FROM SEA TO SCREEN: GIS MODELLING OF BRONZE AGE SHIPS IN THE CYCLADES

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"I certify that (i) any material in this dissertation which is not my own work is properly identified and acknowledged, (ii) the dissertation complies fully with the University of Liverpool regulations on academic integrity, (iii) no part of the dissertation has ever figured in material successfully submitted for the award of any other degree"

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Abstract

The subject of networks in the ancient Mediterranean has bought forward numerous discussions surrounding connectivity and the importance of seafaring. At present, this dissertation is focused on using a GIS methodology first discussed by Leidwanger (2013) in order to model the Keros-Syros and Minoan networks that are present in the Cyclades at different points during the Bronze Age. This is to highlight the physical component of seafaring in the networks discussed, presented as the time taken for certain voyages. Moreover, this can also visualise the possible process of these networks expanding to encapsulate the Cyclades. Overall, Leidwanger's methodology allowed for models to be produced that were adequate for the current study, and provide a useful resource for the interpretation of maritime networks.

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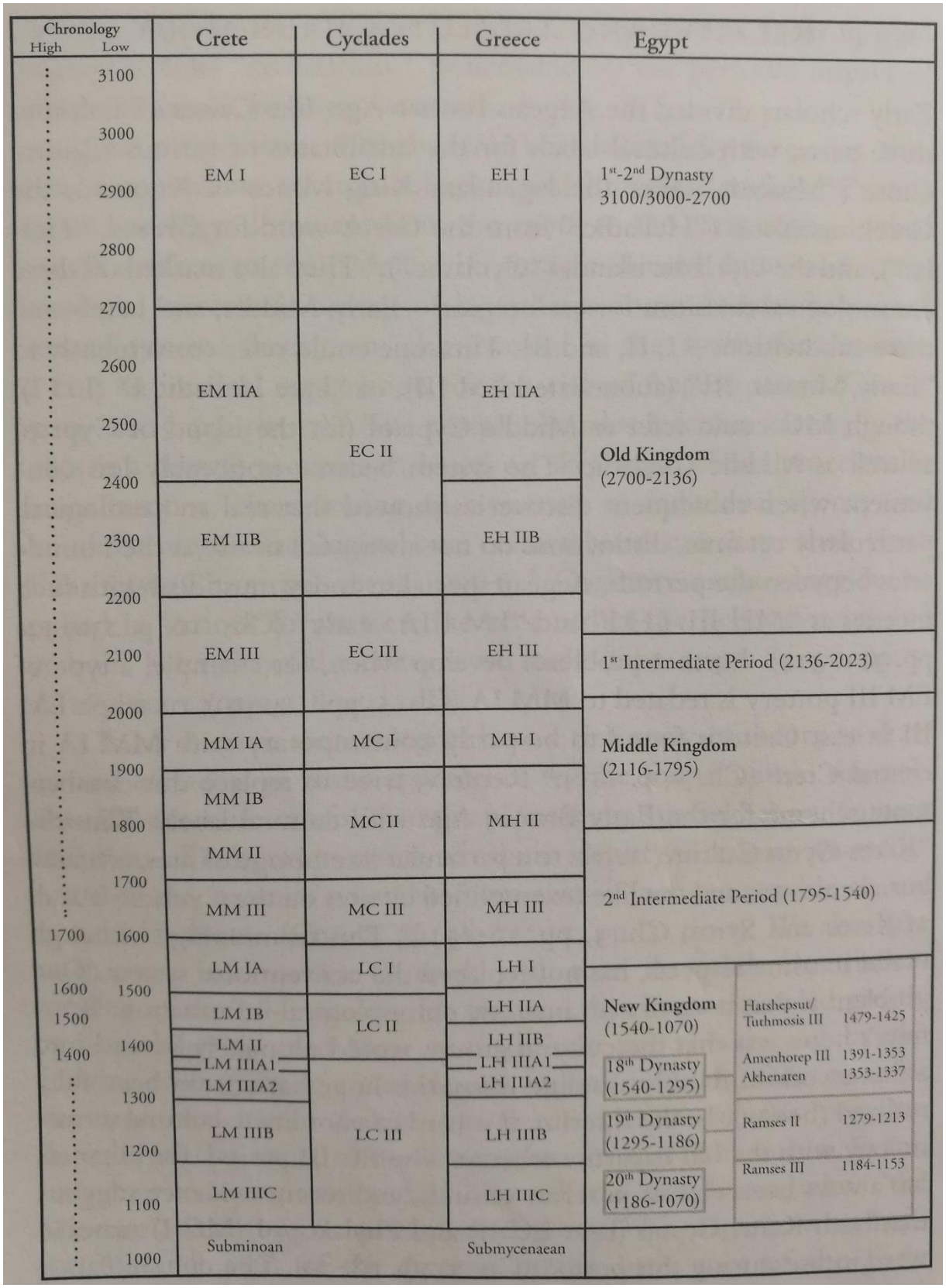


Figure 1: Chronology of the Bronze Age Aegean (Shelmerdine, 2008, 4).

Introduction

The modern world is characterised as a place that is interconnected and globalised. However, this idea of a connected network is not entirely new, and networks, albeit on a smaller scale have existed since the Neolithic period. The Mediterranean Sea is the focal point for much of these networks, it is the earliest maritime foci in the world. It is in this area that the earliest networks, which could only be possible through seafaring occurred; with the circulation of Obsidian from Melos and other sources across the eastern Mediterranean during the Neolithic. However, the maritime networks were developed further during the Bronze Age, and eventually connected the entire Mediterranean, allowing for trade and communication to occur.

In particular, the origins of this can be noted in the Cyclades, a group of islands in the Aegean Sea. These islands formed an interconnected network by the Early Bronze Age, possibly following on from the Neolithic. The first network is established by the Keros-Syros culture, which came to dominate the Cyclades through a maritime network, and is a culture that is characterised by ceramic 'frying pans' depicting long boats. As will be discussed, this culture could not have come to dominate without the ability to travel across the seas. Next, the second main culture to dominate the Cyclades and form a network are the Minoans. Originating from Crete, the Minoans integrated the Cyclades into a network and also utilised them to connect to the mainland of Greece. Both of these networks share one factor in common; they are reliant upon seaborne transport in order to remain connected, and also to dominate this network. Therefore, knowledge of the physical capabilities of ancient seagoing craft is important for considering the effort undertaken in forming and travelling in these networks, especially for the time it would take to travel. One key variable between the two is ship technology. As aforementioned, the Keros-Syros culture is mainly represented by depictions of long boats that would have been propelled via oars. The Minoan vessels however utilise sails in order to propel themselves using the wind. This is a key difference in technology and creates a significant difference in physical capability.

It is the intent of this dissertation to model the physical capabilities of the ships of the Keros-Syros culture, and the Minoan vessels using GIS as a platform. This will allow for a greater understanding of these networks, suggesting the likeliest routes, and the factor of travel time between locations within the network. This will indicate the physical side of the network, and also a key difference between the different types of ship involved. Furthermore, the methodology utilised is one that was pioneered by Leidwanger (2013). Therefore a secondary aim is to test the applicability of Leidwanger's GIS methodology in the environment of the Bronze Age Cyclades.

Moreover, the dissertation will be organised as such. A thematic literature review discusses the current state of scholarship in a variety of topics pertaining to this dissertation, including Mediterranean archaeology, maritime and nautical archaeology and the use of GIS in archaeology. A discussion of the history of seafaring in the Mediterranean will emphasise the importance of seafaring in this region, and its implications of colonisation, trade and communication. It will also highlight the early networks that connected the Mediterranean. The Cyclades will be focused upon in depth in the third chapter, discussing their physical features, and the networks that occurred within the Cyclades. Moving on, a discussion about harbours is essential, they are an integral facility to maintain trade and manage the movement of ships, and as such, a discussion of the development of harbours in the Aegean is necessary, and will provide some basis for the locations used in the GIS model. Next, a discussion of boats and ships in the Mediterranean, and the evolution of ship building will follow. This will indicate the development of ships, and also discuss the types of ship utilised in the model, and early assumptions of their capabilities. Methodology and the process of gathering data, using GIS and modelling the environmental factors that undoubtedly affected ancient sailing, such as the wind. This will be discussed as an ongoing process. Finally the results and final figures from the GIS models will be presented, including what they indicate, with some discussion and interpretations based on the information. Finally, the conclusion will present some observations based upon the methodology and its application in this environment.

Literature Review

As this thesis' aim is to model the physical capabilities of Bronze Age ships in the Aeagean, specifically the geographic area of the Cyclades, this study will utilise a methodology that will be useful in highlighting the physical nature of ancient networks, in particular, the time needed for maritime travel in the Mediterranean. Therefore, the current scholarship surrounding Mediterranean archaeology, the Cyclades and their archaeology, GIS and its uses in archaeology and maritime archaeology will be reviewed thematically, as these are the areas relevant to this dissertation.

Mediterranean History & Archaeology

There have been considerable studies based around the history and archaeology of the Mediterranean (Broodbank, 2013. Purcell & Horden, 2000). Broodbank's is more up to date, and is an extensive study of Mediterranean history, ranging from the Palaeolithic, through to the classical period. There have been studies focusing specifically on the Cyclades islands as a geographical area (Broodbank, 2000, Yeranolou & Stamatopou, 2005). Of these two, Broodbank's study bears more relevance. The studies into connectivity and networks in the Aegean, as well as the maritime component in the early history of the Cyclades are significant, as these serve as a key progenitor for later networks of trade. Broodbank also discusses the technological developments in regards to seafaring, which bears relevance to other areas of this study. Furthermore, there are numerous discussions of networking in the Aegean based around the Greek islands, it is a recent topic of interest for Mediterranean history (Kougioumoutzis, et al. 2017. Constantakopoulou, 2007). This highlights that the study of ancient networking is a subject that will be benefitted from further research in the framework of highlighting the physical aspects of these networks. The wider topic of Maritime activity in the Mediterranean is linked with the discussions of networking, and is a major theme relevant to this present study. Casson (1995), broadly focuses on the topic of maritime history in the Mediterranean, tracing key developments in the maritime side of the Mediterranean.

Archaeology of the Cyclades & Crete

The Cyclades islands, located in the central Aegean are the main geographical area discussed in this dissertation, therefore it is important that they are discussed, the variances in their archaeologies and environments will be discussed in greater detail in a later chapter. The Cyclades are the subject of some studies. In particular, Broodbank (2000) is an essential view of the islands as a network rather than as individual islands, despite contrasting island physical environments. This recognises the cross island cultures that are present in the Cyclades in the early Bronze Age, such as the Keros-Syros culture, up until the emergence of Minoan influence on the region. Moreover, Broodbank discusses the islands in detail, and discusses their own natural features and geologies, that make them important in a network.

Furthermore, Barber (1987) discusses the Cyclades throughout the Bronze Age, focusing in depth upon the connections between the archipelago and Crete. Moreover, Barber elaborately discusses the physical geography and the climate of the Cyclades including unique mineral resources which the Cycladic islands are rich in, namely obsidian and marble. Barber finishes with a discussion on the Mycenaean connection to the Cyclades, and their incorporation into the Mycenaean network, that also included the wider Mediterranean. Finally, Schallin (1993) focuses on this Mycenaean connection questioning what the nature of this Mycenaean connection was, and also aims to establish the political and economic organisation of the Cyclades. A topic that Broodbank (2000) follows with.

Overall, the Cyclades is an area that has been subjected to a few articulated studies. However, although the Minoan connection to the islands has been discussed heavily, the physical nature of this connection will aid the current understanding and grant an idea of scale to it, particularly in terms of time would be required for contact between locations to be established.

Reconstructing Ancient Ships and Maritime Landscapes

The literature surrounding ancient ships and maritime archaeology in the Mediterranean is also numerous. Broader studies include Casson (1995), a source on maritime archaeology in the ancient world, including specific chapters discussing ancient harbours. Wachsmann (2009), focuses upon the Bronze Age, albeit in the Levant, however this still bear's relevance. Wachsmann (2009) highlights key similarities in harbours across the eastern Mediterranean. Both of these studies include discussions of harbours, however Blackman's (1982) discussions of ancient harbours in the Mediterranean deal with harbours in depth. Moreover, an Aegean focus on harbours is discussed by Shaw (1990), using examples from across the region. Importantly, Minoan harbours and their associated settlements have been discussed at length (Watrous, 2012. Day et al, 2011). This shows that there is a great amount of information surrounding harbours, particularly from the Late Bronze Age. However there is comparatively little written on any earlier material, this will be discussed further in a later chapter.

The reconstruction of ancient ships relies heavily on iconography produced by the culture or other contemporary cultures and the physical wrecks of ships lying upon the sea bed. Tilley (2004) discusses the iconography of ancient ships at great length, arguing that the iconography can indicate techniques of propulsion using oarsmen, as well as ship design whilst citing sources from across the Mediterranean. Furthermore, period specific shipwrecks with preservation of the ship's hull, such as the Uluburun wreck (Bachhuber, 2006. Pulak, 1998), are important for reconstructing the size of ships, this will help approximate the capabilities of vessels of this type. These have led to some studies featuring experimental archaeology to rebuild ancient ships based upon iconography and the preserved remains of the hull, to test the capability of these ships against ancient testimony, a major example of this is the reconstruction of a trireme, dubbed the Kyrenia (Katzev, 2005).

It is important that ancient ships can be reconstructed, to ascertain the ships' aesthetic, and the possible functions of the ship, both of which are key to determining the ship's purpose.

Developments in shipbuilding such as methods of joinery, and the style of construction are important aspects of reconstructing a ship. Steffy (1994), is a thorough examination of shipbuilding using a number of examples chronologically. Steffy also goes further in depth and is a broad source on wooden ship building in general from the ancient world onwards. Furthermore, developments in ship building, in particular the transition from shell first to skeleton first construction are discussed in detail by Pomey, Kahanov and Rieth (2012).

When discussing the physical capabilities of ships, such as the speed and the performance in weather conditions. Casson (1995) is once again useful, addressing this topic with a specific section based upon the accounts of roman voyages. Giesecke (1983) compares his own rowing experience and correlates this against the ships depicted in the Thera fresco, this is a tenuous source however. The use of experimental archaeology, in particular the Kyrenia sea trials indicate a reliable source for the performance of sailing ships of this period. These were documented in detail by Steffy (1994).

GIS in Archaeology

GIS and its uses in archaeology has been discussed at length, particularly by Connoly and Lake (2006). The technology's use specifically for modelling maritime networks, involving environmental data is more niche, but has been the subject of studies focused on Polynesian colonisation (Irwin et al. 1990). Indruszewski and Barton (2008), utilised environmental data alongside historic accounts to provide plausible routes for Viking voyages in GIS. Finally, the study from which the current methodology takes origin from Leidwanger (2013) provides a useful methodology of analysing maritime networks, utilising works such as Morton (2001) for help with environmental data. This is the methodology mainly being utilised by this thesis, and has been underused since its conception.

