for a culmination of desk-based study and additional remote sensing to inform survey targets. In some cases, a predictive modelling phase is included either prior to remote sensing or after, here I have proposed that predictive criteria should be set out to provide basic parameters for prioritisation of locations, followed by additional predictive modelling and criteria with the insight and data gained from the remote sensing phase.

7.4.8 Phase 8: Direct observation

At the time of this thesis, diving and snorkelling remain the optimal ways to confirm the presence of archaeological material at a prospective area. However, the use of ROV's, coring, and in some cases, grab sampling to test areas may be applicable in areas of substantial depth where diving is logistically complicated or not feasible. Diver survey strategy is likely to vary depending on the area, but linear searches, circular searches, and jackstay search patterns are all commonly used methods to map the seabed with divers. Additionally, a GPS may be attached to a float carried by a diver to map the coverage of the survey. This can also then be coordinated with cameras to provide a method for georeferencing photographs taken during the survey. Alternatively, USBL acoustic locational systems may be mounted on an ROV to allow for spatial control at depth. Bottom conditions may dictate whether divers or coring should be used, and may be reinforced by sub-bottom profilers.

This phase is included in all of the modes of practice assessed, but may vary depending on the region. The Israeli Model (Galili et al. 2019b) advocates for regular survey of areas with divers and snorkellers due to varied rates of exposure along the Carmel Coast. In a different scenario, Gagliano et al. (1982) and Faught (2014) place greater emphasis on the collection of geological samples and cores to test for archaeological remains. In Australia, the differences in direct observation procedure are also likely to vary based on the area, as well as the project's aims and objectives. Additionally, logistical considerations may come into the decision of including divers, or testing the seabed through coring and grab sampling. Given the variation in modes of practice globally, it is likely that this variation will be reflected in submerged landscape archaeology across the Australian continent, but knowledge can be drawn from international practice.

7.4.9 Phase 9: Post-fieldwork

At the post-fieldwork phase, many aspects will be standard to terrestrial and underwater archaeological projects, as well as legislative requirements for the reporting and processing of material. However, there are some key points to emphasise that are specific to submerged landscapes. The first is the potential difficulty in establishing a date of any material encountered, particularly with stone artefacts and features. In many cases, it may be possible to date organic material found in association with material culture, or with the landform being sampled. Limiting dates based on inundation and the likelihood of in situ material may be necessary if typological or absolute dating cannot be carried out. Additionally, it is important that any material located is integrated into the broader archaeological record for the region, to better understand aspects of adaptation to the marine environment as well as climate change. This is based largely on the Israeli Model, which emphasises assessing sites in comparison to other known submerged sites (or terrestrial sites), in addition to evaluating the significance of the results with respect to climate change adaptation and marine adaptation in the archaeological record. Galili et al. (2019b) also note the importance of cultural resource management for submerged landscapes, and that post-fieldwork procedures should address the long-term management of any material or site identified through survey procedure.

This Australian Model, as presented here, is intended to provide a baseline framework for work on the Australian continental shelf. It is a model based on international best practice and adapted based on the results of fieldwork in northwestern Australia. However, it is presented with the belief that ongoing surveys and fieldwork will inform future iterations and adaptations of this framework, and provide correction and reinforcement to the procedures addressed here. Moreover, regional models are recommended to better address the substantial variation in coastal environments in Australia. To improve, it is important to firstly have a baseline to work from, and this is the aim of this study. This suggests that there is no need to 'reinvent the wheel', but that successful methodologies may be considered as a template and adjusted to suit the region. It is worthwhile noting that this is also largely a research model. While many types of projects will undertake work on submerged landscape archaeology, including marine industry, they will not go through each of the steps as part of the proposed Australian Model, as these projects have different aims to accomplish. While the Australian Model as written here describes a start-to-finish 'academic style' research project, industry and smaller scale projects may only adhere to some or part of the steps proposed here. Nonetheless, for research projects that are targeted specifically to the prospection of submerged landscape archaeology, the Australian Model set out by this study may contribute useful guidelines.

7.5 Rationale of the model and comparison

This section compares the outlined Australian Model with the two central models it has been based upon, the Danish Model and the Israeli Model. Additional models are referred to depending on the issue discussed and its relevance (see Appendix 3). By design, an Australian Model must place greater emphasis on practice than developing predictive criteria, which still requires further testing in the Australian context and is likely to vary by region, and this serves as a key difference between an Australian Model and other modes of practice. Here, the context of the model is reviewed, alongside factors that may impact the use of an Australian Model including financial constraints and data availability. The distinctions between an Australian Model and its counterparts are re-emphasised for clarity.

An important aspect to characterise is the context of models. Who is the model for? In the case of the Danish Model according to Fischer (1995), this provided a method for locating Mesolithic sites in a way that was entirely novel, and represented a major methodological leap for Danish submerged prehistory. This was then built upon by Benjamin (2010b) to demonstrate the applicability of the Danish mode of practice elsewhere in the world, and through this re-evaluation widened the methodological insight gained by the Danish Model to the broader research community. The Israeli Model, having been published at a later date than the Danish Model, provides greater focus on reflection on lessons learned and best practice established over several decades. In any case, both examples are relevant to both academic researchers, as well as cultural heritage management practitioners, as the frameworks can also be applied in scenarios where the potential for submerged landscape archaeology must be factored into marine development. This Australian Model is designed with an 'academic style' research project in mind, but principles may be applicable to other projects as well.

Consideration should be given to what should constitute the first part of the process in an area for submerged landscape archaeology. This issue is entirely dependent on the context, and likely to vary case by case. However, it is a part of the models studied here where a level of discrepancy emerges. Some models suggest that sea-level studies are the first place to start, others suggest the regional geology and sea-level studies guide the operation, others suggest starting with the archaeological material onshore. In some cases, these aspects may occur at the same time as part of a regional assessment of an area for submerged landscape potential, however, broadly speaking, the stance presented by this Australian Model is that suitable geological conditions for preservation, and a sound understanding of sea level, should underpin all survey operations. This is to ensure that probability of site preservation is predicted with all available information. There may also be variation in this first step depending on whether the area has had no previously demonstrated offshore potential, or whether there are intertidal sites and chance finds to address. In these areas, some knowledge can already be gained about the potential for material offshore based on what has preserved as a chance find, or alternatively, in the intertidal zone. These types of finds may prompt further investigative work offshore, and can follow the procedure of an extensive desktop study in accordance with this Australian Model. However, it is important to note that some areas have also already had archaeological survey work carried out, and may be starting based on previous survey work. This would be the case in an area such as the Cootamundra Shoals, researched by Flemming et al. (1982). This kind of research provides a detailed level of information to plan additional surveys, and may indicate areas that are less prospective than others that would not otherwise necessarily be indicated by desktop research alone. While a first step of establishing the geological background and sea-level history of an area is provided for this Australian Model, it is important to acknowledge the varied nature of archaeological research and the variety of situations that could prompt an archaeological investigation.

This Australian Model has included a remote sensing phase, however, in some cases, this may not be deemed necessary. Indeed, the models it has been based upon have generally found great success without remote sensing technologies. The Danish Model relies upon a combination of nautical chart bathymetry, while the Israeli Model prioritises regular surveys to monitor for exposures of submerged archaeology. As noted by Benjamin (2010a), there is a debate surrounding the effectiveness of remote sensing for submerged landscape archaeology, which persists in the present. In some cases, it may not be necessary to acquire further remote sensing datasets, as the data is already provided through marine industry partners or other previous survey efforts. This data should be prioritised where it is available, however additional data should be sought out as necessary. Remote sensing may provide a considerable level of detail and refinement to large study areas, and may be especially useful in these cases. At the same time, remote sensing may be deemed unnecessary if the scale of the area may be mapped and photographed readily by divers. The scale and conditions of the survey area guide the necessity for remote sensing, as well as the consideration of any previous data that has been collected.

The issue of budget may also influence the need for remote sensing data as distinct from using divers for direct observation. In some cases, it may be required to alter the survey design to fit the budget of a project, and in these situation more cost-effective options such as diver survey or the use of a vessel's echosounder may provide useful data (per Benjamin 2010a). Additionally, the Israeli Model has seen considerable success with the use of water-jet probes to identify bottom types consistent with the preservation of submerged landscape archaeology, while the model set out by Faught (2014) recommends coring and sediment sampling to effectively test an area. Depending on the area, additional remote sensing may be able to provide sufficient information to establish target areas for diver survey, and thus additional remote sensing may provide little new information. These areas are, however, likely to be a minority of locations across Australia, and in many cases, remote sensing may be used to map high potential areas and derive targets. It should be noted that suitable data resolution is essential for this phase, and thus familiarity with remote sensing techniques is essential. In summary, a project's budget can impact the decision to include a remote sensing phase, however cost-effective alternatives may be considered, in addition to greater reliance on past survey data where possible.

Land use models and predictive modelling are also considered as part of the proposed Australian Model. Some of the modes of practice analysed do not include a predictive modelling component, or may only rely on a few categories of predictive criteria. The Danish Model includes a topographic site location model, and thus shows greater reliance on probability modelling. At the core of predictive modelling is the issue of data quality and resolution. Higher resolution data will yield greater and more specific insight and areas for testing than coarser resolution data, and may also provide a useful way to refine search efforts. Additionally, it must be acknowledged that predictive models may generate testable hypotheses and provide ways to visualise patterning in material culture, but the testing of the models is essential to this process. While there are many predictive models for submerged landscapes in different parts of the world, there has been less focus on examining these models and verifying the hypotheses generated. In many cases, it may be costly and time-consuming to verify models with divers, and subsequently the effectiveness of many models is somewhat limited. As important as predictive models may be to generating new information to test, this testing process establishes whether the model is able to predict high potential locations for sites accurately.

Another issue of predicting sites and mapping sites is the boundaries associated with different components of the archaeological record, and their respective scales. In Denmark, hundreds of artefacts are recognised and registered as single, isolated finds, and it is possible that the location of isolated finds will take place in Australia as well. Establishing the boundaries and extent of a site is a crucial part of the archaeological process, and particularly so with submerged landscape archaeology as the nature of the research lends itself to questions surrounding human-environment interactions and landscape approaches. This is discussed by O'Shea (2021) in the recommendation of a 'micro-regional' approach, which follows a similar methodological procedure to that outlined by this Australian Model, but emphasises the importance of mapping a micro-region in a high level of detail to provide greater context to the archaeological material in the landscape. In areas such as Denmark where isolated artefacts may be found over a long period of time, this approach may assist in connecting archaeological material across a broader landscape, and providing more detail to the potential interactions across the landscape in terms of resource procurement.

Many of the international models reviewed lack information on the phases of acquiring permissions to conduct fieldwork, and other ethical and legal precursors to archaeological research. This is not viewed here as a shortcoming of these models, which focus in greater detail on survey procedure for specific regions. However, it is included in this Australian Model, to emphasise the importance of not only acquiring the suitable legislative permissions to conduct research, but also building a relationship with communities and industry partners who may be able to contribute significantly to the proposed research. Similarly, most international modes of practice do not provide data on the post-fieldwork procedure. Indeed, the guidance for post-fieldwork procedure is described simply in Benjamin (2010a) as "standard practice". While it is true that all submerged landscape archaeology research should be carried out to the same standard as its terrestrial counterpart, there are considerations specific to the submerged environment, as well as the processing of that material.

The procedure of dating submerged landscape archaeology is an example of post-fieldwork processing for consideration. This is best illustrated by the two fieldwork expeditions carried out over the course of this PhD: the first as the work conducted at Murujuga, Western Australia, where stone artefacts required dating, and the other at the Carmel Head, Israel, where stone arrangements on a rocky seabed were analysed. In the case of Murujuga, submerged lithic artefacts were not able to be dated through associated organic material, or through dating the marine growth on the artefacts, or typologically, and thus the best estimate of their date is the time at which they were likely to have been submerged. It must be acknowledged that the artefacts could be substantially older than this date, however, the time at which they were submerged serves as a limiting date. To provide an example where knowledge of the regional archaeology is key, the Carmel Head off the coast of Israel involved the analysis of several stone piles which were sampled and reviewed for their rock type and assessed by applying the principles of the Israeli Model. Given that the rock types encompassed several types that were imported to the Carmel Coast area (some potentially from a considerable distance such as Anatolia), in addition to the lack of associated anthropogenic finds, it is likely that these deposits represent more recent (non-prehistoric) ballast piles rather than a submerged, in situ prehistoric feature. This can be assessed due to the presence of numerous shipwrecks including ballast piles on Carmel Coast, and given that there are no other features in Israeli prehistory to suggest that stone mound features were constructed using imported stone. However, this is not to say that all stone features at the Carmel Head are not prehistoric, as only two stone features were tested. In the dating of both of these examples, an understanding of the regional archaeology, and its limits, is crucial to establishing the window of time that these objects may represent. It is for this reason that the early phases of the proposed Australian Model strongly emphasise an understanding of regional geology and archaeology, based on desk-based research and in accordance with community knowledge.

Although an Australian Model provides a baseline mode of practice for surveyors and researchers to draw upon, the model is intended to be built upon with further research and following use in a variety of environments and situations in Australia. It is designed with these variety of examples and cases in mind, but is likely to adapt with ongoing research in Australia. Regional preservation criteria are expected to develop, and these are discussed in the following chapter.

7.6 Australian legislation for submerged landscapes

Having outlined the potential of the proposed Australian Model, it is important to establish what protective measures exist for submerged landscape archaeology. The earlier legislation to protect underwater cultural heritage in Australia was the Historic Shipwrecks Act 1976, which has since been replaced by the Underwater Cultural Heritage Act 2018 (Table 7). The former did not include submerged landscape archaeology, but included all shipwrecks from lowest astronomical tide to the end of the exclusive economic zone or continental shelf. The Underwater Cultural Heritage Act 2018 expanded on this definition of cultural heritage, as well as cultural significance. However, the Underwater Cultural Heritage Act 2018 does not acknowledge Indigenous heritage, or sites submerged by sea-level rise, to the same extent as other historical material. In the Underwater Cultural Heritage Act 2018, shipwrecks and sunken aircraft older than 75 years receive automatic protection, while submerged Indigenous heritage may only be covered by the Act with Ministerial approval. Another Commonwealth act exists for the protection of Indigenous heritage, the Aboriginal and Torres Strait Islander Heritage Protection Act 1984 (or ATSIHP). The ATSIHP Act is intended to provide a ‘failsafe’ for Indigenous heritage in cases where individual state or territory legislation does not adequately protect sites. However, very few protections have been granted through the Act, and its lack of contribution in Australian heritage management is a point of discussion (Winn and Taçon 2016).

This therefore leaves submerged Indigenous archaeology, primarily, to the management of individual States and Territories. Each Australian state has heritage legislation that encompasses the state's coastal waters, defined as a boundary at 3 nm. However, this indicates that for sites located further offshore, protection is not automatically afforded by state legislation nor Commonwealth legislation. Additionally, the process for establishing site protection varies by states, where some states may grant protection automatically, while others must be reviewed for significance (as seen in Western Australia). This creates inconsistency in the management of submerged Indigenous heritage. There is also inconsistency in the approach to seabed development across the nation. Victorian legislation provides an exemption to the creation of a cultural heritage management plan for seabed development. New South Wales, however, views the excavation of land as the same when excavating land beneath State waters. Dredging is included in this definition. From this, it is clear that there is no consistent approach to the protection of submerged Indigenous heritage, and certainly not with consideration to protecting Indigenous heritage threatened by offshore development.

Legislation	**Area**	**Description**
Aboriginal Heritage Act 1988	South Australia	Sites protected following registration, includes South Australian coastal waters
Aboriginal Heritage Act 2006; Heritage Act 1994	Victoria	Seabed development "exempt" from requiring a cultural heritage management plan. Includes Victorian coastal waters.