Overall, GIS provides an analytical tool for monitoring ancient maritime networks, and can be utilised in tandem with environmental data in order to simulate these routes. Leidwanger (2013) highlights a nuanced study modelling different types of ship over different periods would be a natural successor to his methodologies.

The Ancient Environment and Climate

The ancient environment has also been a specific topic of interest for a number of studies, some directly link to GIS, such as Safadi (2016), who discusses the merits of modelling wind and waves in GIS. Murray (1987), discusses the issue of similarity between modern and ancient winds, concluding that there has been little change, thereby validating the use of modern wind data that will be highlighted in this dissertation's methodology. Morton (2001) discusses the role that the physical environment played in Greek seafaring, this includes the winds, as the primary mechanism for propulsion, and discusses the best times for sailing. Although the literature surrounding the ancient environment, with regards to seafaring is not in abundance, the referenced works provide a useful basis to work off of, particularly, Murray's analysis that ancient and modern winds are equal is the most valuable for the present study.

Overall, this literature review has displayed the most prominent discussions of areas concerning the subject of my dissertation. Furthermore, it highlights that the dissertation is targeting an area that, previously has had little scholarly exploration, however the extent of discussion of the Cyclades, networks, maritime archaeology and the GIS that surround this thesis are adequate to provide validation.

A General History of Mediterranean Seafaring

The Mediterranean is one of the world's earliest primary focal points for maritime activity, serving as the link for many cultures to engage in trade, warfare and diplomacy. The name of the sea originates from the Latin terms *medius,* meaning middle and *terra,* being land. The Mediterranean was naturally suited for seafaring, and was an ideal basin for maritime activity (Rauh, 2003). As it is the geographical setting for this study, the aims of this chapter are to discuss a general history of seafaring on the Mediterranean from its earliest point in the Palaeolithic to the development of the earliest networks. The focus will primarily be on the eastern Mediterranean, but the bigger picture will also be regarded. This development of trade networks in the Mediterranean will be highlighted using related archaeological evidence to support.

Firstly, seafaring in the Mediterranean has been undertaken since prehistory. It can be argued that the first evidence of seafaring on the Mediterranean took place in the Middle Palaeolithic (Broodbank, 2006, 204. Polzer, 2011). Stone tools from this era have been found in several groups of the Greek islands in the Sporades, Ionian Islands and potentially the Cyclades (Broodbank, 2000: 99. Broodbank, 2006). Consequently, this infers that during the Middle Palaeolithic, a degree of island hopping was being undertaken as a form of human colonisation of these islands, although some of these islands would have been linked to the mainland via a land bridge, some were not and likely had a distance of about 10km of sea separating them (Broodbank, 2006).

Likewise, comparisons between lithic finds from Morocco and Spain entails a *terminus post quem* for the crossing of the Gibraltar Strait at 300,000 years ago (Marcus, 2002). Interestingly, populations who colonised these areas may not have been *Homo Sapiens* and instead are likely to be *Homo Neanderthalensis.* This assertion is supported by the Neanderthal site at Abric Romani, Catalonia, in which fragments of wood, fashioned for an unknown purpose were found (Broodbank, 2006, 5). Ferentinos et al. (2012) also argue for the Neanderthal colonisation of these islands during this period. However, this would have still required some form of sea going transport to traverse the sea,

these distances would have been around 10km at their longest, and suggests a degree of sea crossing ability. Although no archaeological examples of these craft have been discovered, it is possible to infer what may have been used from contemporary ethnographic examples. For example, simplistic water transport can and has been made by indigenous populations out of a multitude of materials, such as papyrus vessels in Egypt, to the simple act of carving a canoe out of a tree trunk (Simmons & DiBennedeto, 2014. McGrail, 2004).

Further, the first anatomically modern humans to enter the Mediterranean occurred during the Upper Palaeolithic, beginning in the Levant and north eastern Africa (Broodbank, 2006). However these populations' movements were largely terrestrial, indicating a lack of marine colonisation. In contrast, the site of Fontana Nuova on Sicily indicates the first definite sign of seafaring in the Mediterranean during this period, dated at around 30,000 years old (Chilardi, et al. 1996). Furthermore, Palaeolithic seafaring is evidenced by sites on Sardinia and Corsica, which would have required some form of seafaring to enable colonisation. Overall, though the expanse of Mediterranean activity in the Palaeolithic was very slight, seafaring was undoubtedly being undertaken by early hominins.

Next, evidence for seafaring continues through the Mesolithic, Strasser et al. (2010) discusses 28 sites in south west Crete dating to Mesolithic and late Palaeolithic contexts, furthermore, due to the separation of Crete from any landmass further supports that these early colonisers must have used some seagoing vessel to get to the island. The same can be said for Cyprus, an island that has previously not been connected to a landmass (Broodbank, 2006), yet has evidence for Mesolithic and upper Palaeolithic activity, including fishing (Knapp, 2010). The evidence for human settlement on the island and exploitation of marine resources further supports the sentiment that early humans crossed the seas in order to colonise lands. In terms of the Neolithic, evidence for long distance seafaring with the intent of colonisation is limited, likely due to these areas being colonised in earlier periods.

As aforementioned, no physical evidence for seagoing craft survives, however preserved dugout canoes from North Africa, with the addition of experimental archaeology allows us to assume that these would have been the types of vessels utilised by early humans (Broodbank, 2006). In terms of the Neolithic, not much evidence for long distance seafaring with the intent of colonisation is on record, with the exception of the colonisation of Cyprus (Bar-Yosef Mayer, et al. 2015: 412). However there is evidence for continued marine exploitation across the Mediterranean. As an example, Molluscs were a resource exploited heavily across the entire area (Colonese, et al. 2011).

The Aegean and Greek islands is a setting for early seafaring and networks in the Neolithic, Broodbank and Strasser (1991: 241), show that agriculture was introduced to Crete by a process of colonization, though the origin is not certain, it is postulated that Anatolia is the likeliest candidate. This was achieved with a flotilla of longboats, carrying cargoes of livestock. The specific technologies of the ships of this period will be discussed in the next chapter.

An important development of this period is an early network of trade in obsidian across the Mediterranean, the source of which were the islands of Sardinia, off coastal Italy (Farr, 2006) and also Melos in the Cyclades (Polzer, 2011). Obsidian originating from this point has subsequently been identified in regions across the Mediterranean, such as the Italian peninsula, the Adriatic and North Africa (Farr, 2006). The large spread of obsidian across the Mediterranean from this point suggests the presence of a prehistoric maritime trade was valued network (Farr, 2006). This is because the obsidian trade could not have become so widespread across the Mediterranean without the use of boats, and serves as a predecessor for later and more complex maritime trade in the Mediterranean.

Overall the evidence for prehistoric seafaring is substantial, the early beginning of seafaring is an indicator of the lengthy history of seafaring in the Mediterranean. Furthermore, the presence of a prehistoric trade network for obsidian is highly significant, as it shows that seafaring had already matured to a point that long distance maritime trade could be undertaken within the Mediterranean.

The Cyclades Islands

The Cycladic islands originally received their name from a number of ancient authors, one such author, Kallimachos imagined that the islands formed a *kyklos* around Delos, the Ionian centre (Broodbank, 2000: 69). Despite sharing the same geographical area and archipelago, the varying islands of the Cyclades differ from each other in a number of ways. The physical geography varies from island to island, and the types of resources, such as minerals, arable land, and drinkable surface water also differs. Furthermore, the archaeology on each of these islands and the human impact on each of the islands is not uniform. This chapter aims to survey not all of these islands, as they number at around 220, but the most archaeologically significant, focusing on the southern Cycladic islands. The main areas of interest will be the physical geography, what resources, minerals and other assets are present on these islands that was exploited? Furthermore, what archaeological evidence exists and whether there are noticeable differences in the occupation history/occupation patterns of the islands?

Finally, the ideas of the Cyclades as a network (Broodbank 2000), of islands for the exchange of resources such as obsidian from Melos (Farr 2006, Georgiadis 2008), as well as evidence for Minoan influence on the Cyclades, during the Late Bronze Age will be examined.

Generally, the environment of the Cyclades differs from the wider Aegean. Broadly speaking the islands have very little arable land and the smaller islands suffer acutely from this problem (Broodbank, 2000: 76). Furthermore, the availability of freshwater also varies, with more frequent occurrences on the larger islands, and the Cyclades suffer from unpredictable rainfall, which is the lowest in the southern Aegean (Broodbank 2000: 78). For example if the conditions of modern Melos are reflective of the ancient environment, droughts could occur once a decade, which would be devastating for an isolated population.

Lastly, the Cyclades make up for their lack of arability with large quantities of mineral and lithic resources, these resources allowed for a network to occur, across the islands, rather than limiting

populations to the most fertile lands. Broodbank (2000) categorises the islands into marble dominant, schist dominant and volcanic geologies. However, specific resources are distributed unevenly. For example, as identified, obsidian is restricted to two known locations in the Cyclades. Furthermore, the Cyclades are renowned for large amounts of metal resources, including copper, silver and lead. Mining activity in this region can be dated with a *Terminus Post Quem* of the Early Bronze Age, and possibly earlier (Broodbank, 2000).

These brief surveys are not intended to be exhaustive, but instead to give the reader an impression of each island's main geographical and archaeological make up. The order that the islands are discussed in relevance to this dissertation, with the more relevant islands being discussed first, consequently these islands also have more previous scholarly discussion.

Melos

Melos is renowned for being a major source of obsidian, interestingly, obsidian from Melos has been circulated around the Aegean and into Anatolia from as early as the Upper Palaeolithic (Farr, 2006: 88). This is undoubtedly one of the earliest examples of a trading network, which would have required seafaring in order to be possible. Moreover, due to the volcanic environment of Melos, the island is also rich in volcanic rocks such as basalt.

Archaeologically, Melos has been colonised since the Mesolithic, possibly because of the source of obsidian present on the island (Cherry & Torrence, 1984). These were likely followed a sporadic settlement pattern. The Bronze Age bought a transition from scattered farming settlements into larger settlements with a more condensed population. Despite this, metal finds remain a rarity on Melos (Renfrew, 1984). During this period, one major site is active, Phylakopi, on the northern coast of the island. This settlement took on an urban form early in the Bronze Age, and is recognised as an early city. From this, nucleation of smaller farming settlements around Phylakopi occurred. Consequently, it can be inferred that during the Earlier Bronze Age, Phylakopi was the dominant

settlement on Melos. Broodbank (1993: 318) argues that the settlement was possibly a fourth trading centre operated by the Keros-Syros culture, that will be elaborated on later in this chapter.

By the Late Bronze Age, Phylakopi was a large fortified town, comparable to a citadel. The site remained the only inhabited large settlement on Melos, a plan of the site can be seen in Figure one (Renfrew, 1984). Furthermore, the finding of two fragments of a clay tablet with Linear A script, which infers that contact between Melos, and by extension the Cyclades as a whole was established with the Minoan culture on Crete (Renfrew, 1984).

Keros

Situated to the South East of Naxos, Keros' geology is mainly of Alluvium (Broodbank, 2000). Archaeologically, the settlements at Dhaskalio and Kavos stand out. The earliest finds dated to the Keros-Syros culture (Renfrew, Boyd & Ramsay, 2012: 145). This culture was present in the Cyclades during the Early Bronze age, particularly the EC II phase, and will be discussed in further detail later.

The settlement at Kavos likely flourished between 2750 – 2550 BCE, with evidence of large scale cult activity and likely served as one of the first maritime sanctuaries in the area (Broodbank, Boyd & Ramsay, 2012). Furthermore, a large hoard of cycladic figurines were discovered at the site, these were possibly a votive assemblage. Moreover, Broodbank (1993) suggests the site was an important trading site for the Keros-Syros culture, which could be another explanation for the large hoard of figurines.

Syros

Located North West of Paros, Syros' geology is largely typical with mainly metamorphic stone.

Archaeologically however, Syros is more interesting. Broodbank (1993: 323), highlights one such site, Chalandriani in the mountainous area of NE Syros as a trader sight. This is because the site is large in size, and rich in marble, metal and pottery finds. The site consists of two domestic sites and one large cemetery, one such settlement is located on the Chalandra plateau. The large cemetery is

located across the entire plateau and was used by both settlements. It is the largest early cycladic burial ground known, with rich graves that concur with the assessment that the site was of the Keros-Syros culture (Marthari, 2017: 304). The presence of the large cemetery aswell as two large urbanised settlements is highly indicative of the importance that Syros and Chalandriani played for the Keros-Syros culture.

Thera

Thera is also known commonly as Santorini, the southernmost of the Cycladic islands. The Island's geology is mostly formed of volcanic rocks (Broodbank, 2000: 80). Before the eruption of the volcano, Thera's environment was diverse and featured oak trees, olive cultivation as early as the Bronze Age, and there is evidence of imports of foreign woods, such as Lebanese cedar (Asouti, 2003: 474).

Archaeologically, the settlement at Akrotiri stands out for its remarkable preservation, namely, Thera stands out for the most overt evidence of association with Crete during the Bronze Age, and is a prime example of 'Minoanisation' occurring, that shall be discussed more in depth later. Evidence of Early Bronze Age marble figurines of various cycladic types from Akrotiri show that the area was inhabited by a cycladic culture, or contact had been established at this point (Sotirakopoulou, 1998). This is corroborated by the large quantity of Early Cycladic pottery discovered at Akrotiri (Sotirakopoulou, 1986). This suggests that the settlement was definitely active by the Early Cycladic Period, and through to the Late Cycladic and Bronze Age periods before the collapse caused by the eruption of the volcano.

Paros

Paros is one of the most important islands in the Cyclades, and the wider Aegean, it is the third largest in this group at 250 km^2. The island's early archaeology is characterised by the early cycladic culture, settlements during this period are a rarity, with only five identified, namely Koukonaries in

the north of the island and Kastro on the eastern side near the modern capital Paroikia (Katsarou & Schilardi, 2004). Even though, cemeteries from this period are more numerous, this is likely due to the situation where underground graves are more likely to survive than a settlement.

Paros is renowned for its unique source of marble. Parian marble is regarded as high quality marble along with the marble present on Naxos. Relating to marble figurines, an artefact indicative of this period which are often made from Parian marble, the type depicting a figure with folded arms is associated with the Keros-Syros culture. Three examples are present in Paros' museum, however there are no accurate associations for their provenance on the island (Renfrew, 1969).

Antiparos

Originally connected to Greater Paros via a land bridge, Antiparos has large quantities of metamorphic rock, namely schist, Gneiss and Amphibolite. However there is not much difference between Antiparos and Paros in terms of geographic environment.

Naxos

The largest and most central island in the Cyclades at 420 km^2, Naxos is also one of the most important. It benefits from a varied geology, containing a mixture of quality marble, granite, metamorphic rock, and deposits of Alluvium, Neogene, and finally a source of Emery on the eastern side of the island (Broodbank, 2000: 80).

Archaeologically, some of the earlier large settlements include Grotta, a coastal settlement in the North-West of the island, which was inhabited from the Neolithic, EBA, MBA and LBA (Cosmopoulos, 1998). Large costal settlements operating during this period is Mikre Vigla and Rizokastellia on the West coast of Naxos, aswell as a number of inland sites, Cosmopoulos (1998) suggests that these are food production sites, whereas Grotta and Mikre Vigla are gateways for trade, and larger settlements. By the LBA however, Grotta is identified as the main settlement, while the former settlements declined (Broodbank, 2000: 327, Cosmopoulos, 1998: 141). This represents a transition

from a large number of sites during the Early Bronze Age, a decline during the EBIII period, with an emergence of newer, but overall less settlements during the Middle Bronze Age (Broodbank, 2000: 327).

Amorgos

Amorgos' geology mostly consists of Permian limestone for much of the east and centre, and marble and granite in the western side of the island (Broodbank, 2000: 80).

Archaeologically, Amorgos is known for material dating to the Early Cycladic period. Early investigations were concentrated on the many cemeteries present on the island, dating back as far as the early cycladic period (Galanakis, 2013: 181). These indicate a further number of settlements on Amorgos dating to the early cycladic period. Furthermore, Marangou (1983: 101), shows that a number of marble figurines made of locally sourced marble were sculpted on Amorgos, as well as figurines sculpted from Parian marble also being present. This suggests that Amorgos was in contact with other islands within the group, and was part of a network.

Siphnos

According to Broodbank (2000: 80), Siphnos' geology is mostly comprised of metamorphic rock, but also an early source of metal in the northern area of the island. The main metals produced from Siphnos were silver, located at Ayos Sostis (Wagner, Gentner & Gropengieser, 1979:157). Moreover, lead and possibly copper were also mined on Siphnos. Gold was also present, but there is no evidence that it was exploited during the Bronze Age (Broodbank, 2000).

Archaeologically, these sources of metal, particularly silver were exploited as early as the Bronze Age (Wagner, Gentner & Gropengieser, 1979). Unfortunately, there is very little information on the wider archaeology of Siphnos, particularly concerning the Bronze Age.

Kythnos

Another important metal source, Kythnos is renowned for its deposits of copper, as well as metamorphic stone.

Kythnos has been inhabited from the Mesolithic onwards (Poulianos & Sampson, 2008: 187). There was a marked increase in activity, including mining activity by the Early Bronze Age. It is possible, that the mineral resources on both Kythnos and Siphnos drove the colonisation, and subsequent intensification (Broodbank, 2000: 80).

Dominant cultures and networks in the Cyclades

Having established the main islands and any distinguishing archaeological sites and resources present, it is now important to contextualise this with a discussion of the varying cultures and networks that operated in the Cyclades, as 'cycladic culture' is a blanket term, which conceals both chronological and regional differences. The two main cultures discussed will be the Keros-Syros culture and Minoan culture. Although a culture known as 'Grotta-Pelos' culture occurred just before the Keros-Syros culture, and is present particularly on Melos (Broodbank, 1989: 321), it is not as relevant to this current study because, the Keros-Syros culture is a more nuanced and developed network. Therefore, the Grotta-Pelos culture is a precursor to Keros-Syros, it does not necessarily differ drastically in terms of maritime transport technology.

Moreover, the nature of these systems will be discussed, can they be seen as a more coercive thalasocracy, or more of a connected network, that changes by a process of veneration, in example the concepts of 'minoanisation'? These networks are the central factor in the present study, without them there would not be an increased occurrence of maritime travel in this geographic area, and therefore would not warrant this study.

Keros-Syros Culture

The phenomenon known as Keros-Syros culture equates chronologically to the EBII period, a period between 2500 – 2200 BCE. As Broodbank (2000: 54) highlights, it is the only culture present across the entire Cyclades. This can be visualised in figure two, which also highlights the locations of some sites discussed in the following text. In terms of material culture, Keros-Syros is defined by a number of items. In particular, common forms such as 'sauceboats', collared jars and rarer symbolically driven objects such as the aforementioned frying pans, often adorned with imagery of boats. Furthermore, the Keros-Syros culture is linked first metal weaponry and jewellery in the area, aswell as folded armed marble figurines. These do not reflect the overall material culture of Keros-Syros however (Broodbank, 2000: 54).

Another key aspect of Keros-Syros culture is the importance of maritime trade, and the eventual network established in the Cyclades (Broodbank, 1989, 1993). This trade was primarily achieved using longboats, as will be discussed in a subsequent chapter with the depictions on frying pans in, these types of long boat will also be the focus for one of the models generated. Broodbank (1993: 317) suggests that three sites are specifically important for this trade: Dhaskalio-Kavos on Keros, Chalandriani on Syros, and finally Ayia Irini on Kea. A fourth site was probably located at Phylakopi on Melos (Broodbank, 1993: 318). These sites boast greater quantities of marble, metal and pottery finds, and were likely dominant during this period because of some of the following reasons: They are all located in close proximity of other islands, so that they can be established as central settlements, and surrounding islands with their smaller settlements can act as satellites. Harbours are not necessarily important due to the nature of the seaborne transport being a long paddled vessel.

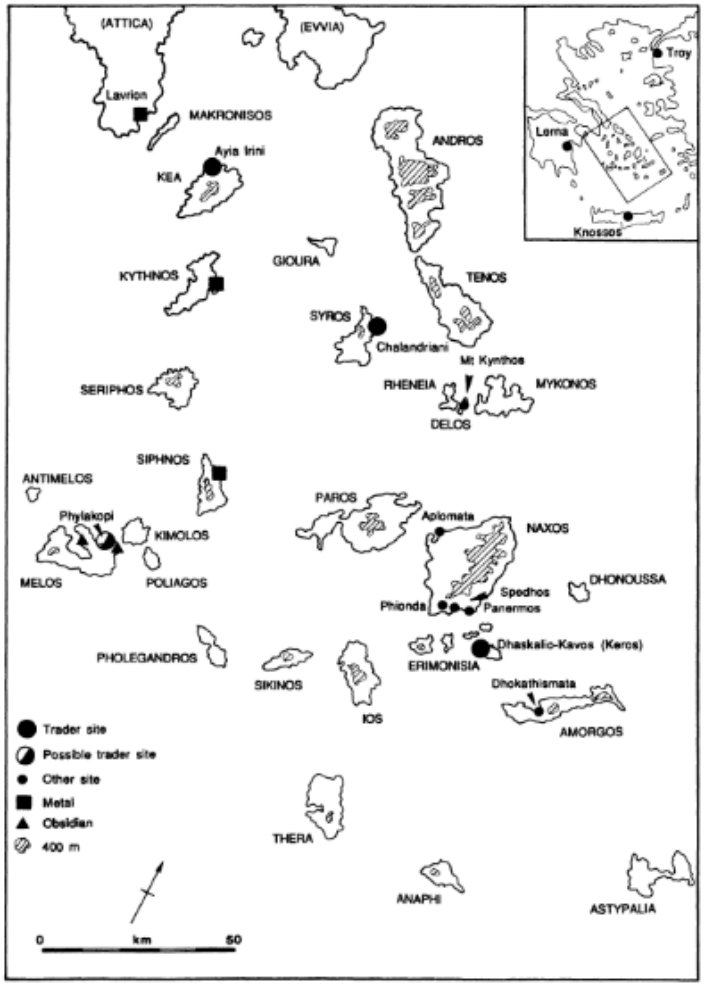


Figure 3: Map of the Cyclades during the Early Bronze Age, featuring the names of site discussed, and key resources (Broodbank, 1993, 317).

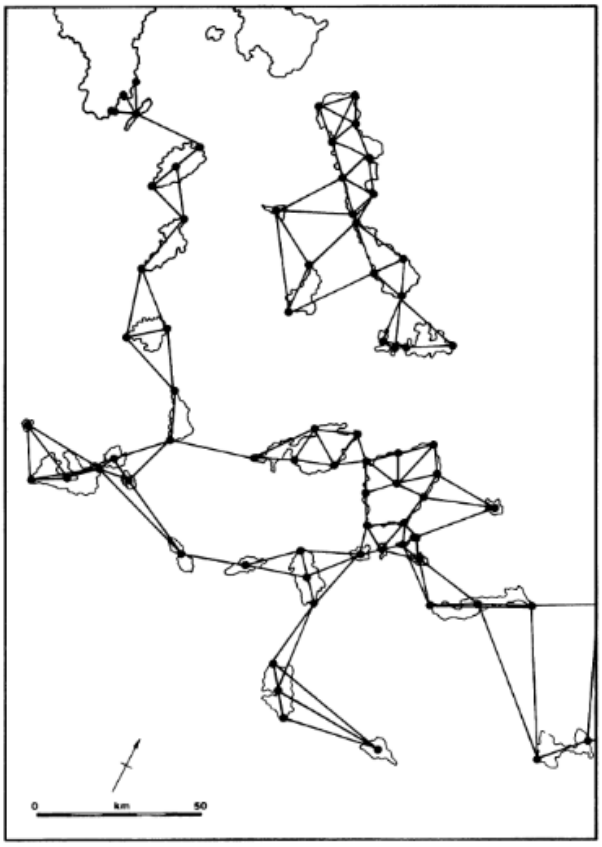


Figure 2: Proximal point analysis showing island connections in the Cyclades during the Keros-Syros culture (Broodbank, 1993, 320).

Moreover, these were all large urban settlements, and although situated further away from natural resources, they could likely control the influx and secondary production of objects from the incoming material. Furthermore, each of these settlements are largely central to island groups within the Cyclades, suggesting that they acted as centres not just on their own island, but for the surrounding islands. Furthermore, having multiple centres, acting as a central place for an area of the Cyclades is more practical, as it negates the need for long distance voyages, this is clear in figure three, which depicts a proximal point analysis, linking sites to each other in the Cyclades.

This entails that seaborne trade was massively important for the Keros Syros culture, utilising central settlements as trader sites or as a centre of distribution, they could use these sites to reach most other islands, including the mainland from Ayia Irini. Therefore, seaborne trade and maritime movement are directly at the Keros-Syros' source of power in the Cyclades Broodbank (1993, 323).

Overall, the Keros-Syros culture is massively important for understanding the Cyclades, and the development of networks in this area. Furthermore, this serves as a precursor to the Minoan expansion and influence upon the Cyclades, particularly in terms of the importance of maritime travel.

Minoan

The first introduction of Minoan culture in the Cyclades occurs early in the Middle Bronze Age, coinciding with the Middle Minoan 1B period in Crete. The appearance of Cretan palatial styled pottery first appeared in small numbers and became more numerous toward the end of this period. These imports are present in large quantity at Phylakopi on Melos and Agia Irini on Kea (Broodbank, 2000: 358, Earle, 2016). Moreover, Minoan influence also affects the architecture present at Phylakopi, with the introduction and use of pillar crypts, a form of architecture only present in central Crete at this point (Earle, 2016: 110). Therefore it can be suggested that inspiration is taken directly from Crete in this sense.

Schofield (1982), states that the western islands, Kea, Melos and Thera are the main areas of influence and information flow from Crete, moreover they also act as a corridor for Cretan trade with the mainland. This would suggest that two of Broodbank's 'centres of trade' from the Keros-Syros culture maintained cultural importance and role as a distribution centre, due to their location in trade networks. Thera was a new addition to this, but it was also in an advantageous position where it could easily launch maritime venture to the central islands and western islands of the Cyclades.

Cretan presence is also noted in the central Cyclades, albeit in lesser scale, particularly on Naxos and Delos, which are subjected to Minoan imports, in particular these appear at the site of Grotta on Naxos (Cosmopoulos, 1998: 132). However, these are likely to have come as a product from the previously mentioned western islands (Schofield, 1982: 10). Moreover, other evidence for assimilation into a Minoan network, such as Minoan architectural styles, is lacking, (Cosmopoulos, 1998: 143), if there were direct contact we would expect evidence for the exchange of information and ideas. Therefore, the presence of Minoan wares on Naxos and other areas of the Cyclades are likely due to the secondary distribution from the western islands. Furthermore, Melian wares were still distributed alongside Minoan wares, suggesting that this remains a cycladic endeavour of secondary distribution.

The evidence suggests that the Cyclades were incorporated into a Minoan network in a role of transiting between Crete and the mainland (Schofield, 1982: 16). This designation is incredibly generalised, and seems like a continuity of the Keros-Syros model, in which large urban centres are responsible for distribution, yet they are incorporated more as ports of call for Minoan ships, and in turn act as secondary redistribution centres for the wider Cyclades and the mainland.

What caused this process of interaction between Crete and the Cyclades? There remains a debate between the aggressive expansions from Crete, equating this relationship to a thalasocracy. This is met against an argument of Minoan cultural growth and influence on the Cyclades. Broodbank

(2000) postulates that Cretan aggression was a prime factor in Minoanisation, highlighting that Phylakopi entered a period of destruction and desertion, before re-emerging with a new pottery tradition and close contacts with Crete. This was originally believed to have been due to an earthquake (Barber, 1978). However, as Broodbank points out, this does not account for the interruption of material culture. It is important to note however, that the new occupants remain very much cycladic, and are not a Cretan colonisation (Broodbank, 2000). This may have been limited to the southern islands however, as further north in the Cyclades, at Ayia Irini on Kea older cycladic traditions that ceased at Phylakopi are continued, such as the production of duck vases, despite being included in the Minoan network, suggesting Cycladic autonomy is still in effect.