Heritage Act 1977; National Parks and Wildlife Amendment (Aboriginal Ownership) Act 1996	New South Wales	Indigenous artefacts automatically protected, includes State waters.
Aboriginal Cultural Heritage Act 2003; Torres Strait Islander Cultural Heritage Act 2003	Queensland	Indigenous artefacts automatically protected, includes Queensland coastal waters
Aboriginal Heritage Act 1972	Western Australia	Significance evaluated by Minister of Indigenous Affairs to grant protection, includes Western Australian coastal waters
Aboriginal Heritage Act 1975	Tasmania	Minister may declare "protected site" if "relics" are present, includes Tasmanian coastal waters
Aboriginal Sacred Sites Act 1989; Heritage Conservation Act 1991	Northern Territory	Sites automatically protected, includes Northern Territory coastal waters
Aboriginal and Torres Strait Islander Heritage Protection Act 1984	Commonwealth	Application made to the Minister to protect "significant Aboriginal area", encompasses Australian waters

Underwater Cultural Heritage Act 2018	Commonwealth	Shipwrecks and sunken aircraft automatically protected, other articles may be protected with Minister's approval

Table 7: A review of key points from heritage legislation in each State and Territory of Australia, in addition to relevant Commonwealth legislation.

Along with the development of a baseline mode of practice for Australian submerged landscapes, it is clear that the current legislation has a number of gaps in the protection of submerged Indigenous heritage. Automatic protection should be granted to these sites under the Underwater Cultural Heritage Act 2018, in the same way that automatic protection has been granted for historic material and shipwrecks.

7.7 Conclusion

This chapter has reviewed the importance of a broad, continental-scale Australian Model based on the research of the history of submerged landscape archaeology. The model and the reasoning behind its criteria are laid out, and then discussed more thoroughly in terms of distinctions between an Australian Model and its international counterparts. Crucially, an Australian Model requires practical use to test and refine the criteria laid out, and to determine their applicability in the Australian context compared to international examples. There is also the issue of legislative protection of submerged landscape archaeology in Australia, which is reviewed in this chapter. Further refinement into regionally specific considerations is necessary, owing to the scale of the national Australian Model, which is a continental-scale question; thus a more detailed breakdown of regional variation and variables is necessary and this will be discussed in more detail in the following chapter.

8.0 IMPLEMENTATION OF AN AUSTRALIAN MODEL

8.1 Introduction

It is possible to generate a broad guideline, a model or mode of practice that is specific to Australian archaeology with consideration for international parallels for submerged landscape archaeology. This may be useful as a starting point, which would then be further refined, adapting the methodological approaches to locating sites with local variables and conditions that would impact site occupation patterns, in addition to site survival variables (particularly the impact of sea-level changes and transgression) and submerged site visibility (and thus the likelihood of researchers locating archaeological material).

With the criteria for the stepped Australian Model outlined in the previous chapter, there are additional factors to consider in its implementation to be successful. Additionally, owing to the continental scale of the national 'problem' (of the gap in knowledge), the potential for regional-scale iterations of this Australian Model is introduced with summary considerations by region highlighted. Finally, this chapter discusses ways in which areas off the Australian coast may be deemed prospective, with examples of areas of high potential for future survey. These are factors that will affect applications of the proposed Australian Model, and are important to acknowledge in moving forward.

8.2 Reviewing the history of submerged landscape archaeology in Australia

Australian submerged landscape archaeology has been largely characterised by a lack of finds. This is due a relative lack of research, despite some notable exceptions (Dortch 2002; Flemming 1982; Nutley et al. 2016). It is also likely that the lack of results from the work that was carried out dissuaded further attempts or created pessimism about preservation potential. The lack of finds historically is, however, not evidence that there is nothing to find. Similarly, the lack of finds in areas that have been researched may indicate areas where factors of tide, currents, sedimentation, and erosion were not sufficient to promote preservation of material. Other areas that have not yielded subtidal finds have instead provided intertidal material, which may be a promising indication of material preserved further offshore (Lewczak and Wilby 2010). Following the discovery of subtidal finds in Murujuga, it is also predicted that there will be greater interest in submerged landscapes across the continent. However, it is this lack of finds that has contributed to a research bias that assumes that material cannot or does not preserve in Australia.

Australian archaeology has also seen 'siloed' approaches in both maritime and Indigenous archaeology, which has created a lack of collaboration between these two fields which relate directly to submerged landscape archaeology. Underwater archaeology has been viewed in Australia as the archaeology of ships, historic structures, and sunken aircraft, and has tended to ignore Indigenous perspectives and communities. Indigenous archaeology has also been viewed as 'terrestrial archaeology', and in some cases does not adequately address past sea level and coastline configurations. The lack of interaction between these two sub-disciplines has enabled the lack of research of submerged landscapes in Australia.

Despite the lack of research and lack of finds associated with submerged landscapes in Australia, the field has the potential to provide significant information on a variety of major research questions in Australian Indigenous archaeology (and maritime archaeology). This includes the peopling of Sahul, marine resource use and adaptation, as well as mobility and activity across landscapes (onshore and offshore). For the settlement of Sahul, it is crucial to view the landmass inclusive of now-submerged environments, as these are the areas that were first inhabited. Coastal archaeology recognises the importance of marine resources to Indigenous Australian communities; however, it does not always recognise the changes in coastal environments from the late Pleistocene to the present day. To address the history of marine resource use in Indigenous archaeology, submerged landscapes must also be researched. Additionally, there are questions surrounding mobility and landscape use, especially in coastal regions, and these must take into consideration submerged environments to view the entire past landscape. Australian submerged landscape archaeology is a field with high potential, but limited work. Through discussions of how to optimise survey strategy, this thesis contributes to the question of locating further sites on the continental shelf of Australia.

8.3 The role of remote sensing in submerged landscape archaeology

From international examples, there is some insight to be drawn on the role of remote sensing in submerged landscape archaeology. The issue of the effectiveness of remote sensing persists as a debate within the sub-discipline, with some areas choosing to focus on direct testing by divers, where others prioritise assessing the area through remote sensing. While diving remains the primary mechanism for directly observing archaeological material on the seabed, remote sensing may allow for detail about the survey area, and the landscape, that cannot otherwise be obtained (see Bailey and Cawthra in press).

At the centre of this, it is crucial to select technology suitable for the aims of the project. A sub-bottom profiler may be critical to understanding the landscape evolution of an area subject to substantial sedimentation, however it may be less efficient in mapping areas where the archaeological material is expected to be exposed at the surface of the seabed (Bailey et al. 2020a). In these cases, a method for mapping the surface of the seabed contributes more useful information, such as sidescan sonar or multibeam sonar. In both cases, the important aspect to address is what archaeological features are expected to preserve, and what resolution is necessary to capture these features (Galanidou et al. 2020).

One method of dealing with this issue was demonstrated in the work at Murujuga. This research implemented a distinction between 'hard rock' contexts (including rock art, quarry sites, and stone structures on rocky surfaces), and 'soft rock' contexts (midden sites and artefact scatters in sand). In this case, it is argued that the assumption of 'like for like' will persevere in hard rock contexts, while soft rock contexts are dependent on sedimentary processes that have been subject to change over time (Veth et al. 2020). In areas where exposed rocky elements are expected to preserve, this may also serve as an important distinction.

In the debate of remote sensing for submerged landscapes, the issue of cost versus benefit is key. Proponents of a diver-based, direct testing approach argue that the cost of remote sensing technologies is insurmountable, particularly in comparison to the benefit they perceive to be derived from remote sensing (Galili et al. 2020). On the other hand, those who argue for the integration of remote sensing suggest that the significant cost of the technology contributes beneficial information to the prospection of submerged landscapes (Gaffney et al. 2017; Missiaen et al. 2017). Based on the international examples of remote sensing for submerged landscapes, I argue that the use of remote sensing should be used with consideration, it is neither a panacea nor a substitute for diver-based survey. Remote sensing may operate as a critical way to review a landscape at a broader scale, before selecting targets for inspection by divers. In the case of the work at Murujuga, high-resolution remote sensing was prioritised, as it was necessary to refine the study area into discrete, testable locations.

However, there may still be areas where remote sensing operations are less necessary. In the case of the Carmel Coast of Israel, given the infrequent nature of exposure of archaeological material, direct observation with snorkellers and divers has served as an effective mechanism for survey. This is also due to the preservation conditions of the material, which are generally shallow (less than −5 m), close to shore, and in some cases, visible from shore. In other areas, existing data may already exist and provide sufficient data for the selection of diving targets. While the data may not have been collected for archaeological purposes, all remote sensing data of an area may contribute to survey strategy.

8.4 Regional-scale models to reinforce an Australian Model

8.4.1 Overview

The focus of this project is a continent-scale mode of practice that focuses largely on methodology, without much focus on specific predictive criteria in environments across Australia. Because of this, it is expected that regionally specific criteria could emerge over time to guide research efforts in specific regions. This would more closely replicate national modes of practice such as the Israeli Model and the Danish Model, which have established local preservation criteria for the region of study. Regional boundaries could be selected based on existing state and territory boundaries, or based on specific seas across the continent. It would also be possible to distinguish regional models from the existing marine bioregion classification system used in Australia (Table 8; Fig 50). The marine bioregion classification system is used to discuss some preliminary criteria that should be factored into regional models for the offshore environments of Australia. Although the distinctions made in the marine bioregion system contribute largely to efforts in conservation and biodiversity, they are still relevant as they describe the different environments across the continent. These are reviewed here to a preliminary extent, and detailed studies should eventually be produced on the submerged landscape potential of these marine bioregions.

	Tidal range	**Average wave height**
Northwest	1.8–10.1 m	< 1 m
North	1.5–5.5 m	0.44 m
Coral Sea	3–8 m	0.7–1.2 m
Temperate East	2 m	1.5–2 m
Southeast	1.1–1.3 m	1–1.6 m
Southwest	0.5–2.6 m	< 1 m

Table 8: Tidal ranges and average wave height for the marine bioregions of Australia (Short 2020).

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Figure 50: Australian's marine bioregions past the extent of state and territory waters (Water Quality Australia 2019).

8.4.2 North

In the northern region, mainly encompassing the Northern Territory, several different coastlines are encountered. To the west, waves are low to moderate, with meso to mega tides in a tropical monsoon climate. Rivers flow to the coast, and deliver substantial sediment offshore. In some parts of the Northern Territory, up to 20 m of fluvial sediment deposition has occurred (Chappell 1993). Tide-dominated beaches with wide tidal flats are prevalent, as well as mangroves, estuaries and river mouths. To the north, meso to macro tides are also encountered, with generally low wave energy. Further east in the North region, the Gulf of Carpentaria forms a semi-enclosed sea with a tropical monsoonal climate (Harris et al. 2008). This area is meso-tidal, with generally low waves. Mangroves and tidal flats are found across the Gulf of Carpentaria. The North marine bioregion is therefore mainly characterised by significant tides, and comparatively minimal wave action, with significant output of terrigenous sediment from river systems. The Northern Territory is reviewed as a case study for a regional approach to submerged landscapes by McCarthy et al. (2021), where several islands across the territory were emphasised for their potential significance in submerged landscape archaeology.

8.4.3 Coral Sea

The Coral Sea marine bioregion is characterised by a humid tropical climate, with onshore trade winds, and the protective barrier of the Great Barrier Reef. Several large rivers and streams flow to the coastline, creating fluvial delta deposits of terrigenous sediment. Sediment transport in this area tends towards the North. Wave energy in the Coral Sea is low to moderate, and the tidal range spans meso-tidal to mega-tidal. The Great Barrier Reef, as well as Fraser Island, prevents large swell from reaching the coast of the Australian mainland, thus creating a low energy coastal environment. The coastline is mostly tide-dominated.

There is also considerable debate in this area about the timing of sea-level change in the mid to late Holocene. Hopley (1983) write that sea level was 2 m higher than present at 6 ka, with the Great Barrier Reef still at a formative stage, with some reefs still forming. According to Hopley (1983), this created a higher energy coastline at this time, due to the reef's formation. Higher energy coastal features are associated with the period of 6 ka to 3 ka. Additionally, a sea-level fall is known in the late Holocene, as Lewis et al. (2015) suggest that sea level dropped rapidly by 1 m, between 1.2 and 0.8 ka. The Coral Sea marine bioregion remains highly prospective for submerged landscapes as a low energy coastline, with substantial protection of the coastline afforded by the Great Barrier Reef.

8.4.4 Temperate East

The Temperate East region has a sub-tropical to humid temperate climate, and is a relatively uniform coastline. It is micro-tidal, with a southerly swell. Sediment transport travels north, with small rivers and estuaries supplying limited sedimentation to the coast. Sediment cover across the Temperate East shelf is thin in part of this region, with the exception of drowned coastal barriers which have allowed the accumulation of sediment (Kinsela et al. 2017). This is partly due to the high wave energy associated with this coastline (Ferland and Roy 1997). There is an exception to this, with a substantial amount of sediment drifting north along the coast of northern NSW and southern Queensland (Kinsela et al. 2017). The Temperate East represents a more exposed coastline compared to the other marine bioregions; however, this may facilitate discovery of archaeological material. Additionally, the presence of coastal barriers offshore may allow for a protective environment for the preservation of archaeological material.

8.4.5 Southeast

The Southeast marine region includes Tasmania, as well as the waters adjacent to the state waters of South Australia and Victoria. The west coast of Tasmania is highly exposed to Southern Ocean westerly waves and winds (Short 2020). Few rivers reach the wave-dominated coastline in the west. This region is microtidal, with moderate wave energy. The Tasmanian coastline is mostly associated with gently sloped, rocky embayments. Lewczak and Wilby (2010) researched the potential for subtidal quarried material in Tasmania, and noted that sedimentation prevented the identification of material. This indicates that material is likely to preserve off the Tasmanian coast, however it may only be identified through excavation or other seabed sampling methods.

The Victorian and South Australian coastlines in this region represent higher energy coastlines compared to Tasmania. Parts of the Victorian coastline are similar to Tasmania, with enclosed bays in a low energy environment (Holdgate et al. 2001), however the coastline becomes higher energy moving towards South Australia (Gostin et al. 1984). This coast is exposed to swell from the southwest, with moderate energy beaches and limited barrier features. Limestone cliffs are found on the western coast, with easterly longshore transport along the coastline. The Southeast region remains at its most prospective in Tasmania, with a series of bays that shows strong similarity to the location of sites in the Baltic Sea. Although Victoria and South Australia have more exposed coasts, there is still the potential for some protected areas that may act as exceptions.

8.4.6 Southwest

The Southwest marine bioregion is a temperate area. This area is micro-tidal, with high southerly swell controlling both onshore and longshore sediment transport. Moderate rivers flow to estuaries along this coastline. The Great Australian Bight is located in the Southwest, and is characterised by steep cliffs, wave-dominated beaches, and rocky platforms (Brocx and Semeniuk 2010). The Bight is likely too exposed to allow for the preservation of archaeological material. This high energy environment continues to the south of Western Australia, which is the highest energy along the Australian coastline. This marine bioregion is exposed, and subject to substantial wave energy, making it a less prospective region compared with other parts of the Australian coastline (James et al. 1994).