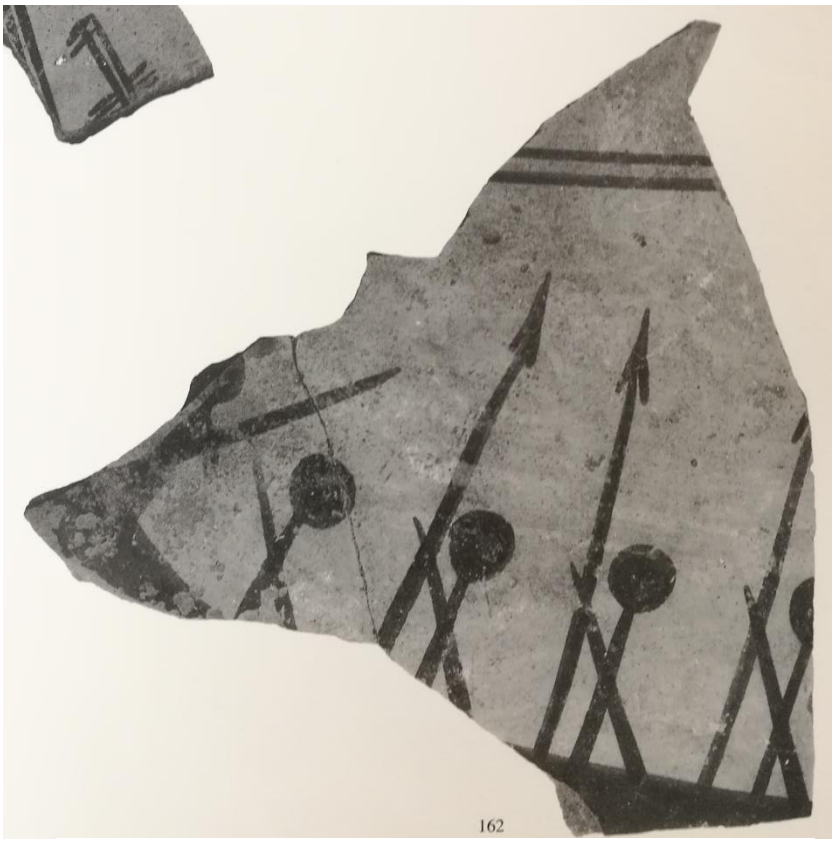


Figure 4: Ceramic from Aegina showing scenes of seafaring. Note the overt presence of weaponry (Siedentopf, 1991: Tafel 38).

Moreover, new types of wares are produced elsewhere in the Aegean, at the settlement of Kolonna, on the Saronic island Aegina, though not a Cycladic island is still relevant. A newly fortified, settlement is established, moreover a new material culture of wares depicting ships with warriors and weaponry emerges (fig 4). This new representation is indicative of some sort of aggressive activity occurring in the Aegean at this time, and adds credence to the possibility of Minoanisation through initial aggression as postulated by Broodbank.

Overall, The Cyclades were incorporated into the Minoan system likely as centres of distribution much like the earlier Keros-Syros system. A shift on emphasis focused on the western Cyclades as

the quickest corridor to reach the mainland, however other cycladic islands were in contact, likely due to secondary distribution from Melos.

To conclude this chapter, The Cyclades benefitted from a range of mineral resources that were massively important for any networks present in the area. This inevitably led to the rise of networks that drew most of their power from the ability to maintain maritime activity, and without this maritime component would not have been established. The information provided suggests that the models from this dissertation could focus on the Keros-Syros system of long boats originating from centralised settlements and islands, and the later Minoan system, focusing on the link between Crete and the Cyclades. As will be addressed, how does a difference in sailing technology affect these systems?

Bronze Age Harbours in the Aegean

The ability to provide safe harbour for a ship is integral for maintaining a system of maritime contact. Therefore, settlement positions are likely determined by a proximity to a natural harbour, in order to benefit from this trade connection. This chapter's aim is to discuss the typical features of an ancient harbour, whether any artificial harbour facilities were utilised, and key examples. The focus is to remain in the Cyclades, but examples from the wider Aegean may be utilised where necessary. Did the onset of maritime networks by the early Bronze Age coincide with the first harbour works in the Cyclades? This is important, as the present study is focusing on two different types of vessel, therefore with the development of ship building in this area during the Bronze Age, did these ships require more nuanced harbour facilities? Moreover, as the Bronze Age continues, a development in harbour facilities must also occur if necessary.

Typical features of a harbour that had been developed include architectural features such as moles, quays for ships and boats to moor against for offloading of goods and passengers. Onshore facilities such as ship sheds would also be pertinent, to allow essential maintenance and repair of vessels to take place.

Early Bronze Age

As Shaw (1990), points out, there is a preference for settlement location on or near peninsulas, highlighting the example of Ayia Irini, on Kea. In this example, the peninsula sits well within a sheltered bay, ideal for birthing ships and boats. This location would give mariners the possibility of either beaching their ship, or anchoring on either side of the peninsula dependent on the state of winds. Another example of settlement location on a peninsula in order to receive trade can be suggested at Phylakopi on Melos, however much of the coastal portion of the site has eroded (Shaw 1990). An alternative example of an area for settlement is suggested to have been on a coastal area with access to an offshore islet, this type of siting can be seen at the site of Dhaskalio-Kavos on

Keros. For the Cyclades however, the Early Bronze Age is unlikely to yield any remains of harbours dating to this period. Broodbank (2000) postulates that due to the usage of the paddled longboat. The natural harbours that settlements aligned themselves with would have been enough, and there was no requirement for any further artificial works.

Conversely, Broodbank did not rule out the presence of storage sheds for boats and equipment in these coastal areas. So what are the merits for the use of this type of structure in the Early Bronze Age?

These types of facilities were very common in later periods, as will be discussed, but there remains little evidence so far for their use in the Early Bronze Age.

Late Bronze Age

Moving away from the Early Bronze Age, much of the evidence for harbours with artificial harbour facilities comes from Crete. A number of coastal sites on the northern coast were established by the Minoans. Two such examples include Gournia, on the Eastern side of Crete, and Kommos, on the southern side of Crete. Gournia is a settlement in Eastern Crete, originally excavations only concentrated on the fortified settlement inland. However later survey and field work revealed the nearby harbour town to also be fortified, features monumental ship sheds, a cobbled street leading to the settlement, a dam in the nearby river, with a gate, and a wall extending between the harbour and town, and costal walls to protect the coast (Watrous, 2012). This entails some of the first harbour works and protection of the harbour, which was not identified in earlier coastal sites in the Cyclades, where only the settlement itself was fortified against attack from land (Shaw, 1990). This possibly highlights that the Bronze Age saw a transition in threat, during the Early Bronze Age, threats were more likely to attack via land, rather than from the sea. Whereas the Late Bronze Age saw a combined threat of attacks that could come from either land or sea. Therefore, fortifying closer to the harbour, and also the river adjacent and the coastal edge, in order to form a defence with depth, was an essential aspect of defence for a settlement for the Late Bronze Age.

Next, The Minoan harbour site of Kommos, located on the southern side of Crete, was a large harbour settlement, with significant evidence of long distance maritime trade connecting Crete to the Aegean, Eastern Mediterranean and Egypt (Day, et al. 2011). The large amount of evidence is possibly due to Kommos' location as the main harbour and approach to the Messara Plain, and Phaistos (Shaw, 1990). Next to the shore, an enormous palace like building stood, however it likely did not function like a palace, due to the lack of religious or domestic areas, aswell as areas for reception of guests (Shaw, 1984). Therefore, its use could be directly connected to the harbour, possibly as a central administrative area, dealing with the bureaucratic side of harbour operations. Moreover, another structure is present at the site designated 'P', this structure consists of four galleries, 5.6 metres wide, built on an east – west alignment, with their western side open to the sea. This description is very similar to that of a ship shed, where ships can be moved into for protection from the elements, particularly out of sailing season, and for any essential maintenance and repair. This is a view that Shaw (1985) shares. It is much stronger than the previous assertion that the sheds are for storage of goods such as grain and wool (Shaw, 1990). However, it would make more sense to store these further away from the sea, and not have the entrance to their storage facing the seas.

Overall, this discussion has indicated that during the Early Bronze Age, when the Keros-Syros longboat was in use, harbours relied mostly on the natural protection afforded by the environment. This entails that the longboats did not require a specific area to moor, but could be beached when necessary. Furthermore, coastal settlements were situated near these natural harbours, but remained fortified independently. Moving forward, by the use of sailed ships, particularly by the Minoans, harbours were more nuanced. They featured ship sheds for the storage of vessels, and the fortifications of settlements incorporated the harbour, highlighting the importance of a specific harbour. This is likely because of the more complex construction in the ships, they cannot simply be beached but require calmer conditions to moor in or storage.

Ships and Ship Building in the Mediterranean

As one of the earliest maritime foci in the world, early evidence for boats and ships in the Mediterranean suggest that they were an early development in prehistory. Furthermore, as previously discussed, given the nature of the Mediterranean, areas such as the Cyclades islands could only have been colonised through the use of seagoing vessels, as early as the Neolithic. They would have been essential for the networks of trade and communication between the varying societies bordering the sea. The earliest representations of boats occur in different areas of the Mediterranean, such as Predynastic Egypt and The Cyclades, suggesting that the introduction of seaborne transport took place independently across the Mediterranean. This chapter will explore the development of ships and boats in the Mediterranean, focusing on the earliest representations from Predynastic Egypt up to later representations in the archaic period, and what information they reveal about ship building in the Mediterranean. Next, the focus will be on the physical remains of boats and ships recovered, with particular attention to the some of the best recorded and most relevant vessels, including the Cheops barque from Egypt, the Late Bronze Age Uluburun and Cape Gelidonya vessels and finally the Kyrenia vessel. The remains of these vessels provide key information as to the methods of Mediterranean ship building, and how these methods as well as vessel forms evolved through time.

Basic methods of ship building and key parts of the ship

Boats, ships and hull form

Hull form relates to the basic outline shape of the hull, and can be affected by technical knowledge, materials available and other factors including cargo, intended routes and environment (Steffy, 1994: 11). Moreover, the hull form of a vessel has a significant effect on the vessel's performance, particularly if travelling upwind (Whitewright, 2011). If a vessel sits deeper in the water, it will generally perform better and be more stable. The distinctive shape of hulls is influenced by the

geographical area from which the ship originates, and also the features that prove beneficial to the ship based on the environment for which it is designed to be used. One such example are the Dashur boats, originating from 12th dynasty Egypt, these follow the most basic hull form, also Classified as a papyriform hull and feature a keelless, gently-rounded bottom that rises slightly at the bow end (Steffy, 1994, 12). This was likely determined by their use on the Nile rather than open-water seafaring.

In contrast, the Kyrenia ship, Dating to the 4th century BC, features a more nuanced hull form and was likely typical of merchant vessels of this period (Steffy, 1994). This vessel included a keel, forming a v-shaped hull that sits deeper, which is one of the most prominent developments in ship design. The bow of the ship is set higher than the stern, to allow the vessel to ride higher in the sea in rougher conditions. This key difference between the Dashur boats and the Kyrenia ship highlight the features of hull form based on differing environments. The Dashur boats, designed for calmer waters of the Nile, did not require features such as a keel, or greater curvature to support load bearing (as they were funerary boats). They were however completely unsuitable for long distance sea faring, they are regarded as boats. The Kyrenia ship in contrast is regarded as a ship because of its capability to travel over sea, and is therefore regarded as a ship.

Carvel and clinker

The two main methods of building a planked vessel are carvel and clinker. In carvel ship building, planks are placed edge to edge so that seems are smooth and aligned, usually joined by a carvel joint (Steffy, 1994, 268). However in the ancient world mortise and tenon joinery was more common (joinery will be discussed subsequently). Conversely, clinker construction, also known as lapstrake is the process of ship building in which the outer planks overlap each other, and are fastened to the plank below it, however, this method of construction is mostly limited to North-western Europe until the wider use of carvel in the medieval periods (Steffy, 1994, 100).

Methods of joinery

Two main methods of joining planks were used in the Mediterranean. These methods were the sewn plank tradition and the mortise and tenon method (Pomey, Kahanov & Rieth, 2012). Sewn plank tradition is likely to have been one of the earliest methods of joinery. Planks were sewn together, and frames lashed to the planking in order to secure them. Sewing alone was not enough to secure the vessel, and this method was often used in conjunction with a fixed tenon, as seen in the Pabuç Burnu vessel (Pomey, Kahanov & Rieth, 2012: 292). Figure five shows a typical example of sewn planking on the Cheops vessel.

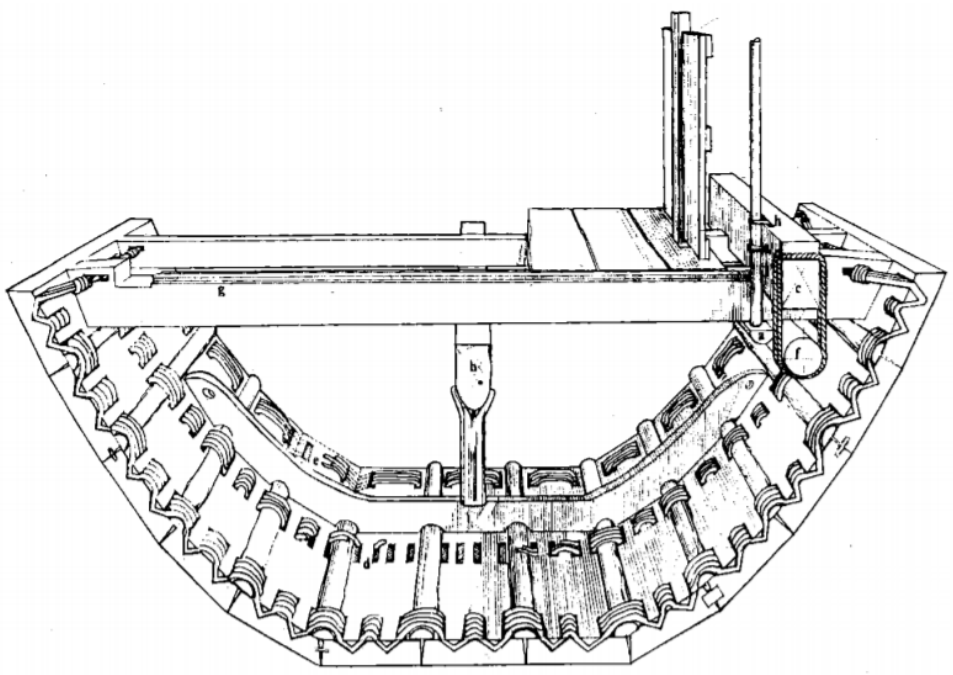


Figure 5: Typical example of planking being joined via sewing, from the Cheops vessel (Steffy, 1994, 25).

Mortise and Tenon joinery is one of the most common in earlier vessels. This involved creating a notch in the plank that a mortise was inserted to, and then pegged in place for extra stability, likely with a treenail. In earlier vessels such as Uluburun, Mortise and tenon joints were large and more

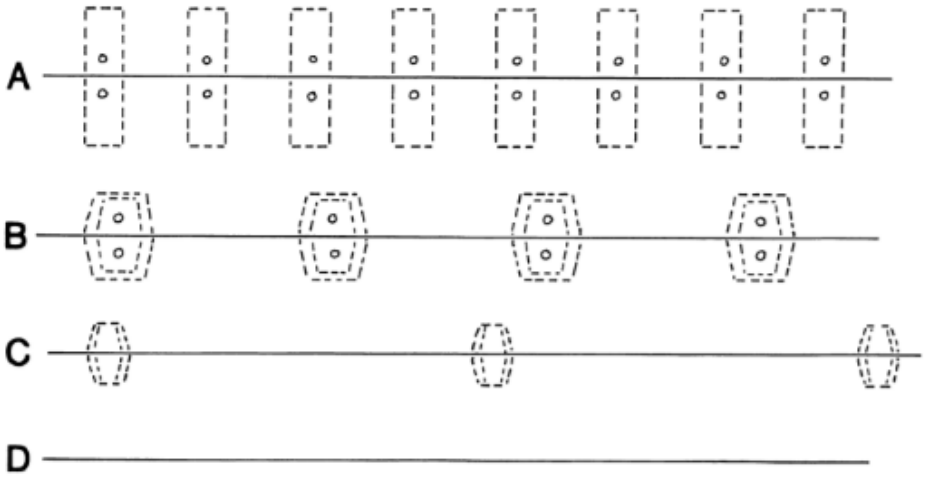


Figure 6: Chronology of Mortise and tenon joinery gradually lessening in use. A: Kyrenia Ship. B: 4th century Yassiada Ship. C: 7th Century Yassiada Ship. D: Serçe Limani Ship (Pomey, Kahanov & Rieth, 237).

frequent. The transition from shell to skeleton construction allowed ship strength to come from other aspects of the vessel, such as the frame, the back-bone of the ship and ceiling and deck constructions. Pegged mortise and tenon joints began to decline, and eventually grew smaller and in some cases became unpegged. A chronological view of the evolution of Mortise and Tenon joinery can be seen in figure six.

Shell/skeleton first construction

One of the earlier methods of ship construction is defined as being 'shell' first, in which the strakes were installed, forming the outer shell of the ship's hull, this is what provided much of the vessel's structural integrity (Steffy, 1994, 83).

A major advancement in ship building was the introduction of the keel, a long thick central plank that runs along the ship and acts as a backbone (Pomey, Kahanov & Rieth, 2012). One of the earliest examples of this occurs on the Uluburun wreck, however, there is insufficient evidence to suggest that the keel was connected to a skeleton (Steffy, 1994, 83). Because of the strength afforded from building frame first and the strength from a keel, the need for mortise and tenon joinery began to decline (Pomey, Kahanov & Rieth, 2012). The final transition from shell to skeleton first building must have occurred at some point during the 1st Millennium AD. However, the evidence from earlier wrecks shows that this was a slow transition that began much earlier.

Overall, these examples form the basic techniques that shaped the development of ship construction, though ships were definitely more complex than this general outline, they provide a useful basis for understanding ships of this time period.

Representations of ships

In the Mediterranean, iconographic representations of ships predate the physical remains that have been recovered from boat burials and shipwrecks. Although the intricate details such as plank joinery and construction techniques cannot necessarily be inferred from iconography, hull forms and

other important information such as the means of propulsion, crew sizes and cargos can be revealed through analysis of depictions of boats and ships. The following examples have been chosen because of relevance to this dissertation in order to display a development in depictions, continuity of seafaring across the Mediterranean and finally emphasis is placed upon those that are related to the geographical area that this dissertation focuses upon.

Figure 7: Depiction of boat from the Naqada II period, Egypt (British Museum).

Some of the earliest depictions of ships and boats occur in Predynastic Egypt, particularly as a decoration for pottery and other vessels for transporting liquids or other goods. Figure seven shows a standard papyriform vessel that would have been the most basic vessel used for transport on the Nile, much like the Dashur boats discussed previously. The vessel is propelled using oars, 30 in total, which would mean a total of 60 oars for both sides of the boat. The depiction also shows two cabins, likely to have been made from reed that would have served as shelter for the crew and cargo. Although the construction of these boats cannot be accurately discerned from this depiction, the presence of reeds on the stern side of the boat suggest that the boat may have been constructed from this material.

Frying pans dating from the Early Cycladic II phase (2700-24/300 BCE) in the Cyclades offer a different view on the types of water-craft from that seen in Egypt. Figure eight shows 12 examples that are distinctly similar. A basic hull form can be discerned, and the bow of the boat rises

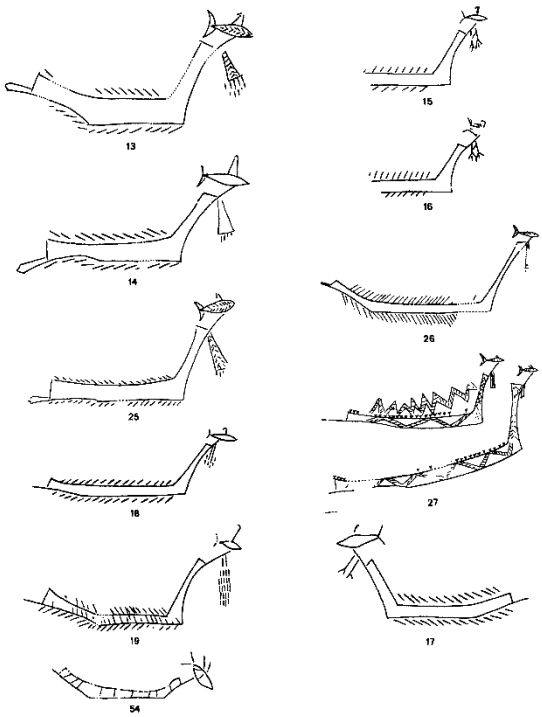


Figure 8: Depictions of longboats typically found on cycladic pans (Coleman, 1985, 199).

significantly higher than the stern, possibly to aid travel between islands in more open water. Each depiction features a figurehead at the bow that represents a fish. These ships were manually propelled with oars, and would have required a crew of at least 25 men in order to operate (Broodbank 1989: 329). The main method of propulsion was likely to have been paddling as opposed to rowing, as the crafts would have been long and narrow (Wachsmann 1980: 288). This entails that due to the likely small population sizes of EC II settlements, and an even smaller availability of manpower to crew a vessel (Broodbank, 1989: 330), these long boats were a communal endeavour, suggesting that contact between communities was an important aspect of EC II life. Unfortunately, the construction process for these long boats is unclear, however, Broodbank (1989) postulates that they could have been built either with skin stretched over a timber frame, or as a hybrid of a dug-out and plank-built craft.

Minoan ships were depicted on a series of frescoes recovered at the Late Bronze Age settlement at Akrotiri, these portray a procession of ships and provide excellent detail pertaining to ships of the Bronze Age (fig 10a). Friedrich & Sørenson (2010), suggest that this scene details a procession from an area of northern Santorini known as the 'swarm of dykes' across the Caldera to Akrotiri in the south of the island. A range of ships are present in this scene, from two man canoes to larger, masted ships. A key feature, and contrast to earlier depictions, is the presence of sails of some of the ships, a significant change from previous depictions. Only the larger ships in the fresco are depicted with mast, and only one is depicted utilising its sails, the rest are powered via oarsmen. The larger craft are identical in design and contain more detail compared to the rowed boats (Casson, 1975). They feature a hull form that is curved, much like other depictions on Minoan seals, as seen in figure nine (Wachsmann, 1980). Furthermore, the sail these ships used was carried high and looks like a square shaped sail, however oars are clearly visible as a secondary means of propulsion. Once again this would have been utilised as paddling (Wachsmann, 1980). This could support the suggestion that these ships are of a military purpose, evidenced by the weaponry carried by and 'battle scene'

later in the fresco. The rear end of the ship, situated behind the stern post contains a cabin that is presumably intended for the ship's captain (Casson, 1975).

From these depictions, Giesecke (1983) has attempted a detailed reconstruction, suggesting that the larger ships must have had a keel and an internal frame in order to maintain structural integrity. Moreover, Giesecke provides a detailed plan reconstructing the ship (fig 10b). Furthermore, Giesecke (1983) also postulates on the performance of these ships, something relevant towards the dissertation. He suggests that a ship of this type when being rowed could have traversed the distance from Thera to Crete within a day.

Figure 9: Depictions of Minoan ships on Minoan seals (Wachsmann, 1980, 290).

10Figure 10a: The Thera fresco, depicting a fleet of ships of varying sizes likely of Minoan origin (Ancient History Encyclopedia, 2017).

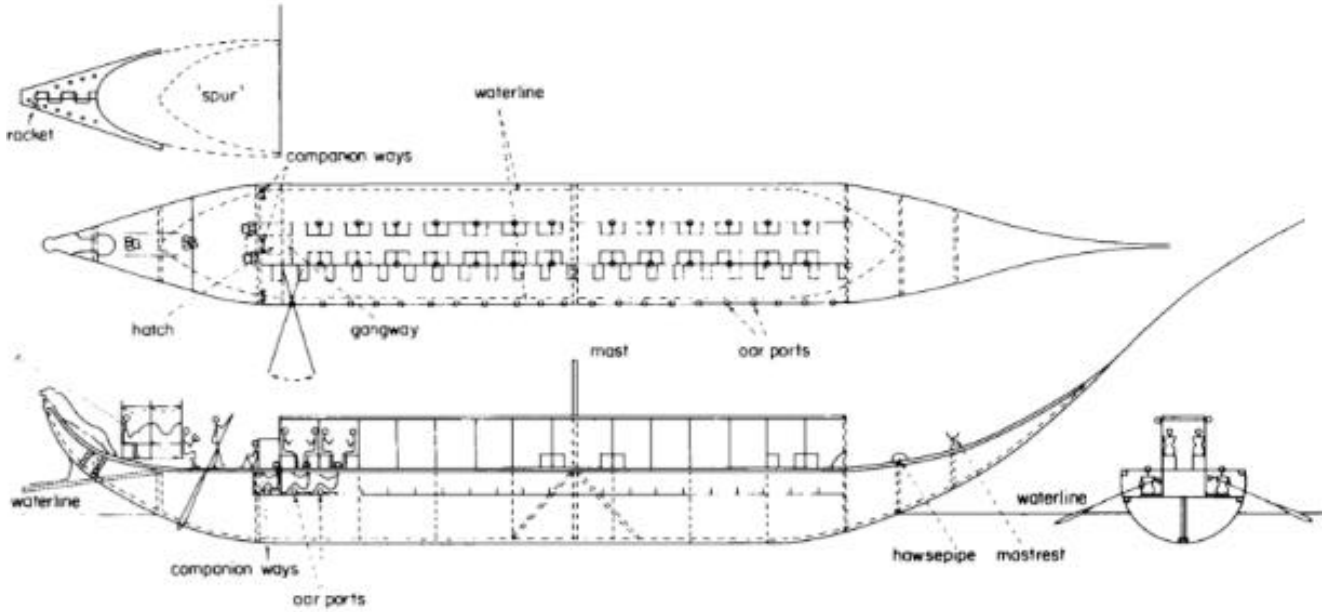


Figure 10b: Giesecke's detailed plans of the Minoan sailing ship (Giesecke, 1983: 137).

Lastly, the final depiction that will be discussed is a depiction of a vessel carrying cargo originating from Cyprus (fig 11). The jar dates between 750 – 600 BCE and depicts a vessel at sail carrying cargo and crew. In a development from the vessels depicted in the Minoan frescoes, oars cannot be seen within the depiction, possibly because they are either stowed away for future use, or not used at all in merchant vessels of this period. Instead the vessel is propelled using its sail and steered using large steering oars at the stern side of the ship. Moreover, the anchors utilised by ships of this period are also depicted, suggesting that stone, round anchors were used at this point. The hull form that can be discerned is relatively unchanged from previously discussed examples, however, the mast can clearly be seen to be a tripod mast. This would provide the mast extra support that would be necessary for the ship to sail in rougher conditions.

Figure 11: Image of an archaic period vessel on a jug, from Cyprus (British Museum, 2017).

Overall, the representation of ships in the Mediterranean begins with simplistic outlines of the hull, and serve to provide an unassuming idea of the shape and characteristics of early vessels in the Mediterranean. In particular, detail in the earliest depictions such as the example from Egypt and the early Cyclades show the vessel's basic shape and means of propulsion. This can allow for estimates of overall crew size and the method of propelling the vessel, between rowing and paddling to be inferred. More detail is introduced as ships get increasingly complex, and the most compelling depiction is through the Thera frescoes, depicting a wide range of vessels in use during the Minoan

period. Interestingly, the same principles in hull form are retained, suggesting that ship building in the Mediterranean was mostly a tradition that lasted with gradual improvements in technology. This however is the limit of depictions, and more evidence must be sought from the physical remains of boats and ships in the archaeological record.

Physical remains

There are few examples of the physical remains of ancient ships surviving in the archaeological record. This is due to the mostly calm nature of the Mediterranean, as the seabed does not often silt up and cover the shipwreck, they often deteriorate or are destroyed by marine organisms often leaving their cargo as the only sign of the wrecking event. However, in the rare case that preservation is achieved, a high amount of information can be revealed about the construction process of the vessel.

The first example is not a ship wreck found under the sea surface. However, its relevance remains as a key case of the preservation of a ship. The ship is also contemporary to the Keros-Syros culture, and therefore contemporary to the longboats depicted on 'frying pans', it could share some construction techniques. The 6th dynasty pharaoh, Khufu's vessel was discovered in a pit next to his pyramid. The boat was quite large for the time, at 43.63 metres long, and 5.66 metres wide (Mark, 2009, 18). The construction of the vessel is largely of Lebanese cedar wood, fashioned into planks. Lebanese cedar was a popular wood that is used continually In the Eastern Mediterranean, and imported specifically by the Egyptians as it is naturally oily and buoyant. Moreover, Egyptian boat wrights cut planks with joggled edges, this was done in order to prevent slippage and allow for an altogether stronger hull (Mark, 2009, 23). Along with the joggled edges, the planks were joined together using a mixture of mortise and tenon joints and sewing the planks together. The tenons used in the vessel have not been drawn or photographed, however later examples such as the Lisht vessel have been, these tenons were tapered, like a long hexagon, and were often too small their corresponding mortise. This indicates that an adhesive must have been needed and Mark (2009),

suggests this is to allow the vessel to be dismantled easily. The method of lashing planks together was used alongside the mortise and tenon joinery. Ligatures were laced through rows of rectangular holes in strategic locations to allow planks to be secured in the best places (Mark, 2009). Furthermore, the boat was intended as a barge to carry the body of the pharaoh, and also likely towed by other vessels, therefore speed was not an important factor of the boat's construction, and as such no efforts were made to reduce drag. Moreover, this example lacks any features necessary for seafaring such as a keel, but could still indicate the types of construction methods that were used in the Keros-Syros ships, despite differing geographical areas.

The next example in question is the 13th century BCE Uluburun wreck, this particular shipwreck was discovered off the Uluburun coast of Turkey at a depth between 44 and 52 metres deep, the variation in depth is due to a slope that the wreck lay upon (Pulak, 1998: 189). The ship is around 16 metres long, which was ascertained by the distribution of the ship's cargo (Pulak, 1998, 210). The ship was clearly a cargo ship, involved in the Bronze Age maritime trading network, and reveals a lot of information regarding the commodities that were traded. The primary cargo was a mixture of metal ingots, most of which consisted of bun-shaped ingots of copper and a large quantity of copper 'ox-hide' ingots. Other cargo recovered included amphorae containing *Pistacia* resin. The ship's hull was also preserved, but only in a limited capacity. Nevertheless it remains the only preserved remains of a late Bronze Age ship. According to Pulak (1998), the ship was built in a shell first manner, and utilised pegged mortise and tenon joinery to strengthen the ship. Interestingly, there seems to be a central plank that runs the length of the ship, much like a keel would. However further examination showed that the keel was rudimentary, and would not have functioned to fully support the vessel stay on course under sail. Instead the proto-keel would have still acted as the ship's spine, but also protected the planks when the ship is beached.