8.4.7 Northwest

The Northwest marine bioregion is composed of an arid desert environment in the south, to monsoonal in the north. The tidal range increases northwards from meso to macro, with some areas exceeding 10 m of tide in the north of this region. Tides range from 1.8 m at Exmouth, to 10.1 m at Derby (Short 2020). Despite the high tidal range in the Northwest region, the area has mostly low wave energy (Semeniuk 1996). Sand transport tends towards the northeast, with coastal sediments a combination of terrigenous material and shelf carbonate (Short 2020). The terrigenous material is deposited by usually dry rivers, which flood during cyclone events. These cyclone events involve strong winds and high storm surge, as well as heavy rain and flooding. The Northwest region is also where Murujuga is located, as the location of the first two submerged archaeological sites in Australia. The relative lack of sedimentation in this area facilitated the discovery of lithic artefacts in this region. It is possible that other, similar sites can be located in the Northwest given the relatively uniform conditions across this marine bioregion.

8.5 Adapting and trialling the model: recommendations for future study

There are too many potential areas where submerged archaeological sites may exist on the continental shelf of Australia to list and consider within the scope of this thesis. However, to provide examples of areas where this Australian Model could be applied, several areas are described below, which represent how a first phase of the model could be implemented. Locations are selected to showcase applicability across the various regions described above, with consideration for local variables and next steps required to further the research of submerged landscapes in these areas. These areas are recommended based on gaps in archaeological data, and the potential for these sites to inform major research questions in Australian archaeology.

Examples include Barrow Island and the Montebello Islands, the Lizard Island Group, Port Phillip Bay, and Kangaroo Island and the Lacepede Shelf. These examples have been selected for various reasons. Barrow Island and the Montebello Islands are selected due to a known Pleistocene archaeological record involving coastal resources and proximity to known submerged archaeological sites in Murujuga. The Lizard Island Group provides an example where intensive coastal occupation from the mid-Holocene is recorded. In some areas, prospective submerged features may be visible from other prior research, both archaeological and geomorphological, and this is the case for Port Phillip Bay. Similarly, Port Phillip Bay has sedimentary deposits that are consistent with international examples of strata where archaeological finds are known to preserve. Kangaroo Island and the Lacepede Shelf has been selected as an example of an area with a highly prospective drowned landscape, as well as oral traditions that may address postglacial sea-level rise. The rationale behind the selection of these areas demonstrates the variety of possible features that may signal that an area may be significant for submerged landscape archaeology.

8.5.1 Barrow Island and the Montebello Islands

Barrow Island and the Montebello Islands are a chain of low-lying limestone islands located off the northwestern coast of Australia (Fig. 51). Both Barrow Island and the Montebello Islands have formed critical areas in the discussion of Pleistocene coastal resource use in Australia, as some of the earliest sites across the continent that demonstrate marine adaptation (Veth 1993; Veth et al. 2014; Manne and Veth 2015; Veth et al. 2017). Noala Cave and Hayne's Cave, located on Campbell Island, provided dates between 31,270 and 8330 BP (Veth et al. 2014). As sea level rises, an increase is seen in marine fauna present in the faunal assemblages from these sites (Veth et al. 2017). Given these early dates, it is clear that people were interacting with a coastal landscape that is now underwater. Based on the similarities between this coastal environment and that associated with known archaeological examples from Murujuga, it is feasible that similar archaeological finds may be identified in the waters surrounding Barrow Island and the Montebello Islands.

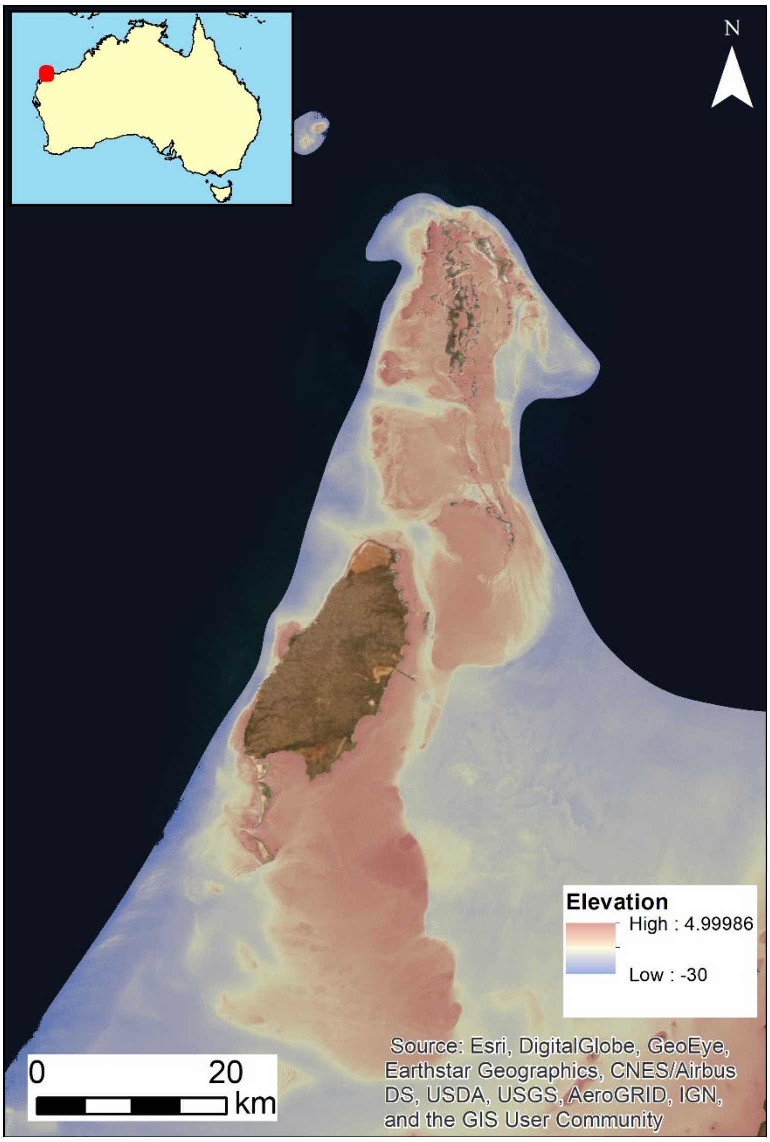

Figure 51: Barrow Island and the Montebello Islands and elevation to −30 m.

Barrow Island and the Montebello Islands were connected until 9 to 8 ka, when they became separated by rising sea level. Preserved coastal features that correspond with MIS 3 (57 to 29 ka), including coastal dunes, lagoons, tidal flats, and estuarine channels, have been located at −70 to −75 m off the coast from these islands (O'Leary et al. 2020). These features indicate the potential for archaeological material contemporary with a known occupation period of the islands to preserve. Additionally, at Noala Cave and Hayne's Cave, non-local stone including igneous rock was found in the lithic assemblages (Manne and Veth 2015). The nearest source for this material is Murujuga (the Dampier Archipelago), approximately 100 km to the east. It is possible that this material may have been obtained from a source that is now submerged. In reviewing existing offshore data, there are submerged depressions similar to the submerged spring of Flying Foam Passage in Murujuga which yielded a single lithic find (Fig. 52). Due to the proximity of this location to an area where this is a known prospective seabed feature, this may also be considered highly prospective for this area.

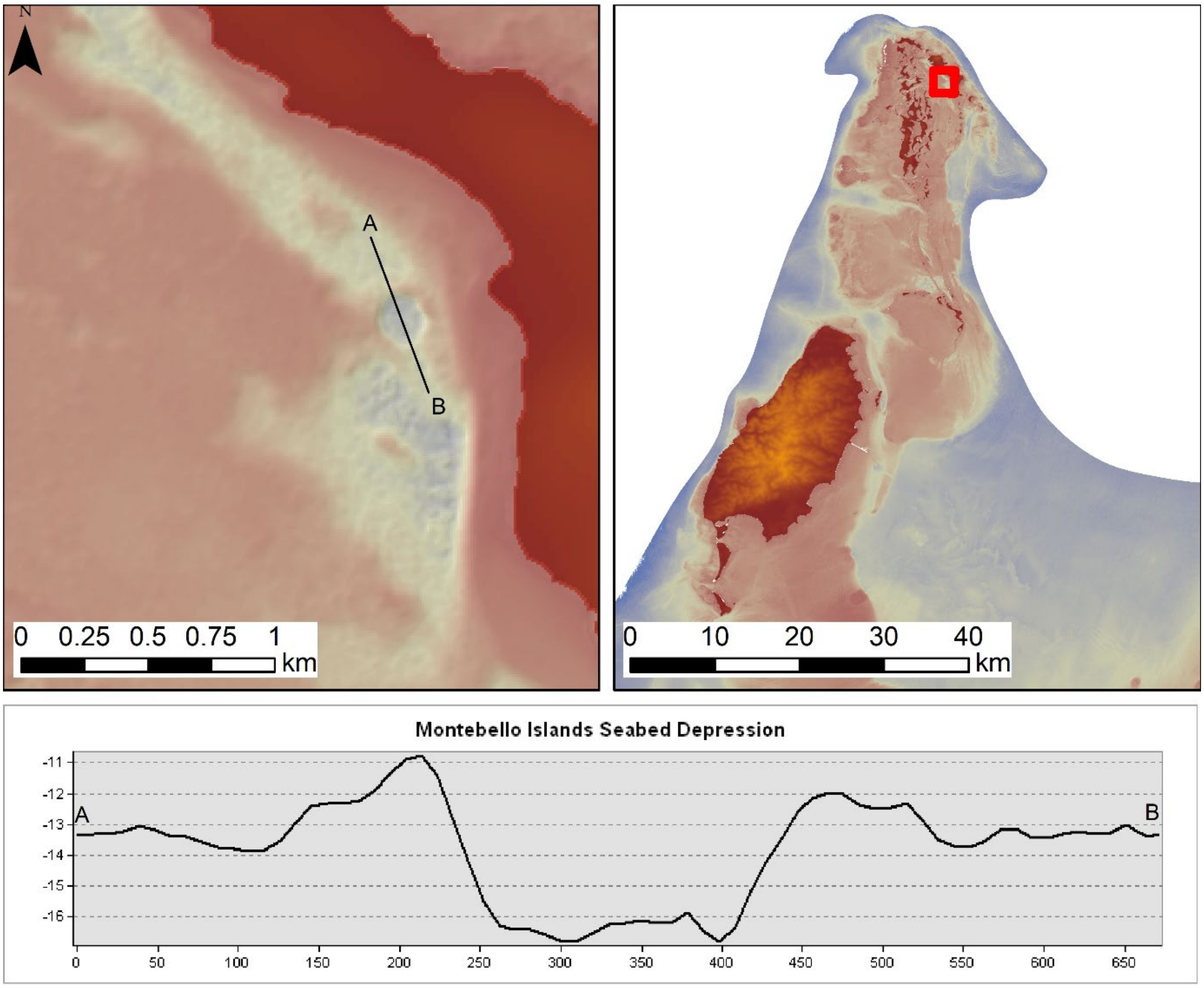

Figure 52: Elevation models of Barrow Island and the Montebello Islands and a seabed depression similar to the feature found in Flying Foam Passage in Murujuga.

Barrow Island and the Montebello Islands are situated near an area that is known to have preserved subtidal Indigenous archaeology, and thus this area should be considered a high potential location, particularly given the preservation of landforms known to correspond with periods of human habitation of the area. Further research in this area would require a comprehensive review of existing maps and geological data, and could be enhanced by additional remote sensing using sidescan sonar, as was conducted in Murujuga.

8.5.2 Lizard Island Group

The Lizard Island Group is a set of islands located off the coast of Queensland amidst the Great Barrier Reef. This granite group separated into a series of islands at around 10 ka, now characterised by grassland environments as well as sand dunes and mangroves (Ulm et al. 2019). The main inference for offshore material at Lizard Island is the prevalence of coastal archaeological material onshore. Thus, the dates from the broader region must be understood. On North Stradbroke Island, occupation dates from Wallen Wallen Creek indicate habitation from 21,800 ± 400 RCYBP (Ulm 2011). Further north in the Torres Strait, the Badu 15 rock shelter was dated to 8,053 ± 42 RCYBP (David et al. 2004). Elsewhere on the eastern coast, Nara Inlet 1 is occupied from 6,700 ± 60 RCYBP (Barker 2004). Thus, habitation of the northeastern coastal region can be assumed to date back to the terminal Pleistocene, with recorded instances of coastal resource use in the early Holocene, as well as use of offshore islands (Fig. 53).

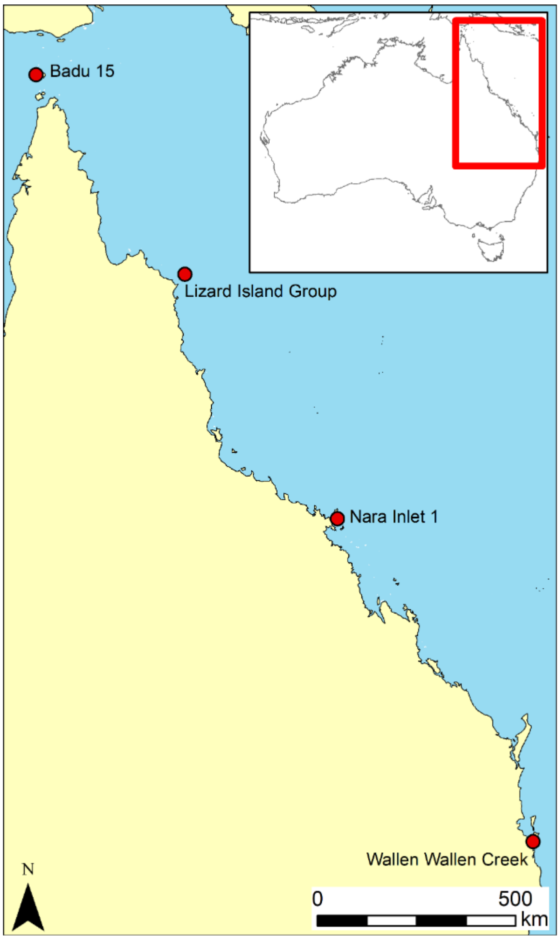

Figure 53: Locations in the northeast of Australia mentioned in text.

Currently, the oldest evidence for occupation of the Lizard Island Group, and for occupation of the islands on the Great Barrier Reef, is 3.8 ka based on Site 17 FBM (Lambrides et al. 2020). The timing and use of these offshore islands is an ongoing question in Indigenous archaeology, with connections to investigations of marine resource use and the development of maritime economies in the Holocene. Shell middens and stone arrangements including cairns, walls, and circular features are well-recorded for this group of islands (Fig. 54). Given the extensive coastal resource use visible in the archaeological record from 4 ka onwards, it is possible that the area was also occupied when sea levels were lower. The investigations of this area have been noted as limited to date (Lentfer et al. 2013). Existing data could supplement this investigation, and original research could prioritise LiDAR recording and drone survey of the coastal environments of the island group to determine priority areas for further survey. Possible offshore investigations of the Lizard Island Group could target areas that were exposed at lower sea levels, particularly in sheltered environments, and areas geomorphologically consistent with known shell midden and stone arrangement sites on land. It should be noted that coral-rich environments, such as that of Lizard Island, present a challenge to the visibility of archaeological material. This area remains prospective, but it is important to be aware of the development of coral across the study area.