The significance of the Uluburun shipwreck, and its cargo reflects this. The period is well documented, with a lot of evidence of trade and networks coming from the Amarna letters (Pulak,

1998). However the wreck is a physical glimpse into those networks. The cargo documented mostly matches the types of cargoes discussed in the Amarna letters. The ship was likely travelling in a west direction, possibly suggesting that it was destined for the Aegean as part of the previously discussed Mediterranean trade circuit. Pulak (1998) interprets the ship as being part of a royal exchange that is discussed heavily in the Amarna letters.

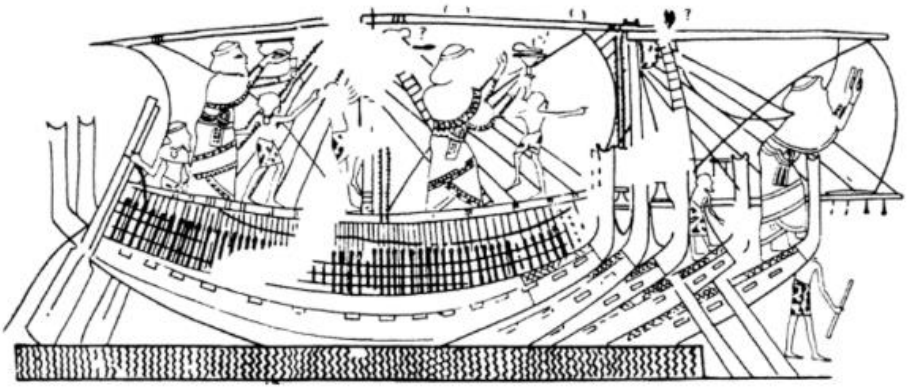


Figure 12: Scene from the tomb of Kenamun depicting a fleet of Syrian merchant ships (Wachsmann, 2009, 44).

This is supported by the mixed presence of raw materials and utilitarian goods in the shipwreck. Given that ships of this period would have travelled as part of a larger fleet, as evidenced by the depiction of a Syrian merchant fleet in the tomb of Kenamun, Egypt (fig 12).

The final example that will be discussed in this section is the Kyrenia shipwreck. This ship was wrecked off the northern coast of Cyprus and dates to the last decade of the 4th century BCE (Steffy, 1994, 42). The cargo carried by the ship included 400 amphorae of different types, milstones, coins, a copper cauldron, fishing weights, almonds and personal items belonging to the crew. The excavation recovered four cups, wooden spoons, salt dishes, wine pitchers and oil jugs which suggests that the ship had a crew of only four (Katzev, 2005, 76). This is much less manpower than has been postulated from earlier examples of ships. The ship had a single mast aft of the foredeck that carried a board square shaped sail, that would have been furled upwards similarly to a venetian blind through lead brail rings.

Interestingly, much of the ship's hull was preserved, and provides a wealth of information on ship building in this period. The ship is estimated to have been 14 metres long and 4.2 metres wide, similar to the dimensions of the Uluburun wreck. In contrast, the ship's timbers were constructed of locally grown pinewood, a soft wood. Once again the ship's shell was built first before an internal skeleton was added (Katzev, 2005, 74). The ship featured a keel that the planks were attached to using pegged mortise and tenon joinery every 12 cm, and were joined edge to edge tight enough to negate any need for additional caulking. The ribs of the vessel were installed after this initial shell, and were secured to the inside of the hull using copper spikes driven from the outside and locked downwards like a staple, however, true to shell first construction, the ship's strength came from the shell of planking. This is also how the garboards were fixed to the keel, with a nail driven through one board, through the knee and out the other garboard before being fixed like a staple.

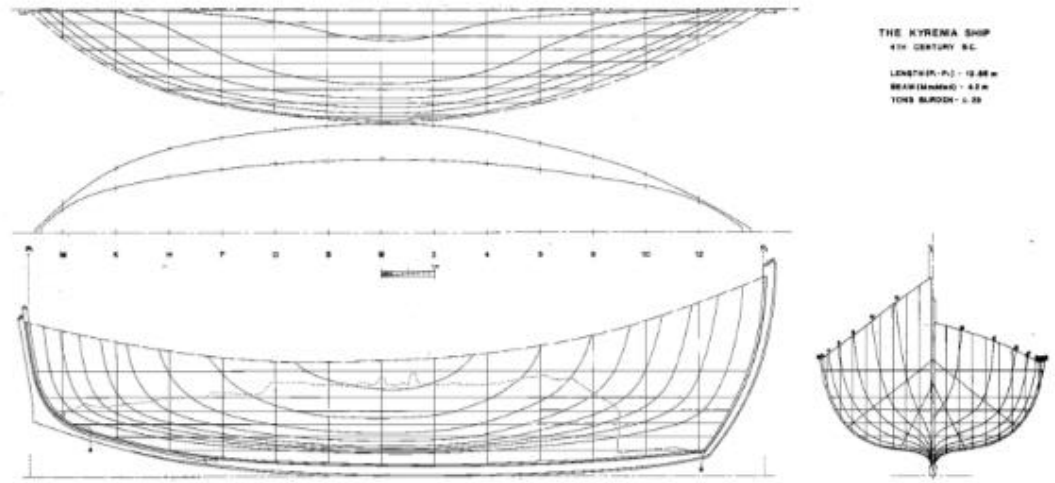


Figure 13: Steffy's plans of the Kyenia Ship (Steffy, 1994, 55).

The preservation of the ship's hull revealed a host of information about ancient Greek ship building, the plans of the vessel, made by Steffy (fig 13), show the ship to share a similar hull form as previous ships, particularly those depicted in the Akrotiri frescoes, with a key difference being steeper and shorter bow and stern posts. This could have been an artistic rendering of the Akrotiri ships though. Interestingly, Steffy (1994, 54), notes that modern fishing boats and interisland vessels in the Aegean and Eastern Mediterranean continue this double edged sheer, with a high stern post. The quantity of information was enough for a full scale physical reconstruction of the ship to be achieved (fig 14). Steffy reports that the subsequent sea trials were successful, and the ship could perform excellently, and could achieve an average speed of 2-3 knots, and faced winds of over fifty knots with insignificant damage to the ship's hull and rigging.

Figure 14: The reconstruction of the Kyrenia ship at sea during trials (Katzev, 2005, 78-79).

Overall, these examples where the physical remains of the ships have been preserved reveals much about the specific methods used to build ships. Examples have been chosen to represent different areas in an effort to highlight the similarities in ship building across the Mediterranean.

Finally, the topics of ships and ship building in the Mediterranean have been discussed at length, focusing upon some basic methods of ship building, with particular attention to hull form. This particular feature could be recognised through the iconographic representations of ships, which reveal a limited amount of information, however they remain an incredibly useful source for the evolution of ships in the Mediterranean. The inclusion of physical remains, fills in much of the questions left by the iconographical evidence. Specifically physical remains give a lot of information

regarding the methods used in constructing these ships, revealing the dimensions, materials used, and in some rare cases including the Kyrenia II vessel allow for a complete reconstruction and experimental testing to take place, granting first hand evidence of the performance these ships could have been capable of.

Regarding this dissertation, the author has chosen to focus on the long boats depicted on the frying pans of the Keros Syros culture, and the larger sailed ships present in the Akrotiri frescoes. This will allow for a model to be produced showing the difference in these two types of vessel, in order to properly highlight their capabilities, and juxtapose the difference in vessels of each of these periods.

Methodology

The aim of this current work is to model the physical capabilities of Bronze Age ships, specifically the longboats of the Keros-Syros culture and the sailed vessels utilised by the Minoans. Having established the sequence of ships and ship building in the Mediterranean, and looked more specifically at the environment and networks of the Cyclades, how can this factor into a model through GIS? The models produced in this work can test the theories based off these networks, particularly questioning the validity of Broodbank's (2000) assertion of the Keros Syros' system of a number of single large settlements acting as a central place. Moreover, the models could suggest why Minoan presence is greater on Akrotiri and Phylakopi, and not so great in the rest of the Cyclades. As Leidwanger (2013) points out, most discussions of maritime connectivity are based around 'natural routes of communication' based off of predominant winds and currents allowing for an easy voyage. These result in fixed numbers or a fixed 'daily sailing distance' being established, for example Broodbank (2000) suggests a daily sailing distance of 100-150 km in the prehistoric Aegean. As a result, these present a figure to work from, but for the most part ignore the complexities and the dynamic environment that seafaring would have occurred in. GIS is more beneficial compared to previous network analyses, which as Leidwanger highlights prefer fixed linear distances, in example the network models of Bronze Age Aegean interaction (Knappet et al, 2008, 2011).

There have been a number of studies using GIS that have incorporated environmental data such as winds, waves and vessel's capabilities. The earliest versions of this include Levison, Ward and Webb's (1973) simulations of the settlement of Polynesia, which then taken further by Irwin, Bickler & Quirke (1990) for testing various theories of how the Polynesian islands were settled. These represent the earliest forms of spatial analysis in theorising human seafaring activity. The next step was bought forward by Indruszewski and Barton (2008), incorporating wind data, historical accounts of a 9th century AD voyage in the Baltic Sea and experimental archaeology hypothesised plausible routes taken, this was the first step in utilising environmental data in models of seaborne voyages in

GIS. Finally, the methodology presented by Leidwanger (2013) shows the most nuanced incorporation of environmental factors and a clear GIS methodology for the modelling of maritime voyages in the Eastern Mediterranean. Using the Pabuc Burnu wreck, a wreck dating to the archaic period as a physical example.

Therefore the methodology outlined by Leidwanger could be incorporated elsewhere in the Mediterranean. It is the intent of this dissertation to apply this methodology to the environment of the Cyclades, focusing on the Keros-Syros and Minoan networks of the Cyclades. These will differ, particularly in the different vessels utilised by these two cultures, and could provide an interesting comparison between the physical aspects of these two networks.

Factors affecting the modelling of seafaring in the Mediterranean

There are a number of factors that require inclusion into the model, so that they can affect it as accurately as possible. These include the environmental factors at play in the Mediterranean, such as winds, tides and currents. As Morton (2001) highlights, the physical environment plays a massive role in Greek seafaring and therefore cannot be ignored. Furthermore, once the environment has been factored in, this can allow the modelling of ship capabilities pertaining to speed, based upon the environment. As aforementioned, this will include the paddled long boats of the early Bronze Age, and the sailed vessels depicted in the Minoan fresco from Akrotiri. At this stage, it can be postulated that the sailed vessel's capabilities will be greatly aided or indeed hindered by the effects of the wind, in contrast the paddled vessel is not reliant on the wind, but could be affected by environmental factors such as waves, which are caused by the wind. However, in the Mediterranean, waves and currents are generally minimal, and most follow wind's headings, therefore their impact would be minor.

Environmental factors

Wind

The wind is the most important environmental factor for sailing, as it serves as the primary means of propulsion for ancient and modern sailed vessels. In the Mediterranean, winds vary based on the season. In summer, northerly winds are predominant, these are known commonly as the Etesian winds. Winter brings more variation to the pattern of winds, incorporating both northerlies, known as the Boreas, and the more dominant south westerly winds, known as the Sirocco winds (Morton, 2001, fig 23). Moreover, the Aegean in particular is affected by daily fluctuations in land and sea breezes, particularly in coastal areas. These diurnal changes were at their most prevalent during the summer season, and therefore could be taken advantage of by ancient mariners to sail in directions different to that of the prevailing winds, likely using a method known as tacking: in which the ship sets sail at an angle, propelling the ship in a different direction from the wind propelling it (Morton, 2001). These were particularly helpful in an island environment such as the Cyclades, where due to the close proximity, land and sea breezes could be used to propel one's ship from island to island.

The process of modelling this wind in GIS is reliant on data pertaining to the direction of travel and the speed of gusts in the Mediterranean. Firstly, Murray (1987) has shown that the cycle of winds in the Mediterranean have not differed over the course of history, and therefore modern wind data is a reliable source for weather data. Two such sources have highlighted the extent of winds in the Mediterranean; The *Wind and Wave Atlas of The Ancient Mediterranean* provides offshore wind speed and direction data from buoys (Med-Atlas Group, 2004). This synthesises buoy data with numerical models in order to produce year round estimates. Moreover, coastal patterns in winds are recorded in observations from coastal meteorological stations, and are available online (www.winderfinder.com).

Overall, the two data sources for wind in the Mediterranean both offer important information, Leidwanger (2013), combined and the two sources, however due to the nature of the Cyclades being a close knit group, the data from Windfinder.com alone is sufficient enough to extrapolate the winds of the Mediterranean, allowing for an average wind speed and wind direction to be ascertained. For the purpose of this dissertation, data from the month of July was taken from a number of weather stations accessible via windfinder.com. This allowed for the wind speeds and direction to be projected in GIS (appendices 1 & 2). The general directions of the winds is northerly, following the pattern of the Etesian winds, however this is not quite as simple as a N-S blowing wind, and can be interrupted by winds blowing from coastal areas.

How would the wind affect each type of vessel that form the focus of this study? The earlier Keros-Syros type long boat is unlikely to be affected by the wind, due to the means of its propulsion being entirely man powered with no reliance on the wind. Waves, caused by the wind could prove a problem, possibly slowing the vessel. However as previously discussed wave height and tidal strength in the Mediterranean are generally minimal. The later Minoan vessels would likely benefit greatly from the wind, due to the use of sails, as previously discussed these would be square shaped, allowing for the ship to properly harness wind. It's assumed that the method of tacking was known by this point, therefore wind should not prove so much of a hindrance. However, the crossing from Crete to the Cyclades does require a degree of open water travel, particularly from Crete to Akrotiri.

Ship Capabilities

Regarding the capabilities of ships in the Mediterranean, what speeds can they be expected to reach on a period of good winds? There is some speculation on the speed ancient vessels are capable of. For example Casson (1995), suggests that vessels had an average speed of 4-6 knots was achievable with good wind, this is based mainly off of Roman sources. However, the experimental sea trials of the Kyrenia II vessel, a reproduction of the Kyrenia ship wreck, previously discussed. As aforementioned, the detailed logs of the crew show that the vessel achieved an average of 3 knots

per hour with good wind. These results, stemming from the crew of the vessel seem more accurate compared to the written accounts of roman authors, who were not the crew. Conversely, this difference could be because of two different types of sail technology being employed. Casson fails to state whether the vessels being discussed are utilising a square rig or lateen rig. The Kyrenia vessel utilised a square shaped rigging. Does this mean a significant difference should be expected? According to Whitewright (2011), both square and Lateen rigs were capable of the same average speeds of 4-6 knots. Therefore, the difference in performance between the two types is not a major factor and can be disregarded. Due to the use of square shaped rigs in the representation of Minoan vessels, and the performance noted by the Kyrenia experiments, the average of 3 knots will be the speed use for the models.

Distance

Using this speed, how far could vessels realistically travel in the timespan of a day? Static figures are previously hypothesised by the likes of Broodbank suggest a daily sailing distance of 100-150 km (Broodbank, 2000). This allows for a massive distance to be traversed (Fig 15). However, there are some problems with these assumptions, how long is a typical day in this assumption? Realistically, one would expect ancient mariners to utilise as much daylight as possible, setting off at first light and seeking harbour at last light, these timings can fluctuate based on season though. Hypothetically, if first light were at 05:00, and last light at 21:00, travelling

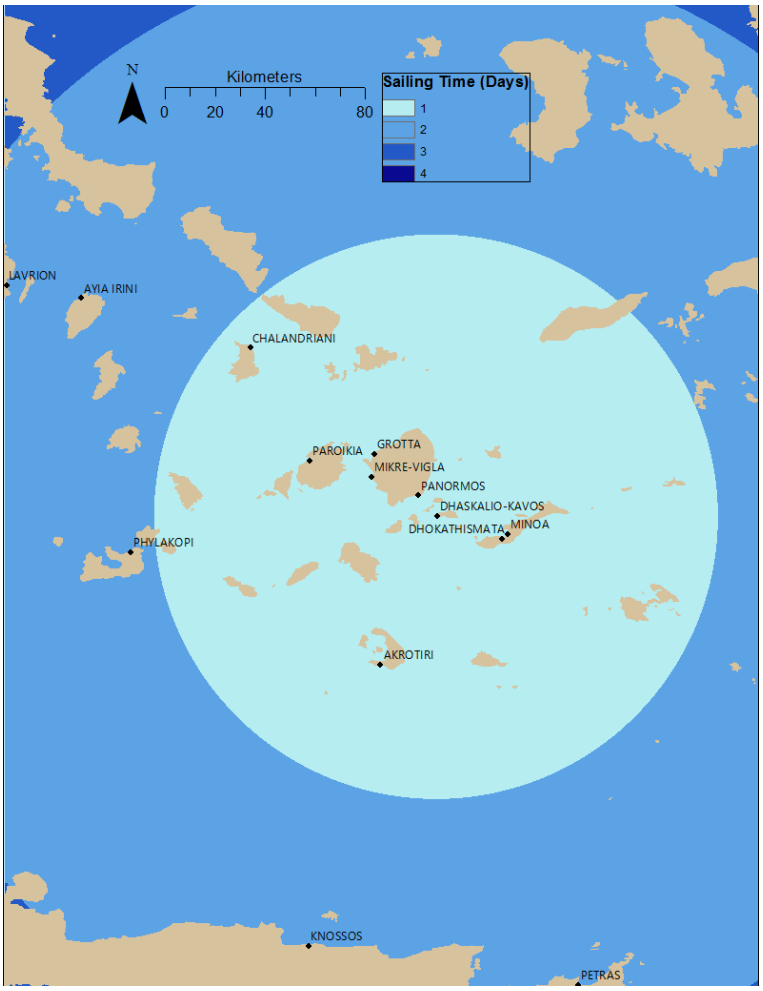


Figure 15: Example of a daily travelling distance of 115km, with Dhaskalio-Kavos as the point of origin. Derived using the Euclidean distance tool in Arc GIS.

at 3 knots, this only makes for a distance of 29.6 kilometres or 18.4 miles travelled[1]. This calculation is only to be taken as a general estimate, based upon a hypothetical that mariners would limit themselves to daylight, and a suggested timing for first and last light, it highlights that these static figures require some second thought. A stronger gust of wind could provide a greater amount of speed and therefore provide a larger distance covered.

Modelling Keros Syros longboats in GIS

One of the main differences in modelling the two types of vessel is the factors that would affect them. The Keros-Syros ships not be affected by wind, and as aforementioned waves in the Mediterranean are generally minimal and would not affect a vessel's heading greatly. Therefore, the model produced would be greatly simpler. Excluding Crete, the model would focus entirely upon the Cyclades. As the wind does not affect a vessel's heading, they can effectively travel in any given direction, as long as they can reach a shelter before nightfall. Due to the large crew size, and no reliance on winds, it is likely that a rowed long boat could travel further. However, the previous calculation of 3 knots (5.55 km) per hour will be used, only the value doubled to 6 knots (11.1 km) per hour. However, a simple Isotropic distance tool would not be accurate enough, due to its tendency to model paths in a straight line. Instead a DEM model was used in order to introduce a vertical parameter, in order to model the circumnavigation of islands. This resulted in a model, where the average distance traversed daily is c. 60 km, and can be affected by the presence of islands, where an area with more islands may take longer to navigate. The results of this will be viewable in the appendices, and discussed in the next chapter.

Modelling Minoan ships in GIS

The modelling of Minoan sailing in the Aegean requires more environmental variables than the previous Keros-Syros model. This is mostly due to the technology of sails utilised in Minoan ships.

[1] 1 knot = 1.85 KM. Using a Speed, Distance, Time calculation where working out distance requires Speed x Time. Therefore, 16 x 1.85= 29.6

Therefore, wind needs to be taken into account. After a mean wind heading and speed is modelled, the tools in ArcGIS, specifically the Path Distance tool can allow for the modelling of maritime movement whilst factoring the winds as an additional cost. For the purpose of this methodology, a hypothetical start point was chosen as Knossos, as one of the most prominent Minoan settlements on Crete. The results produced from this are adequate, and reflect the impact of the physical environment in which seafaring took place. These results will be viewable in the appendices, and discussed in the next chapter.

Overall, the methodology presented here produces adequate models that can be used to discuss the key physical capabilities of the two types of vessel. These models can then be analysed, and their contribution to the current theories on maritime connectivity in the Bronze Age Aegean can be ascertained.

Results and Discussion

The aims of this study were to model the physical capabilities of Bronze Age Ships, accounting for the effects of the physical environment. This is in order to highlight the physical nature of the main networks discussed previously, and to support or challenge the theories surrounding these networks that have been previously stated.

As a result, the following models have been created in order to highlight the physical capabilities of two types of vessel. Firstly, the long boats utilised by the Early Bronze Age Keros-Syros culture. These boats were propelled manually using a crew of oarsmen. The second vessel modelled are the sailed ships utilised by the Minoans during the Late Bronze Age. Broadly speaking, these ships had different capabilities that are affected by their environment.

Models of Keros-Syros voyages in the Cyclades

Following chapter four, the Keros-Syros culture was dominant in the Cyclades during the Early Bronze Age. Broodbank's (2000) theory that this network was managed by a group of settlements situated in different areas of the Cyclades, so that a settlement could easily contact a group of islands, suggesting the domination of three or four settlements, Dhaskalio-Kavos, Chalandriani, Ayia Irini and possibly Phylakopi. Moreover, a degree of overlap is expected between boundaries, this is logical so that a two settlements could contact or reach areas concurrently. This theory could be tested with the tools in GIS, each of these settlements were modelled with a daily sailing distance of c. 60 km. Moreover this tool could be used to imply the development of this network, as will be seen.

The Keros-Syros network – central settlements?

Dhaskalio-Kavos on the island of Keros is the logical settlement to begin with (Appendix 3). As can be seen, the islands of Paros, Naxos Amorgos, Thera, Ios and Sikinos are within a day's travelable distance. This entails that the settlement of Dhaskalio-Kavos could initiate contacts with a large

amount of locations, and easily access the marble deposits on both Paros and Naxos, this also suggests that they could maintain control over a larger amount of islands.

Next, the analysis of the area reachable from Chalandriani on Syros (appendix 4) shows that the islands of Andros, Tinos, Mikonos, Delos, and Paros, aswell as the settlement of Grotta on Naxos. This highlights the overlap between settlements discussed, which is to be expected in an island environment such as the Cyclades. Moreover, the eastern shore of Kea, the island that Ayia Irini is situated on could also be reached within a day, possibly via Giaros in order to avoid a long voyage across open water.

Next, Ayia Irini (Appendix 5) provides an important link for the Keros-Syros network to the main land through the site of Lavrion, Euboea, Kithnos and Serifos. This link to the main land is an important area for trade to take place. Moreover, there is yet more overlap between Ayia Irini and Chalandriani's boundaries.

Phylakopi (Appendix 6) is the fourth settlement that Broodbank postulates is part of this network. This island has a degree of overlap with Ayia Irini's boundaries, meeting at Kithnos, and Chalandriani overlapping at Anti-Paros.

Overall, these sources confirm that the four settlements suggested by Broodbank could preserve contact with a sector of the Cyclades in order to maintain control over other islands that would act like satellites. Moreover, the overlapping nature of each islands boundaries adds credence to this, as two settlements could maintain contact with an area of the Cyclades at any given time.

Spread of the Keros-Syros network

The validity of the central locations has been tested, and it is highly likely that this is the case, in line with previous theories. However another aspect of the Keros Syros system can be inferred from this GIS data. Using Dhaskalio-Kavos as the hypothetical origin for this system, it can be indicated that the network was set up sequentially. As can be seen in appendix 4 Chalandriani is within a two day

voyage of Dhaskalio-Kavos, however it is likely that a vessel would find shelter rather than attempt a two day voyage, perhaps voyaging to Paroikia, and then starting the next day. This is supported by the journey times from Paroikia, that show that Chalandriani is within a reachable distance of a day's voyage (Appendix 7). From here, Ayia Irini could be reached from Chalandriani.

It is possible that this was the order in which the Keros-Syros network was established. This however leaves a slight anomaly with Phylakopi, it remains a two day voyage from each of these settlements. This may have still been incorporated last, as the obsidian on the island is a major natural resource to be exploited.

This could suggest that the settlements of this network were integrated sequentially, with a possible exception for Phylakopi, which could have been integrated concurrently to either settlement, or may have remained independent of the Keros-Syros network, yet remained in contact.

The Minoan network

The Minoans came to have an increased presence in the Cyclades and the wider Aegean during the Late Bronze Age, specifically at the sites of Akrotiri and Phylakopi, with much less evidence on other islands within the Cyclades, such as Paros and Naxos. The GIS models employed could provide an explanation for this, and much like the Keros-Syros models, can also suggest at the sequence of the network's establishment. As previously discussed, the special relationship between Crete and the Cyclades was possibly centred on the chain of western islands, providing a corridor to the mainland (Schofield, 1982).

Starting with Knossos (Appendix 8), the voyage to the Cyclades during summer is a lengthy one, taking roughly three days of sailing to reach Akrotiri. This would be a long voyage, and over open water, which would be the only option, the only exception to this is a longer trip via the Ionian Islands and coastal Anatolia. Once Akrotiri is reached, the Cyclades are accessible following a two day trip reaching Phylakopi, and the main islands discussed, this trip would likely feature a stop on

Sikinos or Ios (Appendix 9). Finally, as the second main settlement with lots of Minoan presence, Phylakopi provides an essential link to the mainland, and the western islands (Appendix 10).

Overall, this reveals that the Minoan settlements at Akrotiri and Phylakopi were necessary for accessing the rest of the Cyclades and the mainland. It also suggests that Schofield's (1982) ideas of the western chain could be accepted, but is overall not entirely necessary given the mainland is accessible from Phylakopi within a day.

Establishing the Minoan network

These maps provide an ideal look at the evolution of the Minoan network, from the appendices previously mentioned, it is most likely that the Minoan network spread into the Cyclades sequentially, likely from Crete, then Akrotiri and finally Phylakopi, this is the most logical sequence of events based off these models.

This shows that an open sea voyage from Crete to the Cyclades was possible, and is more logical for explaining the shortage of Minoan material in the eastern cycladic islands, however it is discussed that a route via the Ionian Islands and entering from the east of the Cyclades was a safer and therefore more likely route. However if that were the case, wouldn't there be a greater amount of Minoan material on islands such as Paros and Naxos?

To conclude, the models presented have proven satisfactory in highlighting the physical nature of maritime travel as part of the Keros-Syros and Minoan networks. They help to visualise and also account for the complexities of travelling by sea, and at times the necessity of travelling over open water when discussing ancient networks. Moreover, these models support the theories of island connectivity discussed in this thesis, and also provide a new outlook on the formation of these networks within the Cyclades, having ramifications for their establishment.

Conclusion

In conclusion, the application of GIS in modelling ancient maritime movements can be used to highlight the physical nature of ancient networks. Moreover, this has allowed the physical capabilities of both sailed and oared vessels to be modelled, this methodology could be used in future research for the discussion of ancient networks. The key objectives of this dissertation were to achieve this, and it has been successful in that respect. Moreover, this dissertation has provided a useful tool for supporting theories of networks in the Cyclades, in particular, Broodbank's central place theory discussed before. The pattern of network establishment has also been discussed, something that may not have been suggested in detail without this methodology.

This entails that these networks, that were based around this marine transport were achievable, and movement between locations was a practicable endeavour.