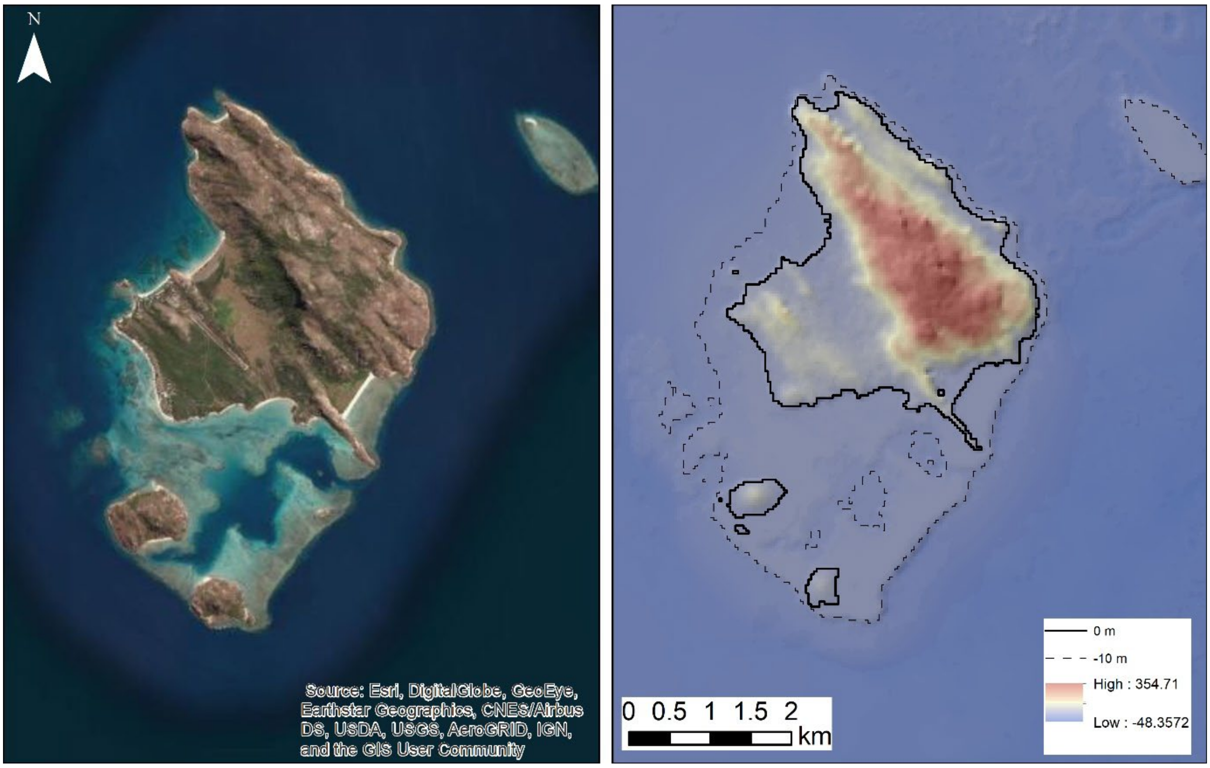

Figure 54 Lizard Island as seen in satellite imagery and as an elevation model with the −10 m bathymetry contour outlined.

8.5.4 Port Phillip Bay

Off the coast of Melbourne, Port Phillip Bay has several underwater features that can be considered highly prospective for submerged landscape archaeology, and also offers a key example of an area with substantial remote sensing (Fig. 55). Existing geophysical data was used for an archaeological landscape reconstruction of the bay at 10 ka, providing an extensive baseline of information draw on for work in this area. Steyne (2009) produced 3D models of the bay at 10 ka, and demonstrated that at this time the area was generally low-lying, and characterised by large, shallow river valleys. The area was flooded by rising sea levels around 8 ka (Holdgate et al. 2001).

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Figure 55 Port Phillip Bay showing the lithology and geophysical work conducted (Holdgate et al. 2011).

In terms of highly prospective features, the first of these is the presence of peat layers and deposits below the seabed, which could preserve organic material as well as more durable objects such as stone tools (Fig. 56). These have been identified based on the extensive seismic mapping, indicated by gas plumes, and supported by coring (Holdgate et al. 2011). The other prospective element is the presence of aeolianite ridges protecting the bay. As is demonstrated by the topographic elements of the Danish Model (Fischer 1995a), the mouths of streams are considered highly prospective, and this is relevant to the example of Port Phillip Bay as a former river valley. Following the Israeli example (Galili et al. 2019b), coastal barrier features assist in protecting submerged archaeology, and it should be noted that the geomorphological composition of alternating hamra deposits and aeolianite associated with the Carmel Coast of Israel is also observed similarly at the Nepean Peninsula at Port Phillip Bay. Several shell middens are located at the Nepean Peninsula, however no dates for these sites are published and therefore cannot be connected to occupation of Port Phillip Bay at times of lower sea level (Zhou et al. 1994).

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Figure 56 Sub-bottom profiler data from Port Phillip Bay (Holdgate et al. 2001).

An additional element of complexity exists in the submerged record at Port Phillip Bay, as the bay is believed to have dried substantially from 2.8 to 1 ka due to sand build-up at the entrance of the bay (Holdgate et al. 2011). This caused Port Phillip Bay’s levels to drop, and it eventually formed a lake. It is therefore possible that sites post-dating the initial flooding of the bay at 8 ka could be found at substantial depth in Port Phillip Bay due to the potential for more recent occupation of the area once the bay had formed a lake.

The landscape reconstruction conducted by Steyne (2009) phases 1–2 of this Australian Model, and demonstrates the importance of reviewing areas with substantial remote sensing for archaeological potential. Additional remote sensing could provide higher resolution data and offer more recent indications of where material may have preserved or eroded to inform further survey efforts. Given the features of the area that are consistent with archaeological sites in both the Danish and Israeli submerged archaeological record, Port Phillip Bay remains an area of high preservation potential.

8.5.5 Kangaroo Island and the Lacepede Shelf

Off the coast of South Australia, Kangaroo Island and the adjacent Lacepede Shelf are both highly prospective areas (Fig. 57). The south and western coasts of Kangaroo Island are likely less prospective with high calcarenite cliffs and eroded barriers, however the north and eastern coasts of the island experience moderate to low wave energy, with tidal inlets and mudflats on the eastern coast which are especially conducive to preservation. The northern coast, while also prospective, is subject to the impact of the tidal currents in Backstairs Passage. The oldest dates for the occupation of Kangaroo Island are based on the Seton Rock shelter, dating to approximately 16 ka (Hope et al. 1977). At this time, Kangaroo Island was connected to the Australian mainland, and located as an upland area near the palaeo-Murray River. The surrounding shelf area was a vast coastal plain (De Deckker et al. 2021). The island was likely cut off from the mainland by 9.5 ka (Hill et al. 2009; Nash et al. 2018). Occupation of the island is known at this time based on the Cape du Couedic site dating to the early Holocene at 8 ka (Draper 1987). These sites indicate habitation of the island both when it formed a hilly upland connected to the Australian mainland, and also following inundation once it had separated as an island. Like many islands off the Australian coastline, the timing and use of offshore islands alongside sea-level rise is an ongoing question, and hiatuses in occupation and potential watercraft use is reported (Draper 2015).

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Figure 57: The LGM channel of the Murray River (Hill et al. 2009:139).

In addition to the questions surrounding habitation of Kangaroo Island and the adjacent shelf area during times of postglacial sea-level rise, there may be evidence of Aboriginal oral traditions that recall sea-level rise. These stories appear to describe the inundation of Backstairs Passage (Nunn and Reid 2016). The stories were first recorded on the mainland from the Raminyerar and Jaralde peoples, and all involve an ancestral figure known as Ngurunduri whose two wives ran away from him. In the story, Ngurunduri pursues his wives across the southern coast of South Australia, and catches sight of them crossing a strip of land connecting Kangaroo Island to the mainland. Ngurunduri then caused the sea to rise to drown them, and the women and their belongings became the small islands now known as the Pages, and the sea remained at its height. There is variation in the story about the nature of the land bridge that connected Kangaroo Island across Backstairs Passage. Some variations describe this as a ‘strip of land’, or a ‘line of boulders’ requiring people to walk or wade, while other variations indicate that swimming was needed to carry out the crossing. Many places across Australia have similar stories describing sea-level rise, and this may suggest higher potential for submerged landscape archaeology as it demonstrates a connection to areas that are now found under water.

Kangaroo Island and its surrounding areas are deemed prospective based on the presence of oral tradition that describe engagement with submerged landscapes, in addition to the importance of researching these areas for submerged sites given the ongoing questions surrounding use of offshore islands and how this is represented in the Australian archaeological record.

8.5.6 Summary

Each of the areas of the Australian coastline described indicates a different reason that areas may initially be highlighted as prospective. Methods to assess the feasibility of the preservation of material on a preliminary basis prior to in-depth collection of maps and data are discussed. The prospective elements include 1) proximity to known submerged archaeological sites (Barrow Island and Montebello Islands); 2) intensive coastal resource use in the terrestrial archaeological record (Lizard Island Group); 3) submerged sediments and landforms associated with international examples of submerged landscape archaeology (Port Phillip Bay); and 4) oral traditions indicating connection to submerged environments or referring to sea-level rise (Kangaroo Island and Lacepede Shelf). The feasibility of identifying material may be assessed by reviewing the likelihood for material dating to the late Pleistocene and early Holocene to have eroded, or alternatively, to have been subjected to substantial rates of sedimentation.

8.6 Conclusion

This chapter has outlined factors affecting the application of the proposed Australian Model in the future. Based on the context of submerged landscape archaeology, there is a research gap and lack of sites in Australia that emerges. While a mode of practice can be suggested for the continent, regional-scale models are also likely to develop over time and are proposed here as variations on the existing marine bioregion classification system. Across Australia, there are numerous nearshore coastlines and island groups which could hold sites. It is likely that there is a substantial amount of archaeology offshore that has yet to be located. This is not to say that submerged landscapes and archaeological sites will preserve in all cases, but there are areas that emerge as highly prospective, as discussed. The research of these submerged sites is crucial to addressing several topics of research in Australian archaeology, including the peopling of Sahul, human adaptation to coastal environments, and dispersal across the continent.

9.0 CONCLUSION

9.1 Thesis Summary

This thesis presents a mode of practice for Australian submerged landscape archaeology, which has not previously been attempted. This is the first time that research has drawn together the lessons learned from a successful investigation in Australia, as well as the knowledge gained from well-established international examples. This demonstrates that it is not necessary to 'reinvent the wheel' when developing methodology for submerged landscapes, but that methodology should be adapted to suit the environmental conditions and requirements of research. This model represents an original study as a comparison of the methodologies demonstrated by several international models. This provides a baseline knowledge to inform submerged landscape archaeology in Australia, and indicates the potential for collaboration and future research to further advance methodology for underwater archaeology. The original contribution to knowledge of this thesis is the development of a mode of practice for Australian submerged landscape archaeology, based on a comparative study of existing modes of practice from across the world. This contributes to an effort to characterise submerged landscape archaeology to better record and protect archaeological sites. The comparison of sites on a global scale informs the potential environments and preservation conditions associated with particular material, as well as the strategies to locate them.

In this thesis, several areas were evaluated international case studies, and the criteria associated with preservation and prospection compared to develop a mode of practice for Australia. These areas were mainly selected from established leaders in the field of submerged landscape archaeology on a global basis. From this, a methodological approach was developed and applied in Murujuga, which serves as the only recorded example of subtidal Indigenous archaeology in Australia currently. This methodology created in Murujuga, while useful to the development of this Australian Model, cannot necessarily be applied everywhere as the coastline of Australia varies substantially in its environments. Regional-scale recommendations have also been made in this thesis to address this issue. The study at Murujuga was compared alongside the international modes of practice to allow for the development of this Australian Model: a preliminary set of guidelines to inform research efforts around the continent.

From a series of site-scale and landscape-scale studies of submerged landscapes, data surrounding site preservation and site selection were reviewed to analyse global trends in submerged landscape archaeology (Chapter 4). This benefited this thesis by providing an inventory of what is currently understood about broad concepts involved in archaeological prospection for submerged landscapes. Models and modes of practice were then reviewed to establish the role of survey strategy and methodology in the discovery of submerged landscape archaeology (Chapter 5). Site preservation and the implementation of suitable methodology are complementary issues, as site formation and preservation should ultimately guide the methodology selected. From the methodological discussions, additional logistical considerations must be considered including diving fieldwork logistics and personnel. This broad baseline of literature is then reinforced by a case study of the currently only known subtidal Indigenous archaeology in Australia (Chapter 6). The work in Murujuga serves as an example of a successful methodology, and aspects of this have been applied to this Australian Model.

The state of research and published stances on submerged landscapes and preservation in Australia were also reviewed, and established that submerged landscapes are often neglected in both Indigenous archaeology and maritime archaeology (Chapter 7). This established that, in Australia, Indigenous archaeology and maritime archaeology are often viewed as distinct, mutually exclusive fields of research, with little scope for collaboration. This collaboration is required to further submerged landscape archaeology in Australia.

Following the review of global modes of practice, including the Israeli and Danish Models alongside other modes of practice that are less frequently recognised in the literature, features were adapted to consider preservation characteristics, and methodological approach, associated with the Australian context. An Australian Model is then outlined as a model with features taken from international modes of practice based on lessons learned in the international examples (Chapter 7). Case study areas were then identified along the Australian coastline where the model could be applied and tested to allow for further methodological refinements (Chapter 8). These examples indicate the range of ways in which locations may be considered prospective, and suggested survey strategies to approach these regional-scale study areas. Regional criteria are also assessed as factors that could impact preservation across the varied coastlines of Australia (Chapter 8).

9.2 Research Question

This thesis set out to answer, ‘How can the discovery and research of submerged archaeological sites in Europe, the Middle East, and North America best inform the understanding of site formation and survey strategy in Australia?’ The modes of practice developed across Europe, North America, and the Middle East have informed 1) the understanding of site formation and survey strategy in Australia, by allowing for an investigation of site formation and site preservation, 2) providing examples of sites that could also be located off the coast of Australia, and 3) establishing survey strategies and technologies and their suitable context. Each of these aspects is summarised here.

9.2.1 Modelling site formation and preservation

The first outcome of the research question is that this thesis has established what is currently understood about submerged archaeological site formation and preservation, in accordance with international examples.

It is widely assumed, and generally appears, that the central distinction for site preservation is the role of protective, sheltered environments with minimal tidal movement and current, as opposed to the potential for destruction brought on by exposed environments with large tides and fast-moving currents. These are useful points to base predictive criteria on, however, Benjamin (2010b) writes that it is still possible for material to preserve in areas deemed less likely for preservation due to exposed coastlines or strong currents and large tides, and that this exposure may facilitate discovery. Fischer (1993) tested a variety of less likely areas to establish the validity of the Danish topographic fishing site model. Fischer (2007) observes that much of the Danish seabed is mud and sand, and might not seem conducive to preservation at first yet has yielded over a thousand submerged archaeological sites. It is important to set out scenarios for the deposition and preservation of archaeological material under water, and then search for this material to test predictive criteria, but also to be mindful of exceptions in areas deemed less likely to allow for preservation. Ongoing research will continue to expand our understanding of areas where material may preserve, which allows for the refinement of models for site preservation.

The submerged landscape archaeology of Australia has mostly had tentative results up until recently with the discovery of the first two subtidal sites. This discovery was based on a methodology designed for this specific area, and based heavily on terrestrial analogy. This indicates the importance of terrestrial analogy for submerged landscape archaeology, however it is also important not to assume continuity from the onshore to the offshore. Important distinctions between environments exist, in addition to cultural distinctions that may also be present which means that terrestrial analogy may not always be suitable to project this material to the offshore environment for predictive purposes (Veth et al. 2020). However, given its use in site discovery thus far, terrestrial analogy provides a starting point, as a known to proceed to the unknown. Archaeologists must be mindful in their analysis, however, not to assume continuity between sites and instead should test whether continuity exists between coastal and submerged sites (as was conducted in Murujuga). Unlike the approach used in Australia, the Danish Model relies heavily on ethnographic analogy to identify suitable fishing site locations under water (Fischer 1993, 1995). Similar to terrestrial analogy, this may also provide a useful way to draw information from the known to the unknown, but once again caution must be taken not to assume strict continuity, especially in ethnographic analogy where thousands of years may lie between the ethnographic comparison and the material culture.

Chance finds may challenge what is understood about submerged landscapes and where material is likely to preserve, as these archaeological finds are located by chance encounter rather than probabilistic modelling for site preservation. These chance finds may provide an indication of more finds in the same area, or indicate that the material is capable of preserving in a particular environment. As with all archaeological finds, it is important to consider the role of site formation processes that have contributed to the material's eventual location and identification. Micro-archaeological studies of the sedimentary context of artefacts will contribute to this understanding of how archaeological finds preserve under water, and this information can be considered at a micro-scale and then considered at broader landscape scales in the development of predictive models.

9.2.2 Site-scale assessments of site selection and preservation

Several examples of submerged sites were identified that could also be located in the Australian submerged archaeological record. This builds on previous research outlining potential site types that may preserve (Nutley 2005), however it approaches the issue with international submerged landscape archaeology in mind. It should be noted that, globally, stone tools are among the more prevalent examples of submerged material culture. These artefacts, as seen in the examples at Murujuga, may vary in their preservation and may be severely obscured by marine growth, or have corroded or rounded over time due to their depositional environment. At this point in time, lithic artefacts are the only example of submerged landscape archaeology in Australia. However, from this thesis, the role of sedimentary contexts such as hamra clay and peaty deposits alongside sediment cover is seen to contribute to the preservation of organic remains. Identifying these deposits will be crucial to mapping areas of high potential for preservation.

9.2.3 Suitability of remote sensing technology for different contexts

Over the course of this thesis, there are several varieties of remote sensing taken into consideration for the identification of submerged landscape archaeology, including LiDAR, multibeam, sub-bottom profiler, and sidescan sonar. These are all useful tools to contribute to locating submerged landscape archaeology, and for recording these sites. However, the suitability of different instruments for different environments must be established, particularly with acknowledgement of the sedimentary context of the material. In Murujuga, sidescan sonar was used to identify upstanding material on the seabed, with the potential to encounter stone features and structures, as well as standing stones (Chapter 6). Sub-bottom profiler was not considered for this survey due to the lack of sedimentation in the area. In Denmark, sub-bottom profiler and sidescan sonar were used to determine the extent of a submerged shell midden (Astrup et al. 2021). From this study, sub-bottom profiler was deemed more successful for locating the midden and establishing its boundary. Off the coast of Israel, sub-bottom profiler has been used, and the use of sidescan sonar would have to coincide with the exposure of sites (Galili et al. 2019b). In the case of the Israeli example, consistent monitoring, with divers is crucial to establishing times of the year when the material is exposed so that it may be recorded. Geological sampling may also assist in supplementing geophysical and remote sensing applications (Gagliano et al. 1982). In all of these cases, cooperation with marine industries may facilitate data access so that there is a greater chance of identifying and protecting submerged archaeological sites (Tizzard et al. 2014; Vos et al. 2015). These assessments of the acoustic and digital signatures of submerged landscape archaeology contribute to the broader recognition of these archaeological features, and could allow for similar features to be located off the coast of Australia.

9.3 Limitations

There are some limitations to this thesis study, and these are mostly due to scale and scope of the thesis. It was not possible to review every publication in submerged landscape archaeology for the methods used and their methodological input. To address this, select studies were chosen based on explicit methodology and methodological discussions. This began with the major examples of the Danish Model and the Israeli Model, and was reinforced by several publications that address survey methodology. This thesis focuses on the development and the rationale of an Australian Model, however testing this model requires further research and additional field campaigns, as well as regionally specific criteria to contribute to regional-scale models. This is outlined to an extent in Chapter 8, in addition to the discussion of potential future research areas. The results from Murujuga are referred to here as a successful example of a submerged landscape archaeology field campaign in Australia, but additional work is required to refine a mode of practice for a continent, and to develop any regionally specific criteria for submerged landscape archaeology in Australia. This is beyond the scope of this thesis, but will form a critical part of future research.

9.4 Impact, Relevance, and Consequences

The impact of this thesis is the understanding of criteria that contributes to the preservation of submerged landscapes, and its application to an area that is currently lacking in finds from these submerged environments (Australia). To better understand the implications of this thesis research, future studies could test this Australian Model to assess if it serves as a functional and useful set of guidelines for Australia or requires further adaptation and calibration.

Over the course of this thesis, several areas emerge that require further research, but have been kept in mind in the thesis. The first is the issue of dealing with material that is out of context, having been eroded from coastlines or subject to processes that have shifted the material under water. While these issues have been highlighted as a significant problem for submerged landscape archaeology, there are already frameworks for dealing with this material on land (including non-site and off-site archaeology) that can contribute to this particular concern. In addition, studies with a landscape approach to the submerged environment will allow for the inclusion of material that has changed over time due to the formation processes of that particular environment. In a similar way, submerged landscape archaeology must address lithic artefacts that are found either corroded or rolled by currents and waves, or alternatively covered by marine growth, as these may still yield substantial information to the interpretation of an area when the find is considered in the broader context of how it was deposited and how it changed over time.

The other issue that has emerged over the course of this thesis is the challenge of identifying and recording hunter-gatherer archaeology under water. The archaeology associated with hunter-gatherer societies is sometimes portrayed as ephemeral in comparison with agricultural societies. However, there are examples across the world of the preservation of hunter-gatherer archaeology under water, with significant contributions to archaeological questions. Hunter-gatherer archaeology also may be associated with significant water depths compared to shallower (and more recent) sites. This introduces significant logistical hurdles of conducting research at increased depth, requiring technical diving or the use of remote sensing technologies including ROV's or sidescan sonar. It is likely that ways of countering these logistical hurdles will develop over time, and this is necessary in order to address global questions around migration and coastal adaptation.

In Australian archaeology, previous attempts prior to the DHSC project in Western Australia had been made to identify submerged landscape archaeology, but none had succeeded. This lack of results is important to consider for two reasons. The first reason is that a lack of results does, in fact, contribute to the understanding of the preservation material, by demonstrating where archaeology likely does not preserve, to inform further research. However, a lack of results is important to consider in that ongoing failure to identify submerged landscape archaeology has ramifications for the discipline, in that projects are less likely to be funded with a lack of results as the dominant narrative. In many cases, the costs associated with these projects can be prohibitive, and establishing high priority areas for intensive research serves to mitigate this issue.

In Australian archaeology, there is an issue of maritime archaeology that has not been well-connected to archaeological theory, and submerged landscape archaeology is included in this issue. Submerged landscape archaeology in Australia will require investigation of material on the seabed, as well as material on land, and with some awareness of the frameworks used to approach this material. Additionally, maritime archaeology in Australia has tended to neglect Indigenous perspectives, and this is especially relevant now that submerged Indigenous heritage is known to preserve. On the other hand, Indigenous archaeology in Australia tends to ignore the sea, viewing the sea as a hard boundary and creating unbalanced interpretations that have generated perceptions of a landscape that are not in agreement with the archaeological material. A combination of

Indigenous archaeological approaches and maritime archaeology is necessary to move both sub-disciplines forward with submerged landscape archaeology.

The importance of cooperation with marine industry may serve to reduce the lack of results in Australia. This is particularly relevant at the time of this thesis, following the destruction of the 46,000-year-old rock shelter at Juukan Gorge by Rio Tinto (Nagar 2021). It is possible that there are many similar sites to Juukan Gorge on the seabed, and communication and partnership with marine industry is key to ensuring that the destruction of archaeological material seen on land is not replicated in the marine environment. This is further complicated by the legislative status of underwater Indigenous archaeology, which is not currently automatically protected unlike sunken aircraft and historic shipwrecks. The Underwater Cultural Heritage Act 2018 should take submerged Indigenous sites into account as an automatically protected form of heritage, as this will allow for greater protection of sites.

This thesis has demonstrated the role of international modes of practice in developing methods for submerged landscape archaeology in Australia. Ongoing research will allow for testing of this baseline model, and will allow for regional refinements to this model. The research of submerged landscapes may generate new insights to issues of coastal adaptation and potentially the earliest settlement of Sahul. Submerged Indigenous sites have the potential to inform important research questions in Australia, and the methodology to locate and study these sites is crucial to their recording and protection.

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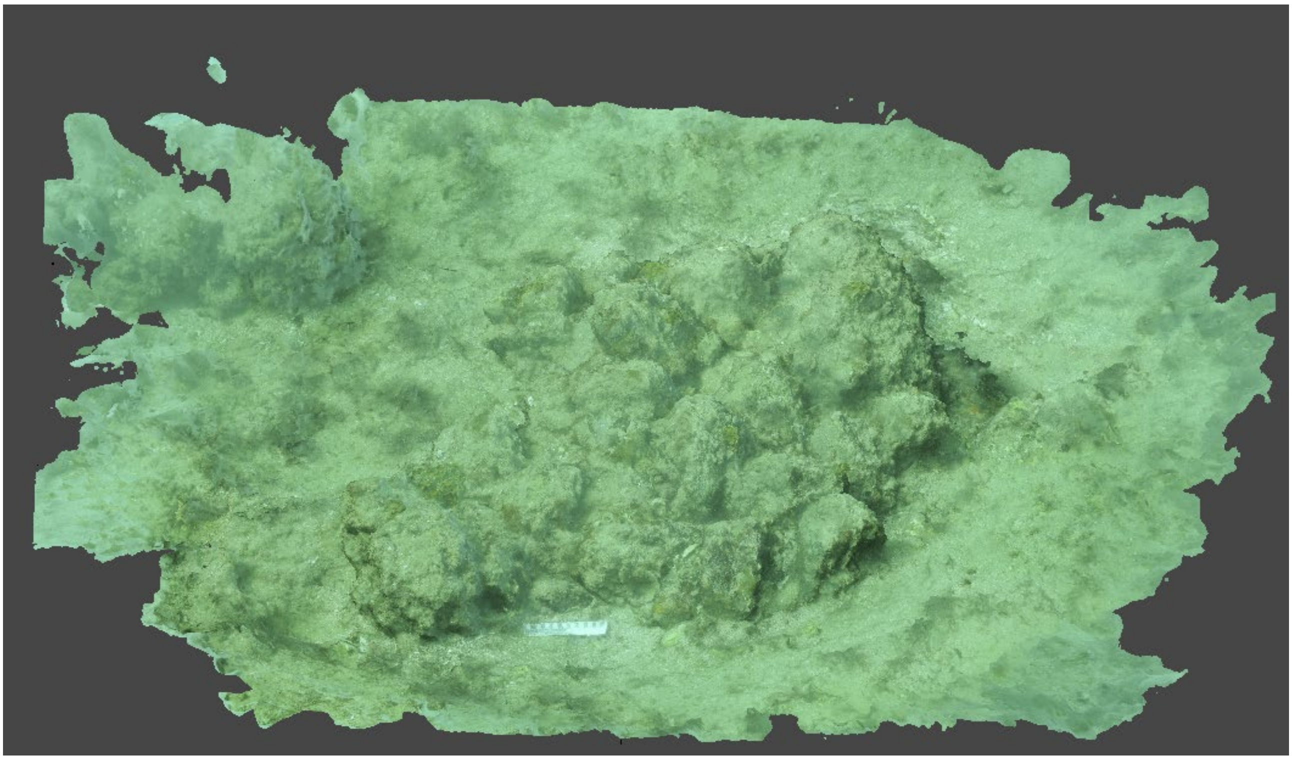
APPENDIX 1: CARMEL HEAD FIELDWORK

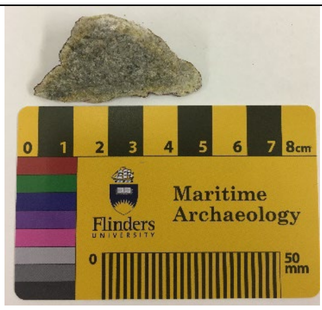
3D Model of Location 1

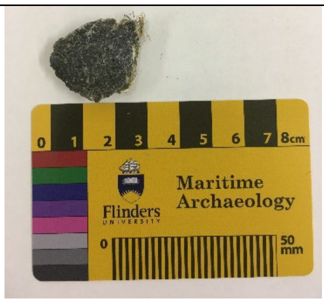
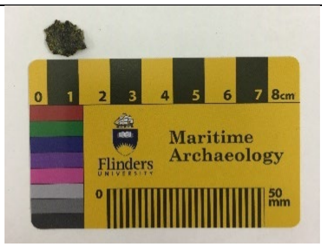
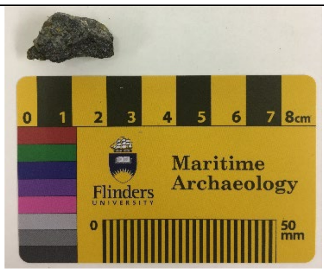
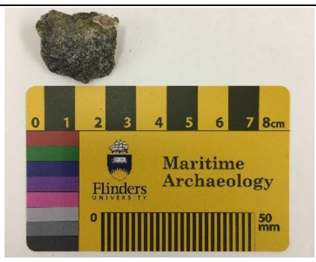


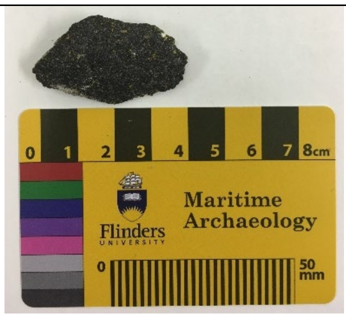
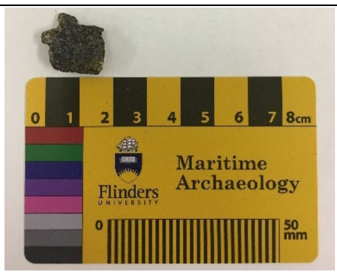
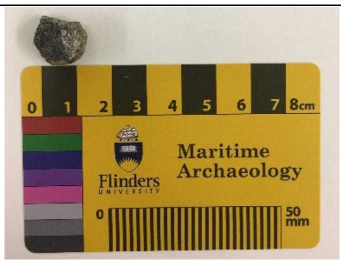
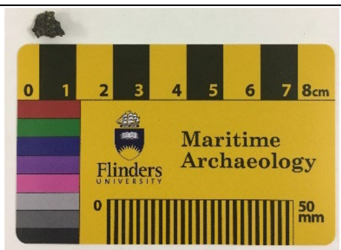
Photographs taken by Ehud Galili, processed by Chelsea Wiseman in Agisoft Metashape.

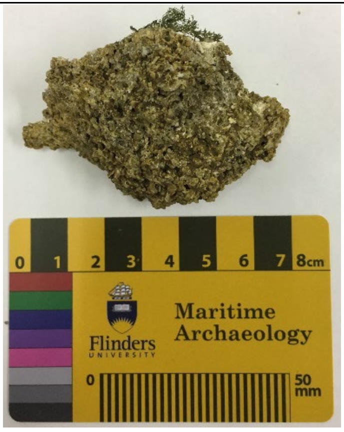
Geological samples

The stone samples collected on the diving survey at this site were collected by Ehud Galili and Isaac Ogloblin, then processed and recorded by Chelsea Wiseman, and preliminary rock types were identified with the assistance of Ruth Shahack-Gross of the University of Haifa's Microarchaeology Laboratory.

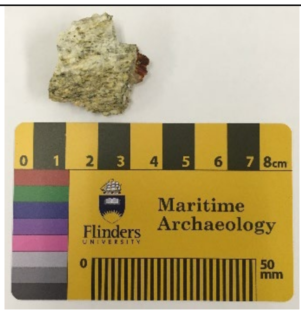
Location #1			
Sample Number	Image	Rock type	Possible origin
CN-L1-01		Plutonic igneous rock	Non-local but unknown

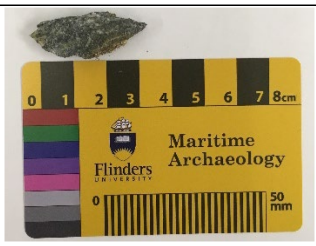
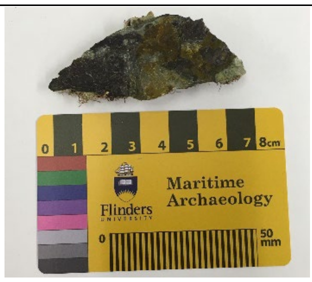
CN-L1-02		Basalt	Cyprus, Northern Levant
CN-L1-03		Basalt	Cyprus, Northern Levant
CN-L1-04		Basalt	Cyprus, Northern Levant
CN-L1-05		Basalt	Cyprus, Northern Levant
CN-L1-06		Basalt	Cyprus, Northern Levant
CN-L1-07		Basalt	Cyprus, Northern Levant

CN-L1-08		Basalt	Cyprus, Northern Levant
CN-L1-09		Basalt	Cyprus, Northern Levant
CN-L1-10		Basalt	Cyprus, Northern Levant
CN-L1-11		Basalt	Cyprus, Northern Levant
CN-L1-12		Basalt	Cyprus, Northern Levant

CN-L1-13		Beachrock	Seafloor surface geology at Carmel Nose, may be from Carmel Coast or beyond

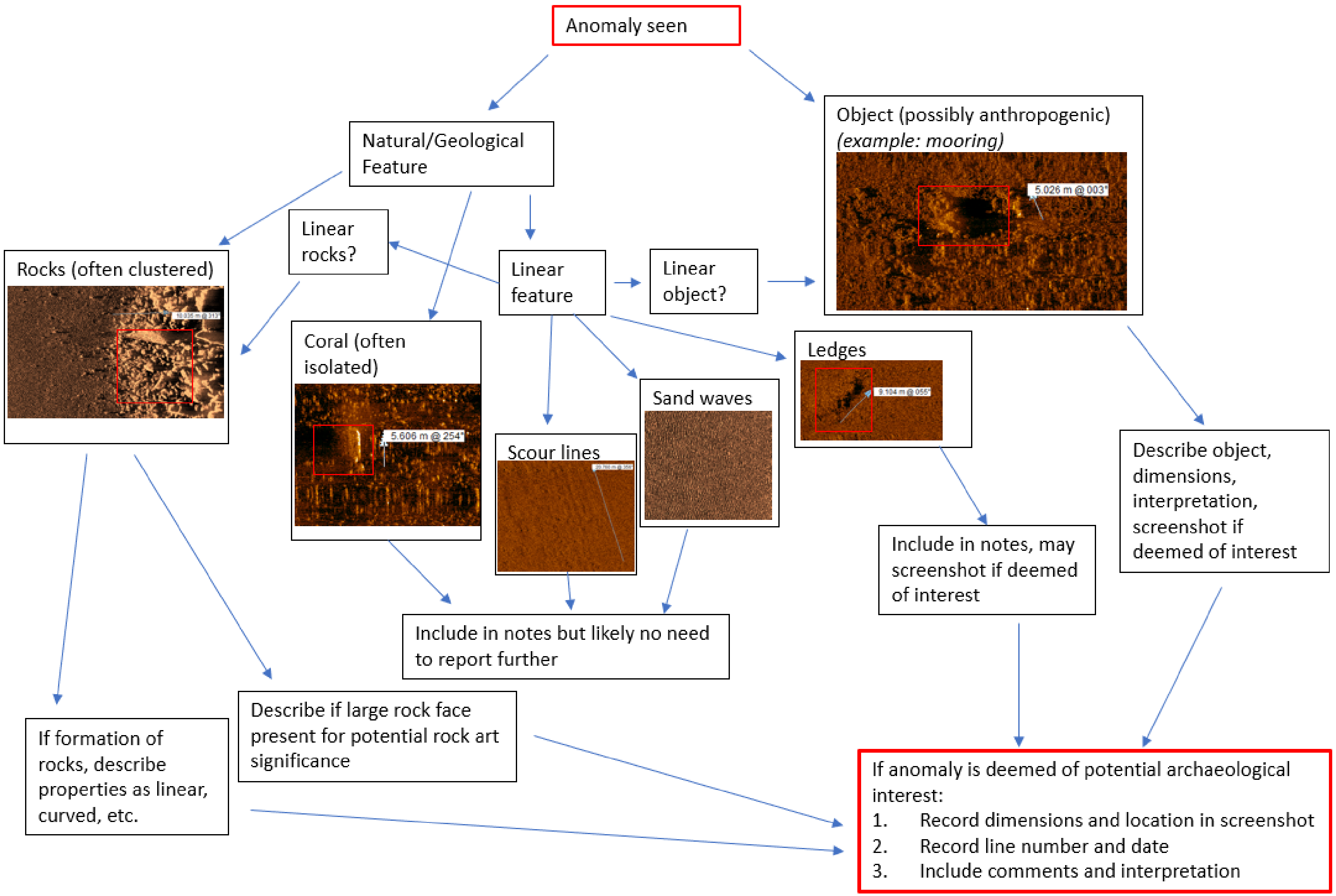
The results from Location 1 show that the stone pile is mostly composed of basalts with one instance of a plutonic rock that could not be identified further.

Location #2			
Sample Number	Image	Rock type	Possible origin
CN-L2-01		Metamorphic	Non-local but unknown
CN-L2-02		Diorite	Cyprus, Aegean, Egypt
CN-L2-03		Andesite	Cyprus, Anatolia

CN-L2-04		Basalt	Cyprus, Northern Levant
CN-L2-05		Schist	Schist is found in southern Israel, but the colour of the sample indicates imported – Aegean, Anatolia?
CN-L2-06		Schist	Schist is found in Israel, but the colour of the sample indicates imported – Aegean, Anatolia?
CN-L2-07		Gabbro	Cyprus, Anatolia, Syria

Location 2 demonstrates greater variety in the stones, with numerous possible points of origin. The analysis of these two stone piles from the Carmel Nose indicates that they are composed of imported, non-local stones. At a preliminary stage, the presence of imported stones supports the hypothesis of ballast piles from ships in antiquity, rather than confirmation of a submerged prehistoric structure. However, numerous stone features exist on the Carmel Head, including large boulders, and their provenance and possible date must also be assessed to provide an accurate assessment of the dates, the origin and the nature of these features found at the Carmel Head.

APPENDIX 2: SIDESCAN SONAR PROCESSING



Sidescan Sonar Recording Sheet				
Date	**Location**	**Line number**	**General comments (bottom type, any noted features)**	**Archaeological potential?**
9/05/2018	Dolphin Island - N/NE	023551	Bommies and rocks present, mainly flat and featureless bottom	N/A
9/05/2018	Dolphin Island - N/NE	024808	Bommies, flat, generally featureless	N/A
9/05/2018	Dolphin Island - N/NE	025548	Sand waves in southern part of line, flattens to north, isolated bommies	N/A
9/05/2018	Dolphin Island - E	031104	Shadow of shark? Large rock faces in sheltered area, sand waves to north of line	Rock faces -> rock art preservation?
9/05/2018	Dolphin Island - E	032220	Circular and linear anomalies? Flat sandy bottom transitions to large rocks	3 features, Linear and circular anomalies, rock faces
9/05/2018	Dolphin Island - E	033911	3 tall stones, transitions sandy to rocky running north south	1 feature, 3 tall stones
9/05/2018	Dolphin Island - SE	034844	Large rock faces, mostly sandy	Large rock faces

9/05/2018	Dolphin Island - SE	035441	Large rocks and boulders following shore, very sandy	N/A
9/05/2018	Dolphin Island - SE	040629	Generally sandy, misc anthropogenic object? Large flat rock faces	Large rock faces, misc anthropogenic object?
9/05/2018	Dolphin Island - SE	041658	Generally sandy, sand waves and rocks to north, large rocks on starboard, noise in water column	N/A
9/05/2018	Searipple Passage	045543	Scattered rocks and bommies, some ledges. Distortion due to shallow depth.	N/A
9/05/2018	Searipple Passage	050346	Rock cluster running perpendicular to passage, scattered rocks and bommies, scour marks	Rock cluster?
9/05/2018	Searipple Passage	051826	Rocky with scour marks throughout, large rocky ledges to eastern part of line	N/A
9/05/2018	Searipple Passage	053512	Rocky with scour marks throughout	N/A
5/06/2018	Flying Foam Passage	011705	Rocky bottom with scour marks, isolated rocky features	N/A
5/06/2018	Flying Foam Passage	012651	Some noise in water column. Rocky ledges.	Ledges may be of interest

5/06/2018	Flying Foam Passage	013907	Limestone bottom? Swell may have caused inaccuracy in data	N/A
5/06/2018	Flying Foam Passage	014929	Three large holes visible, possible sinkholes?	sinkhole features (?) may be of interest
5/06/2018	Flying Foam Passage	015804	Swell and inaccuracy in data, some rocks	N/A
5/06/2018	Flying Foam Passage	020836	Ledges, a lot of noise in water column	N/A
5/06/2018	Flying Foam Passage	022010	Significant noise in water column, rocky outcrop but difficult to detect details	N/A
5/06/2018	Flying Foam Passage	023017	Scour visible throughout, noise in water column	N/A
5/06/2018	Flying Foam Passage	024016	Scour and ledges, noise in water column	N/A
5/06/2018	Flying Foam Passage	025032	Ledges, rocky outcrop, noisy	N/A
5/06/2018	Flying Foam Passage	025937	Rocky and bommies, but noisy and only few features visible	N/A

5/06/2018	Flying Foam Passage/Gidley East	031025	Highly rocky and scoured	N/A
5/06/2018	Flying Foam Passage/Gidley East	032005	Possible anthropogenic debris and sinkhole, rocky, scour	N/A
5/06/2018	Flying Foam Passage/Gidley East	033005	Rocky ledges, scour, scattered bommies and noise in water column	N/A
5/06/2018	Flying Foam Passage/Angel Northeast	034040	Very stripy and noisy line, quite rocky throughout	N/A
5/06/2018	Flying Foam Passage/Angel east	035228	Very stripy and noisy line, quite rocky throughout	N/A
5/06/2018	Flying Foam Passage/Angel east	040012	Less noise than prior lines, highly rocky	N/A

5/06/2018	Flying Foam Passage/Angel east	041010	Distortion caused by swell, some ledges and dispersed rocky areas	N/A
5/06/2018	Flying Foam Passage/Angel east	042026	Some scour visible, one circular rocky arrangement near larger rocky outcrop	Rock circle
5/06/2018	Flying Foam Passage/Angel east	043020	Some scour visible, rock clusters and small bommies	N/A
5/06/2018	Flying Foam Passage	051533	Flat and featureless	N/A
5/06/2018	Flying Foam Passag	052650	Scattered rocky outcrops, some noise caused by fish and swell	N/A
5/06/2018	Flying Foam Passage/Dolphin	054011	Scattered rocky outcrops, some noise caused by fish and swell	N/A
5/06/2018	Flying Foam Passag	055010	Rocks scattered throughout, some scour	N/A

5/06/2018	Flying Foam Passage/Dolphin	060243	intertidal rock scatter	Intertidal rock scatter - see screenshots
5/06/2018	Flying Foam Passage	061305	Highly rocky but flat	N/A
5/06/2018	Flying Foam Passage	062310	short line - rocky	N/A
5/06/2018	Flying Foam Passage	062321	Highly rocky but flat	N/A
5/06/2018	Flying Foam Passage	063314	Some distortion caused by swell, highly rocky but flat	N/A
5/06/2018	Angel Island North	064405	Rocky but flat, some scour, shallow line	N/A
5/06/2018	Angel Island North	065617	Numerous sand waves close to shore but becomes rocky	N/A
6/06/2018	Enderby Island West	040406	Sand waves, follows the rocky edge of coastline	N/A
6/06/2018	Enderby Island West	041454	Follows coastline - some distortion from swell, one square rock arrangement	Rock square

6/06/2018	Enderby Island West	042543	Initially rocky but flattens out, isolated sand waves	N/A
6/06/2018	Enderby Island West	043735	Isolated sand waves, rocky clusters, and some fish in water column	N/A
6/06/2018	Enderby Island West	044821	Isolated sand waves and rocky clusters	N/A
6/06/2018	Bare Rock	051212	Mainly flat but becomes rockier closer to Bare Rock	some targets on line, but not highly visible
6/06/2018	Bare Rock	052217	Rocky, noise from swell and fish, one isolated area with sand waves	N/A
6/06/2018	Bare Rock	053327	Rocky, noise from swell and fish, one isolated area with sand waves	N/A
6/06/2018	Bare Rock	054547	Sand waves, rocky towards centre, mild distortion	rock square
6/06/2018	Bare Rock	060147	Featureless, then rocks and bommies	N/A
6/06/2018	Bare Rock	060747	Large bommie, rocky ledges, sand waves	rock circle, kind of horseshoe shaped?
6/06/2018	Bare Rock	061554	Large rocky ledges and sand waves, rock circle from prior line not visible	N/A

6/06/2018	Enderby Island South	064901	Mostly featureless bottom type, some rocks from island outcrop	N/A
6/06/2018	Enderby Island South	070129	Mostly featureless bottom type, bommies	N/A
6/06/2018	Enderby Island South	071304	Sandwaves, but few other discernible features	N/A
6/06/2018	Enderby Island South	072339	Mostly featureless bottom type, bommies	N/A
6/06/2018	Enderby Island South	073335	Mostly featureless bottom type, bommies	N/A
6/06/2018	Enderby Island South	074335	Mostly featureless bottom type, bommies	N/A
7/06/2018	Madeleine Shoals	010550	Some stones, limestone? fish in water column	N/A
7/06/2018	Madeleine Shoals	011540	Very rocky area, major fish disturbance	1 feature, 4 tall stones
7/06/2018	Madeleine Shoals	012447	Rocky but without extensive feature	1 feature, 4 tall large stones in isolation

7/06/2018	Madeleine Shoals	013456	Several rocky ledges, especially in port side	1 feature, rock circle
7/06/2018	Madeleine Shoals	014513	Large scattered rocks, large ledge	N/A
7/06/2018	Madeleine Shoals	015533	Limestone bottom? Very featureless and flat	N/A
7/06/2018	Madeleine Shoals	020535	Limestone with few rocky ledges	N/A
7/06/2018	Madeleine Shoals	022246	Very rocky with scattered rocks	N/A
7/06/2018	Madeleine Shoals	023530	Rocky ledges on strbrd, very flat	N/A
7/06/2018	Madeleine Shoals	024530	Abundant large rocky ledges and flat limestone platforms	1 feature, 5 tall linear stones
8/06/2018	Enderby Island West	004231	Numerous ledges, distortion from swell?	N/A
8/06/2018	Enderby Island West	005822	Sand waves and ledges	N/A

8/06/2018	Enderby Island West	011015	Sand waves and ledges	N/A
8/06/2018	Enderby Island West	012020	Sand waves and ledges	N/A
8/06/2018	Enderby Island West	012933	Sand waves and ledges	N/A
8/06/2018	Enderby Island West	014022	Rockier than previous lines, some scour, sand waves and ledges	N/A
8/06/2018	Enderby Island West	014733	Short line - limestone bottom?	N/A
8/06/2018	Enderby Island West	014904	Short line - limestone bottom?	N/A
8/06/2018	Bare Rock	014939	Sand waves and ledges, circular rock formation from 060747 visible	N/A
8/06/2018	Bare Rock	020431	Sand waves	N/A
8/06/2018	Bare Rock	021049	Sand waves and extensive rock	N/A
8/06/2018	Bare Rock	022025	Sand waves, ledges, bommies	N/A

8/06/2018	Bare Rock	022030	Sand waves and ledges	N/A
8/06/2018	Bare Rock	024019	Limestone? Ledges	N/A
8/06/2018	Nth of Enderby	025016	Limestone? Ledges	N/A
8/06/2018	Nth of Enderby	030022	Sand waves and ledges	N/A
8/06/2018	Nth of Enderby	031037	mainly sand waves	N/A
8/06/2018	Nth of Enderby	032016	Sand waves and ledges	N/A
8/06/2018	Nth of Enderby	033019	Highly rocky, sand waves and ledges	N/A
8/06/2018	Nth of Enderby	034153	Highly rocky, sand waves and ledges	N/A
8/06/2018	Nth of Enderby	035011	Highly rocky, sand waves and ledges	N/A
8/06/2018	Roly Rock	040029	Limestone, generally flat with sparse ledges	N/A
8/06/2018	Roly Rock	041012	Rocks, bommies, sand waves	N/A
8/06/2018	Roly Rock	042015	Rocks, bommies, sand waves	N/A
8/06/2018	Roly Rock	043016	Rocks and ledges, one possible anthropogenic object?	N/A
8/06/2018	Roly Rock	044013	Rocky ledges and sand waves, fish disturbance	N/A
8/06/2018	Roly Rock	045037	no discernible features, limestone bottom?	N/A

8/06/2018	Roly Rock	050009	no discernible features, limestone bottom?	N/A
8/06/2018	Goodwyn Island	051930	Sand waves, rocky, limestone	N/A
8/06/2018	Goodwyn Island	053021	Extensive sand waves throughout	N/A
8/06/2018	Goodwyn Island	054031	Rocky and ledges	N/A
8/06/2018	Goodwyn Island	055011	Wavy rocky ledge formation?	N/A
8/06/2018	Goodwyn Island	060016	Wavy rocky ledge formation?	N/A
8/06/2018	Enderby Island Northeast	061007	Rocky and bommies	N/A
8/06/2018	Enderby Island Northeast	062032	Scattered bommies	N/A
8/06/2018	Enderby Island Northeast	063105	Rocky outcrop from Enderby and bommies	N/A
8/06/2018	Enderby Island Northeast	064024	Rocky outcrop from Enderby and bommies	N/A
8/06/2018	Enderby Island East	065048	Old moorings	N/A

8/06/2018	Enderby Island East	070034	Old moorings and lines	N/A
SEPT/OCT FIELDWORK - NOTE LINES OBTAINED USING GRID FROM HYPACK				
25/09/2018	Enderby Island South	083	Rocky with rocky overhang towards end of line	N/A
25/09/2018	Enderby Island South	087	Elevated rocky ridge and tall corals	N/A
25/09/2018	Enderby Island South	091	Short line, no major features	N/A
25/09/2018	Enderby Island South	091_1	Extended rock ledge, scattered corals	N/A
26/09/2018	Enderby Island South	079	Extended rock ledge	N/A
26/09/2018	Enderby Island South	075	Mainly flat - rocky seabed?	N/A
26/09/2018	Enderby Island South	071	Rocky ledge at end of line	N/A

26/09/2018	Enderby Island South	067	scour marks?	N/A
26/09/2018	Enderby Island South	065	scour marks?	N/A
26/09/2018	Enderby Island South	065_1	Elevated rocky areas	N/A
26/09/2018	Northwest Reef	099	Rocky reef	N/A
26/09/2018	Northwest Reef	103	Rocky reef w/ groups of bommies	N/A
26/09/2018	Northwest Reef	107	Reef ledges	N/A
26/09/2018	Northwest Reef	111	Small sand waves and reef ledges	N/A
26/09/2018	Northwest Reef	115_1	Small sand waves and reef ledges	N/A
26/09/2018	Northwest Reef	115	Numerous very small to much larger bommies, limestone bottom?	N/A
26/09/2018	Northwest Reef	119.001	Sand waves and large reef ledges, small dark pock mocks on port side	N/A
26/09/2018	Northwest Reef	119_1	Sand waves and bommies, some darker stripes may indicate change in bottom type	N/A

26/09/2018	Northwest Reef	119	Extensive rock ledges and bommies	N/A
26/09/2018	Northwest Reef	127.001	Sandy and featureless	N/A
26/09/2018	Northwest Reef	127	Abrupt change to darker return, clay? Channel? Sand waves and granophyre ledge outcrop of island	N/A
27/09/2018	Malus	239.001	Rocks and bommies in clusters, some scour	N/A
27/09/2018	Malus	239	Rocky reef and bommies throughout	N/A
27/09/2018	Malus	rosemary1.0001	Abrupt change to darker and lighter returns - clay and sand?	N/A
27/09/2018	Malus	rosemary1	Boulders and large bommies	N/A
27/09/2018	Malus	245	Coral ledge, varying changes from clayish to sandy bottom comp, some scour marks	N/A
27/09/2018	Malus	245.001	Short line, large bommies	N/A
27/09/2018	Malus	rosemary2	Bommies and extensive reef	N/A
27/09/2018	Malus	rosemary2.001	Small ridges and reef	N/A
28/09/2018	Malus	245_1	Ledges and rocky reef	N/A

28/09/2018	Malus	249.001	Noise from echo sounder - clay to sand transition seen in colour change?	N/A
28/09/2018	Malus	249	Some change in bottom comp evident in colour as above - noise from echo sounder	N/A
28/09/2018	Malus	tonorth	1 line to north. No changes in bottom comp, flat.	N/A
28/09/2018	Malus	321.001	Boat echosounder noise problematic, 1 large ridge	N/A
28/09/2018	Malus	321	Small scattered bommies, boat echosounder noise	N/A
28/09/2018	Malus	325.001	Small scattered bommies, boat echosounder noise	N/A
28/09/2018	Malus	325	Scour marks, small scattered bommies and boat echosounder noise	N/A
28/09/2018	Malus	314	Very scattered boomies, mainly featureless	N/A
28/09/2018	Malus	317	Featureless, boat echosounder noise	N/A
28/09/2018	Malus	317.001	Scattered bommies, some lines of bommies and elevated ridges	N/A
29/09/2018	North Enderby	233	Lighter pock marks, no features otherwise	N/A
29/09/2018	North Enderby	219_001	Scattered bommies, uneven bottom with elevated ridges, some ridges curved, patch of darker return	N/A

29/09/2018	North Enderby	235.001	Scattered bommies	N/A
29/09/2018	North Enderby	235.002	Transition from darker to lighter returns, scattered bommies, noise from boat echosounder	N/A
29/08/2018	North Enderby	216.001	Rocky reef floor	N/A
29/09/2018	North Enderby	217	Rocky reef to limestone, groups of corals	N/A
29/09/2018	North Enderby	215	Stones continue from onshore, bordered by coral bommies	N/A
29/09/2018	North Enderby	216	Pock marks, groups of corals	N/A
29/09/2018	North Enderby	219	Small pock marks, groups of corals	N/A
29/09/2018	North Enderby	223_1	Small pock marks, limestone	N/A
29/09/2018	North Enderby	223	Transition from limestone to sand? (very light toward end of line)	N/A
29/09/2018	North Enderby	227	Bright pock marks	N/A
29/09/2018	North Enderby	231	Bright beginning of line, transition to dark, bright pock marks	N/A
29/09/2018	North Enderby	235	Transition from dark to light, pock marks	N/A

29/09/2018	North Enderby	239.001	Brighter line (relative to previous Nth End lines), faint pock marks	N/A
29/09/2018	North Enderby	239	Large sand waves clustered, coral cluster, 'causeway' ridge very prominent	N/A
29/09/2018	North Enderby	243.002	Bommies and rock reef ledges	N/A
29/09/2018	North Enderby	149	Scattered bommies, boat echosounder noise	N/A
29/09/2018	North Enderby	243.001	Mainly flat, scattered small corals and marine vegetation	N/A
29/09/2018	North Enderby	243	Flat and no discernible features	N/A
29/09/2018	North Enderby	247	Some sand waves and faint pock marks, very prominent ledges which could be sheltered areas, or reef?	Ledges may be of interest
29/09/2018	North Enderby	251.001	Flat, scattered bommies	N/A
29/09/2018	North Enderby	251	Flat, sand waves at beginning of line, faint and bright pock marks	N/A
29/09/2018	North Enderby	lowtide	Flat, faint pock marks	N/A
30/09/2018	North Enderby	271.002	short line, no features	N/A
30/09/2018	North Enderby	275.001	Bright pock marks	N/A

30/09/2018	North Enderby	275	Sand waves, bands of light and dark that vary throughout the line	N/A
30/09/2018	North Enderby	271.001	Sand waves, mainly flat and sandy with some rocky ridges	N/A
30/09/2018	North Enderby	271	Large sand waves and bright pock marks	N/A
30/09/2018	North Enderby	255.001	Scattered corals and causeway ledges	N/A
30/09/2018	North Enderby	255	Sand waves, mostly flat, bright pock marks	N/A
30/09/2018	North Enderby	259.001	Mostly flat with bright pock marks	N/A
30/09/2018	North Enderby	259	Mostly flat with some sand waves	N/A
30/09/2018	North Enderby	263.001	Edge of central raised area visible, sand waves	N/A
30/09/2018	North Enderby	263.002	Short line, no features	N/A
30/09/2018	North Enderby	263	Bright pock marks, edge of central raised area visible as steep ledge	N/A
30/09/2018	North Enderby	267.001	Dark sand waves adjacent to ridge, sand and bright pock marks	N/A
30/09/2018	North Enderby	267	Prominent sand waves, causeway edges	N/A

1/10/2018	North Enderby	3	Clusters of rock and coral, semi-circle feature in proximity to the rocky coastline, possibly just coral formation	rock feature?
1/10/2018	North Enderby	225	Noise from echo sounder problematic, scattered marine vegetation	N/A
1/10/2018	North Enderby	380	Rock and coral cluster	rock cluster may be of interest but no features seen
1/10/2018	North Enderby	384	Rock and coral cluster	rock cluster may be of interest but no features seen
1/10/2018	North Enderby	388	Transition from flat to tall clusters of rock and coral	N/A
1/10/2018	North Enderby	392	Small scour lines running NE-SW, scattered bommies	N/A
1/10/2018	North Enderby	227	Uneven, undulating seabed, sand waves, scattered bommies	N/A
1/10/2018	North Enderby	231	Small ledges, bommie cluster	N/A
1/10/2018	North Enderby	223.001	Sand waves, short line	N/A
1/10/2018	North Enderby	223	Small sand waves, large steep ledges parallel to shoreline	N/A

1/10/2018	NthEn - Causeway	8	Scattered bommies and sand waves, edge of causeway visible	N/A
1/10/2018	NthEn - Causeway	9	Scattered bommies and sand waves, edge of causeway visible	N/A
1/10/2018	NthEn - Causeway	10.001	Noise from echosounder, dark, rocky?	N/A
1/10/2018	NthEn - Causeway	10_1.001	Short line, no features	N/A
1/10/2018	NthEn - Causeway	10_1	Ridges along edge of causeway	N/A
1/10/2018	NthEn - Causeway	10	Sheltered side of causeway, large scattered bommies and sand waves	N/A
1/10/2018	NthEn - Causeway	11	Causeway appears narrower in this section based on ledges?	N/A
1/10/2018	Bare Rock	85	Darker wavy area to west, then sandy with bommies and rocky ledges	N/A
1/10/2018	Bare Rock	89	Large coral bommies and rocky outcrops, dark wavy area in west	N/A

1/10/2018	Bare Rock	93	Dark wavy area in west, rocky extension of Bare Rock, contact DHSC_014 cannot be seen (060747_F01)	includes previously sighted anomaly but not seen here due to noise
1/10/2018	Bare Rock	95	Dark wavy area in west, rocky extension of Bare Rock (min. 15 m based on altitude of towfish), some small sand waves	N/A
1/10/2018	Bare Rock	97	Small sand waves, rocky extension of Bare Rock, corals at the edge of rocky formation	N/A
1/10/2018	Bare Rock	101_1	Rocky extension of Bare Rock gradual transition to sparse corals	N/A
1/10/2018	Bare Rock	101	Rocky extension of Bare Rock	N/A
1/10/2018	Bare Rock	105_1	Flat rock surfaces and corals visible on outer edges of Bare Rock	N/A
1/10/2018	Bare Rock	105	Rocky extension of Bare Rock, possible rock formations of interest on outer edge?	sheltered side of the rock, unusual formations
1/10/2018	Bare Rock	109_1	Rocky extension of Bare Rock appears to continue to at least ~25 m based on altitude of towfish	N/A
1/10/2018	Bare Rock	109	Northern edge of Bare Rock, disconnected rocky outcrop, darker area possible channel	N/A

1/10/2018	Bare Rock	113	Northern edge of Bare Rock, corals adjacent	N/A
1/10/2018	Roly Rock	59	Sand waves, southern extension of Roly Rock	N/A
1/10/2018	Roly Rock	61	Sparse corals, southern extension of Roly at least ~10 m based on towfish alt	N/A
1/10/2018	Roly Rock	63_1	Sparse corals, eastern extension of Roly Rock	N/A
1/10/2018	Roly Rock	63	Sparse corals and large rock faces on western side of Roly	N/A
1/10/2018	Roly Rock	65_1	Large bommies and coral clusters	N/A
1/10/2018	Roly Rock	65	Curved rocky extensions from Roly Rock and scattered bommies	N/A
1/10/2018	Roly Rock	67	Mainly rocky, a few isolated bommies	N/A
2/10/2018	Madeleine Shoals South	51	Southern edge of shoals, otherwise mostly flat with scattered corals. DHSC_018 not visible, distortion in original?	N/A
2/10/2018	Madeleine Shoals South	55	Across the centre of the southern shoal area	N/A

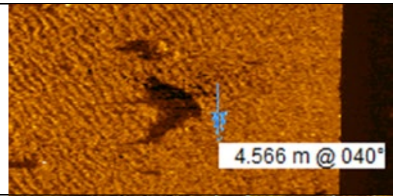
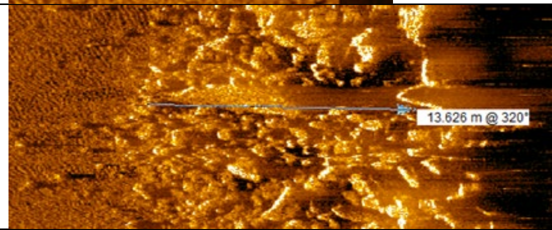
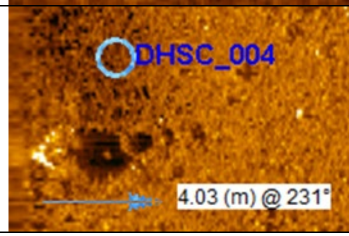
2/10/2018	Madeleine Shoals South	59	Some distortion, shoals and tall bommies	N/A
2/10/2018	Madeleine Shoals South	63	Northern edge of southern shoal, few other features	N/A
2/10/2018	Madeleine Shoals South	67	Small ledges and scour marks	N/A
2/10/2018	Madeleine Shoals North	65	Scattered corals	N/A
2/10/2018	Madeleine Shoals North	67.001	Short line end of 67	N/A
2/10/2018	Madeleine Shoals North	67	Elevated possibly rocky ridges, scattered corals	N/A
2/10/2018	Madeleine Shoals North	71	Large steep shoal ledges	N/A
2/10/2018	Madeleine Shoals North	75	Centre of northern shoals area, DHSC_015 not visible, distortion in original?	N/A
2/10/2018	Madeleine Shoals North	79	Steep ledge in north of line, centre of northern shoals area, scattered corals	N/A

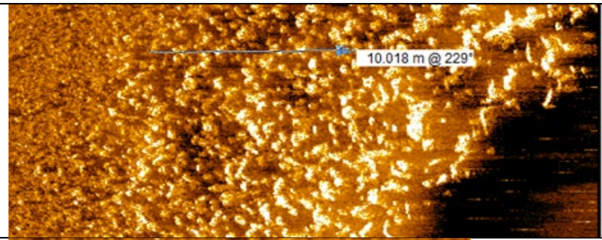
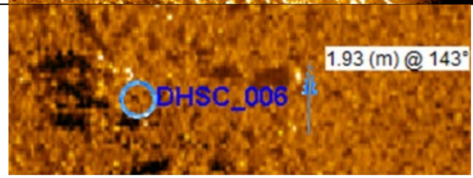
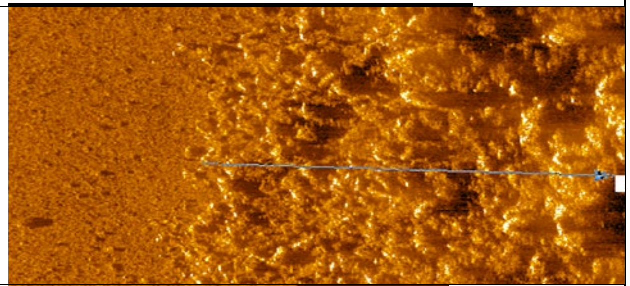
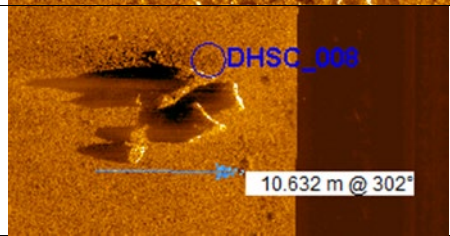
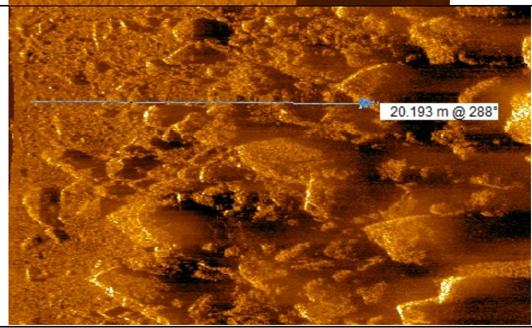
2/10/2018	Madeleine Shoals North	83	Northern part of northern shoals area, DHSC_016 not visible (distortion in original?), DHSC_017 visible, defined sand waves	N/A
2/10/2018	Madeleine Shoals North	87	Stripy line and mostly flat, northern edge of shoals	N/A
2/10/2018	Madeleine Shoals North	91	Stripy line and mostly flat, northern edge of shoals	N/A
2/10/2018	Legendre North	COAST	Boulders on the edge of the shore, submerged limestone platforms	potential for sea-level indicators
2/10/2018	Legendre North	COAST.001	Abrasion and scour more apparent across platforms than in first line	potential for sea-level indicators
2/10/2018	Legendre North	COAST.002	Rockier, more abraded platforms and boulders	potential for sea-level indicators
2/10/2018	Legendre East	313	Edge of submerged platforms from Legendre, ridges and smaller platforms	N/A
2/10/2018	Legendre East	317	Limestone seabed, less steep ledges and scour marks	N/A
2/10/2018	Searipple Passage	STH	Alluvial deposits in southeast, continuation of rocky coast in submarine environment represented by bright returns	rock faces potential for rock art

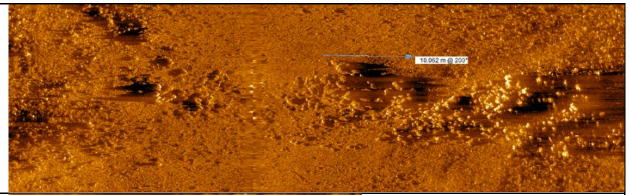
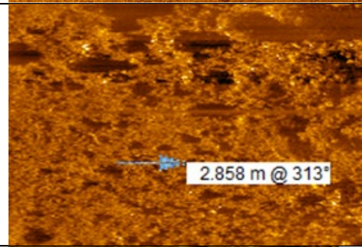
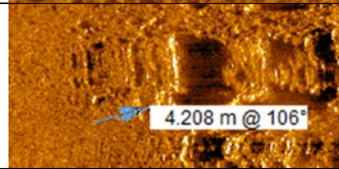
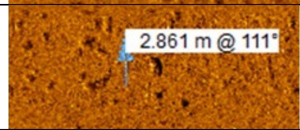
2/10/2018	Searipple Passage	STH.001	Scattered bommies	N/A
3/10/2018	Flying Foam	intertidal.001	Near lithic scatter in intertidal zone, some marine vegetation, rocky areas, and generally flat topography	lithic scatter not identified here but nearby
3/10/2018	Flying Foam	intertidal	Near lithic scatter in intertidal zone, some marine vegetation, rocky areas, and generally flat topography	lithic scatter not identified here but nearby
3/10/2018	Flying Foam	28.001	Generally flat, some marine vegetation and rocky areas	N/A
3/10/2018	Flying Foam	28	Possible alluvial deposits, clusters of corals throughout	N/A
3/10/2018	Flying Foam	29	Rocky continuation of Dolphin into the passage?	N/A
3/10/2018	Flying Foam	turnaround	Line taken while turning in passage - mainly sand and featureless sea floor	N/A
3/10/2018	Flying Foam	turaround.001	Line taken while turning in passage - mainly sand and featureless sea floor	N/A
3/10/2018	Flying Foam	20.003	Steep rocky ledges on the western side of passage, rocky continuation of islands	N/A
3/10/2018	Flying Foam	20.002	Mostly sandy with sandy rise	N/A

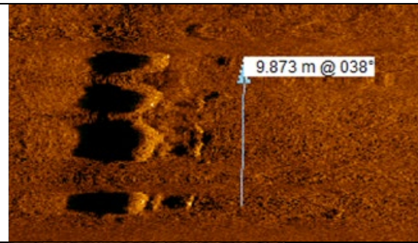
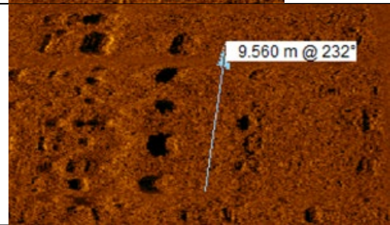
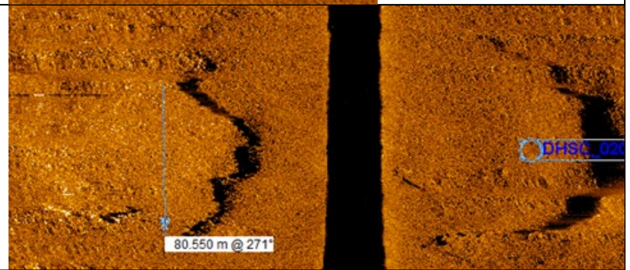
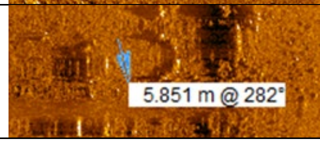
3/10/2018	Flying Foam	20.001	North of line reflects darker with vibrant pock marks, clay? Rocky continuation of islands	N/A
3/10/2018	Flying Foam	12	Very shallow, transition from rocky to very sandy sea floor?	N/A
3/10/2018	Flying Foam	16	Short line, too noisy to establish features, appears rocky	N/A
3/10/2018	Flying Foam	18.001	Mainly sandy except for the earlier noted dark patch with pock marks	N/A
3/10/2018	Flying Foam	18.002	Mainly sandy, raised rocky area towards centre of passage	N/A
3/10/2018	Flying Foam	18.003	Possible scour marks but mostly flat	N/A
3/10/2018	Flying Foam	18.004	Elevated ridges and possible scour marks through centre of passage	N/A
3/10/2018	Flying Foam	18.005	Rocky continuation into passage, DHSC_011 not sighted but presumption of adjacent environment supported by this line	N/A
3/10/2018	Flying Foam	18	Rocky continuation into passage, large rocky outcrop in centre of passage opposite location of lithic scatter	possibly not archaeologically significant but unusual geology

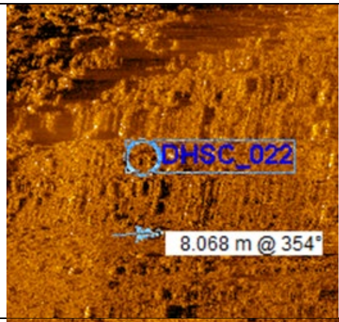
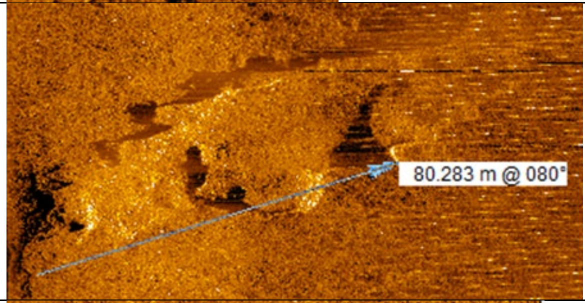
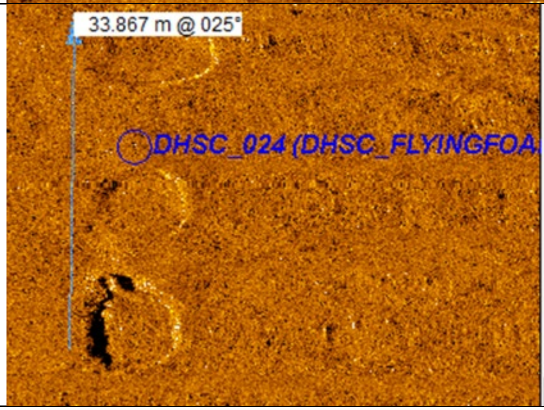
3/10/2018	Flying Foam	20	Some steep ledges in centre of passage and sand waves	N/A

Sidescan Sonar Anomalies						
Date	**Number**	**Dimensions**	**Location**	**SonarWiz contact #**	**Interpretation**	**Screenshot**
9/05/2018	031104_F01	Approx 4m	Dolphin Island - E	DHSC_001	Shark?	
9/05/2018	031104_F02	Ruler for scale	Dolphin Island - E	DHSC_002	Large rock faces	
9/05/2018	032220_F01	1.4 x 0.6 m	Dolphin Island - E	DHSC_003	Anthropogenic linear object?	
9/05/2018	032220_F02	4.0 x 1.5 m	Dolphin Island - E	DHSC_004	Circular with hole, anthropogenic?	

9/05/2018	032220_F03	Ruler for scale	Dolphin Island - E	DHSC_005	Rock faces to south of enclosed bay	
9/05/2018	033911_F01	1.9 x 0.8 m	Dolphin Island - E	DHSC_006	Initial interpretation as 3 tall stones, probably coral	
9/05/2018	034844_F01	Ruler for scale	Dolphin Island - SE	DHSC_007	Large rock faces	
9/05/2018	040629_F01	Ruler for scale	Dolphin Island - SE	DHSC_008	Rock faces? Anthropogenic?	
9/05/2018	040629_F02	Ruler for scale	Dolphin Island	DHSC_009	Large flat rock faces	

9/05/2018	050346_F01	Ruler for scale	Searipple Passage	DHSC_010	Rock cluster	
5/06/2018	042026_F01	Ruler for scale	Flying Foam Passage	DHSC_011	Rounded rock formation	
6/06/2018	041454_F01	4 x 4 m	Enderby Island West	DHSC_012	Square rock formation	
6/06/2018	054547_F01	3.8 x 2.3 m	Bare Rock	DHSC_013	Square rock formation	
6/06/2018	060747_F01	2.9 x 2.3 m	Bare Rock	DHSC_014	Circular rock formation	
7/06/2018	011540_F01	4.7 x 1.0 m	Madeleine Shoals	DHSC_015	Linear rock feature	

7/06/2018	012447_F01	10 x 1.2 m	Madeleine Shoals	DHSC_016	Linear rock feature	
7/06/2018	013456_F01	4.0 x 2.6 m	Madeleine Shoals	DHSC_017	Circular rock formation	
7/06/2018	024530_F01	9.3 x 0.5 m	Madeleine Shoals	DHSC_018	Linear rock feature	
8/06/2018	043016_F01	3.0 x 1.2m	Roly Rock	DHSC_019	Possibly anthropogenic?	
29/09/2018	247_F01	approx 80 m	North Enderby	DHSC_020	Two semi-circle ridges	
1/10/2018	3_F01	5.9 x 1.5 m	North Enderby	DHSC_021	Semi-circle feature	

1/10/2018	105_F01	8.4 x 7.8 m	Bare Rock	DHSC_022	Rectangular rock formation	
3/10/2018	18_F01	95.8 x 45.1 m	Flying Foam	DHSC_023	Rocky outcrop in centre of passage	
5/06/2018	014929_F01	7.1 x 5.0 m	Flying Foam	DHSC_024	Possible sinkholes?	

APPENDIX 3: COMPARISON OF MODELS

Australian Model (this thesis)	Preliminary reconnaissance and feasibility assessment	Detailed desk-based study	Meetings and permissions	Develop preliminary predictive criteria	Select areas for remote sensing	Remote sensing	Detailed predictive modelling	Direct observation	Post-fieldwork
Danish Model (per Fischer 1995a)			Ethnographic component	Use of nautical charts and topographic model		Delimitation of sites by echosounder	Topographic fishing site model	Mark site with buoy, investigate with divers	
Danish Model (per Benjamin 2010b)	Regional familiarisation		Ethnographic component	Map and imagery analysis, location plotting		Observation of potential sites physically and with sonar		Mark theoretical site with GPS and dive to investigate	Post-fieldwork in accordance with standard procedure
Israeli Model (per Galili et al. 2019b)	Use of aerial imagery in unfamiliar areas			Depth-dependent and substrate-dependent		Sub-bottom profiler and jet drilling		Intentional surveys, rescue surveys, excavation	Typology of sites, reconstructing coastal change, coastal adaptation, CRM
Gagliano et al (1982)	Synthesise geophysical and geological data			Identify areas with thin sediment cover, geologically in span of human occupation		Tight-grid geophysical survey for optimum scale	Identify areas of high probability for site occurrence (prior to remote sensing)	Collect geological samples	Analysis of geological samples
Faught (2014)	Identification of relevant antecedent landforms,					Using different kinds of underwater acoustic		Coring or dredging	Geological analysis of samples

	culture groups, and sea-level history					devices and identification target genres			
O'Shea et al. (2021)	Identify size of micro-regions, establish how many	Detailed mapping of seabed				Sub-bottom, coring, and ROV		Direct observation by divers or submersibles	Apply micro-regional approach to data collected
McLaren et al. (2020)		Creating sea-level curves, generating bare earth DEM		Creating predictive models				Ground-truth predictive models	Determine if material dates to the late Pleistocene
Bates et al. (2012)		Reconstruct sea-level change and landscape, establish time period of human occupation in landscape		Identification of locations favourable to archaeological preservation				Identify and assess target locations	
Westley et al. (2011)		Reconstruct sea-level, map coastal evolution and buried landscapes				3D modelling of landscape evolution	Predictive modelling of site locations	Archaeological testing of potential areas	
Vos et al. (2015)		Review existing data including boreholes				Chirp, sparker, MBES, additional boreholes followed by additional high-detail testing of priority areas		MBES before and after grab sampling	