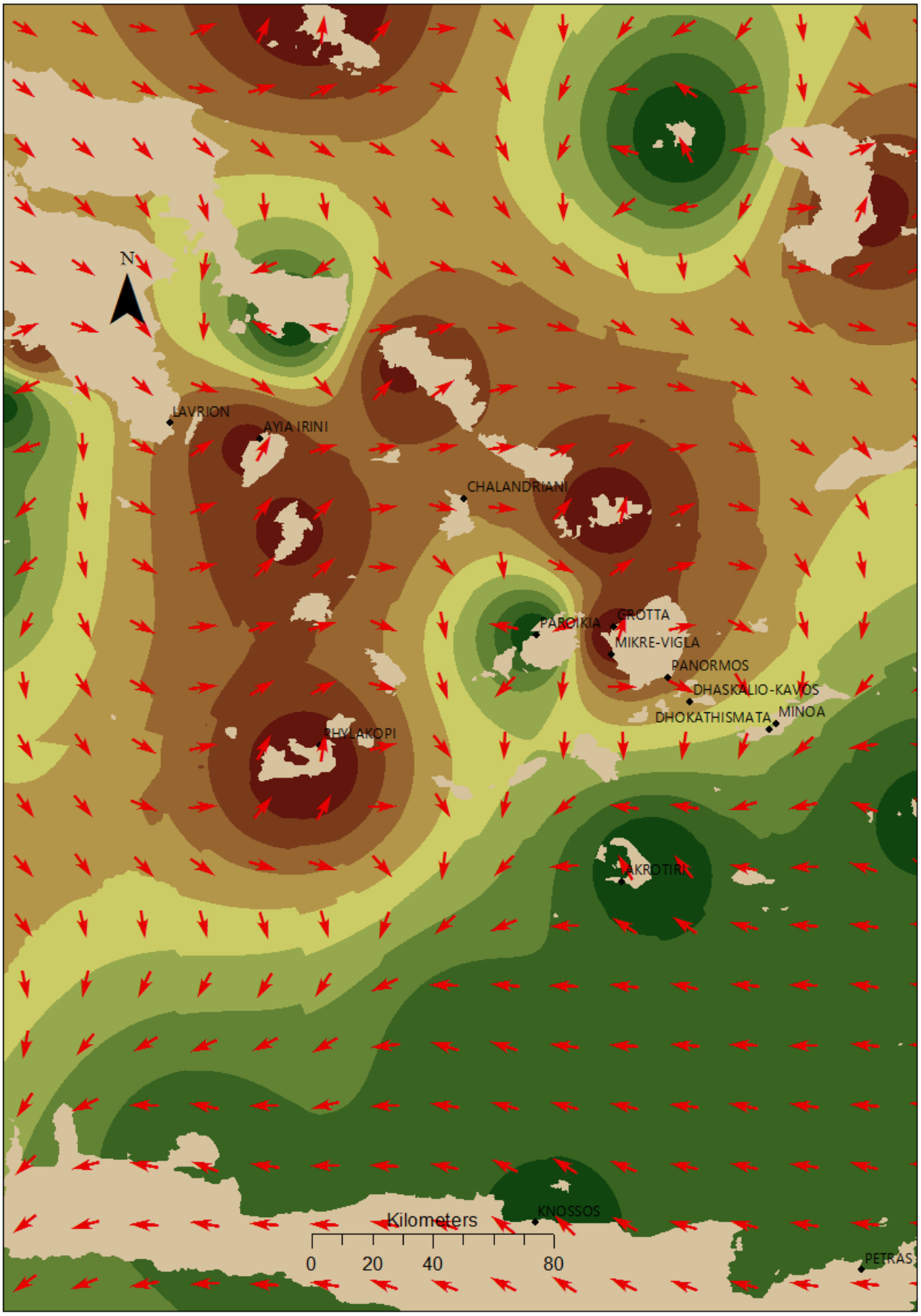
There are however limitations to this methodology, firstly for the modelling of sailed vessels a complete picture of the winds of that environment must be available, fortunately both the ancient and modern winds of the Mediterranean are well documented and available. Nevertheless, the strength of this methodology is it adaptability. It could be applicable to any environment, given the necessary information is present. Moreover, this methodology could possibly be used in works revisiting previous models of marine interaction, such as the models of pacific colonisation. Conversely, the methodology could be utilised on a much larger network, possibly on spanning the entirety of the Mediterranean, such as the inter-cultural network of the Late Bronze Age that as previously discussed, the Cyclades were incorporated into by the Minoans. This could potentially be a large project factoring in contemporary accounts such as the Amarna letters, and often characterised archaeologically by the Uluburun wreck and an anti-clockwise circuit of movement and trade.

Finally, this discussion of the Cyclades, with this methodology highlight a different approach to network analysis that provides more nuanced information from sources such as the physical environment, as compared to the vague estimates of travel time that came before.

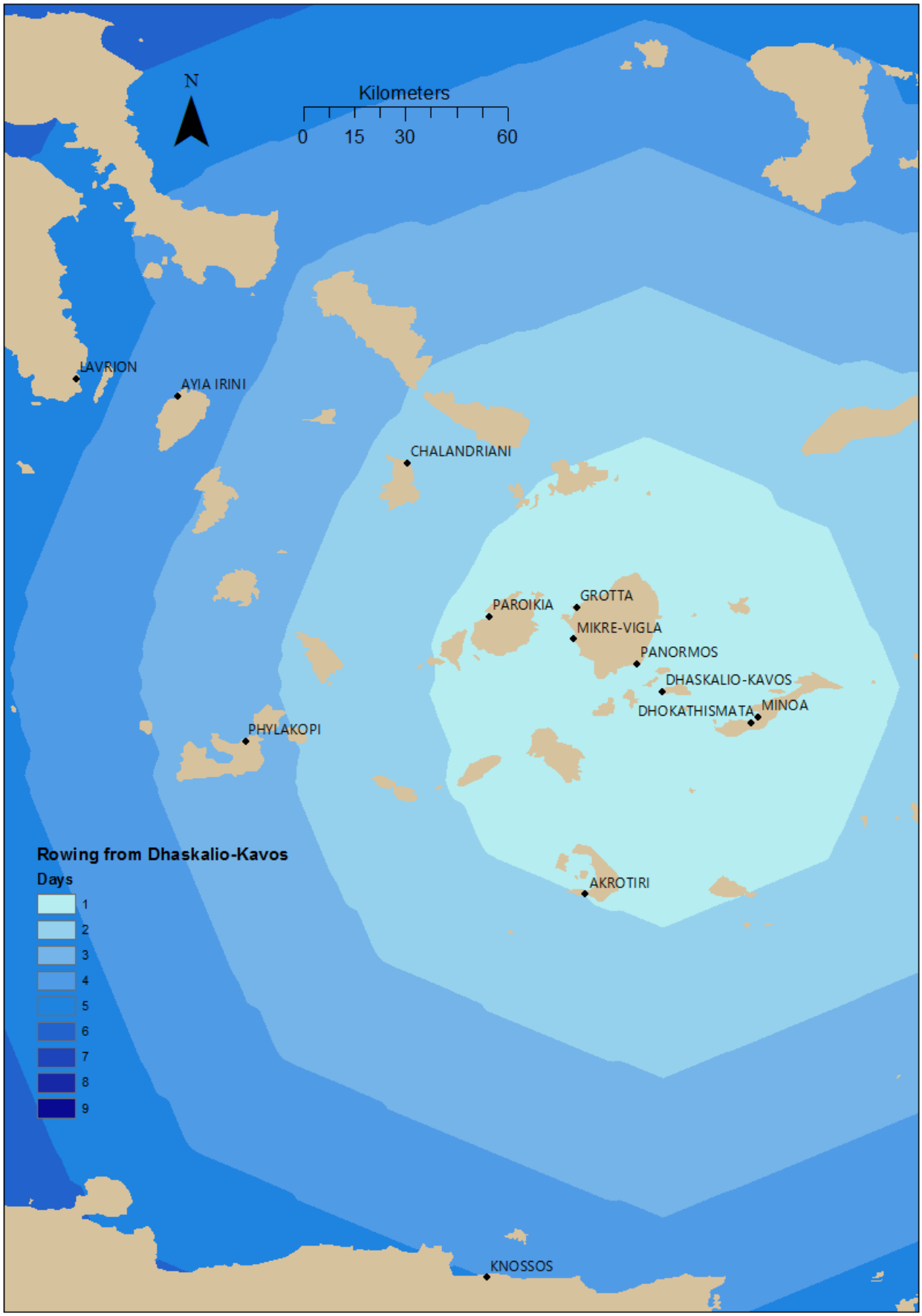
Appendices

Appendix 1 – Average wind speed in the Cyclades

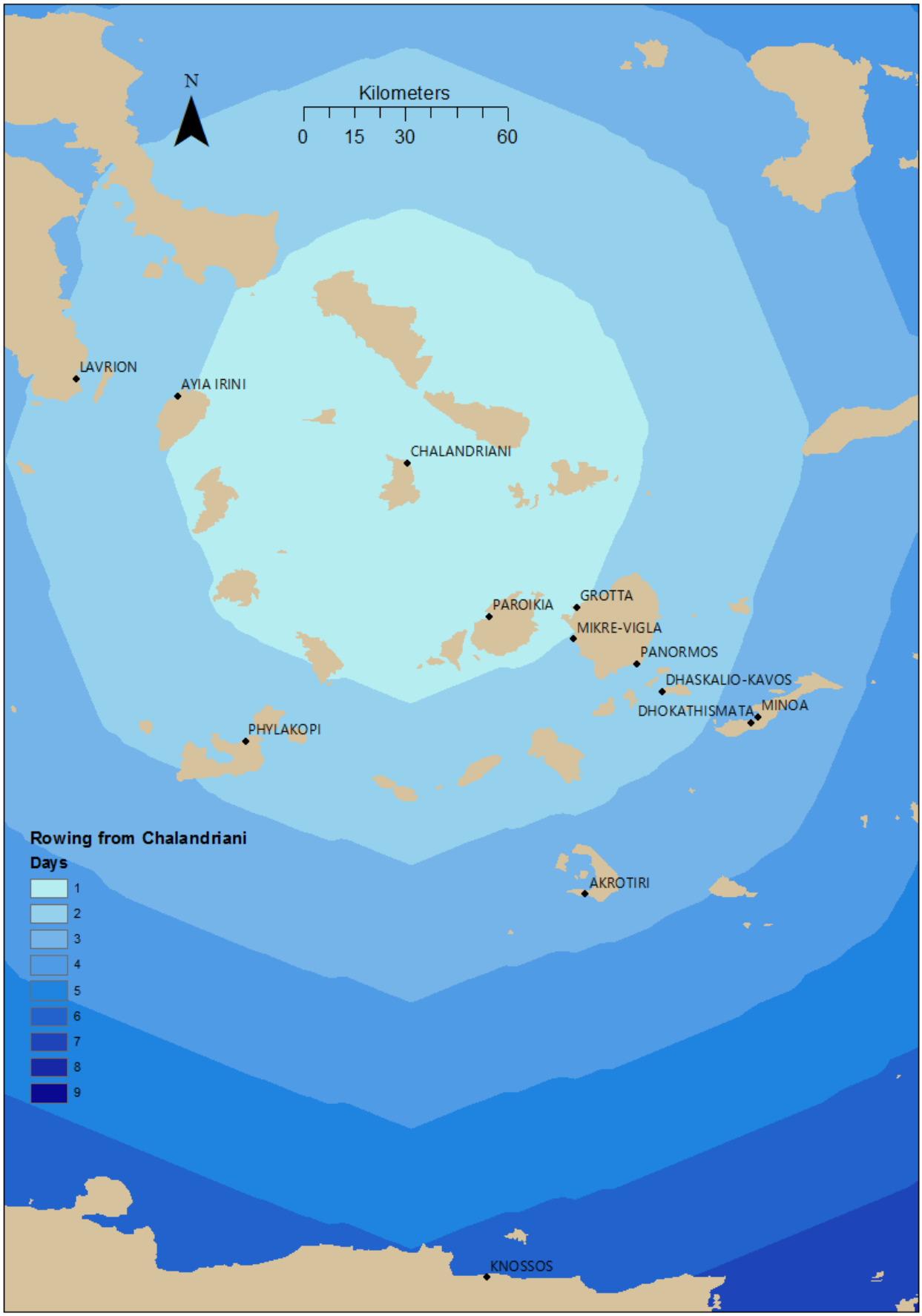
Appendix 2 – Average Wind heading in the Cyclades



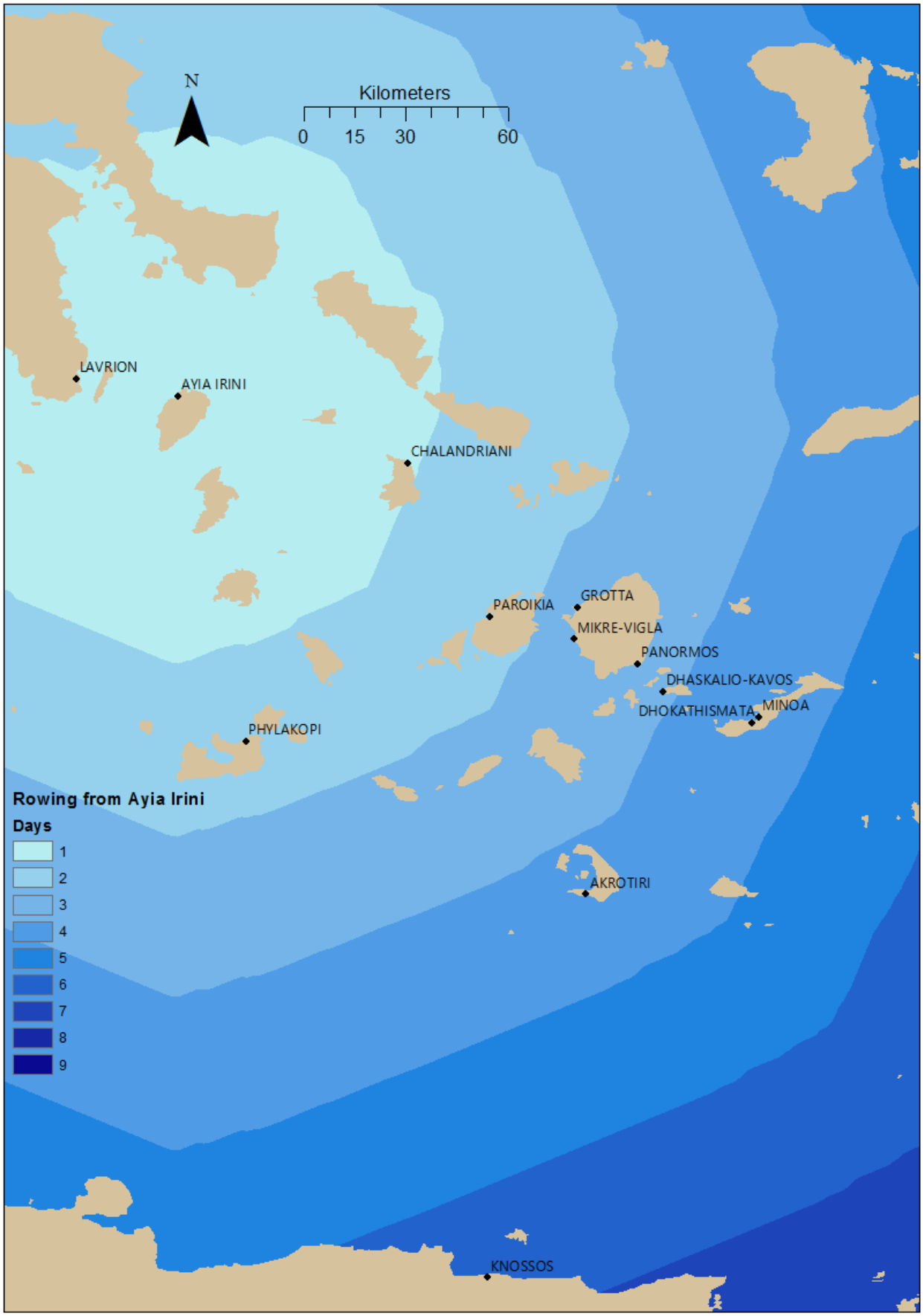
Appendix 3 – Rowing time from Dhaskalio-Kavos.



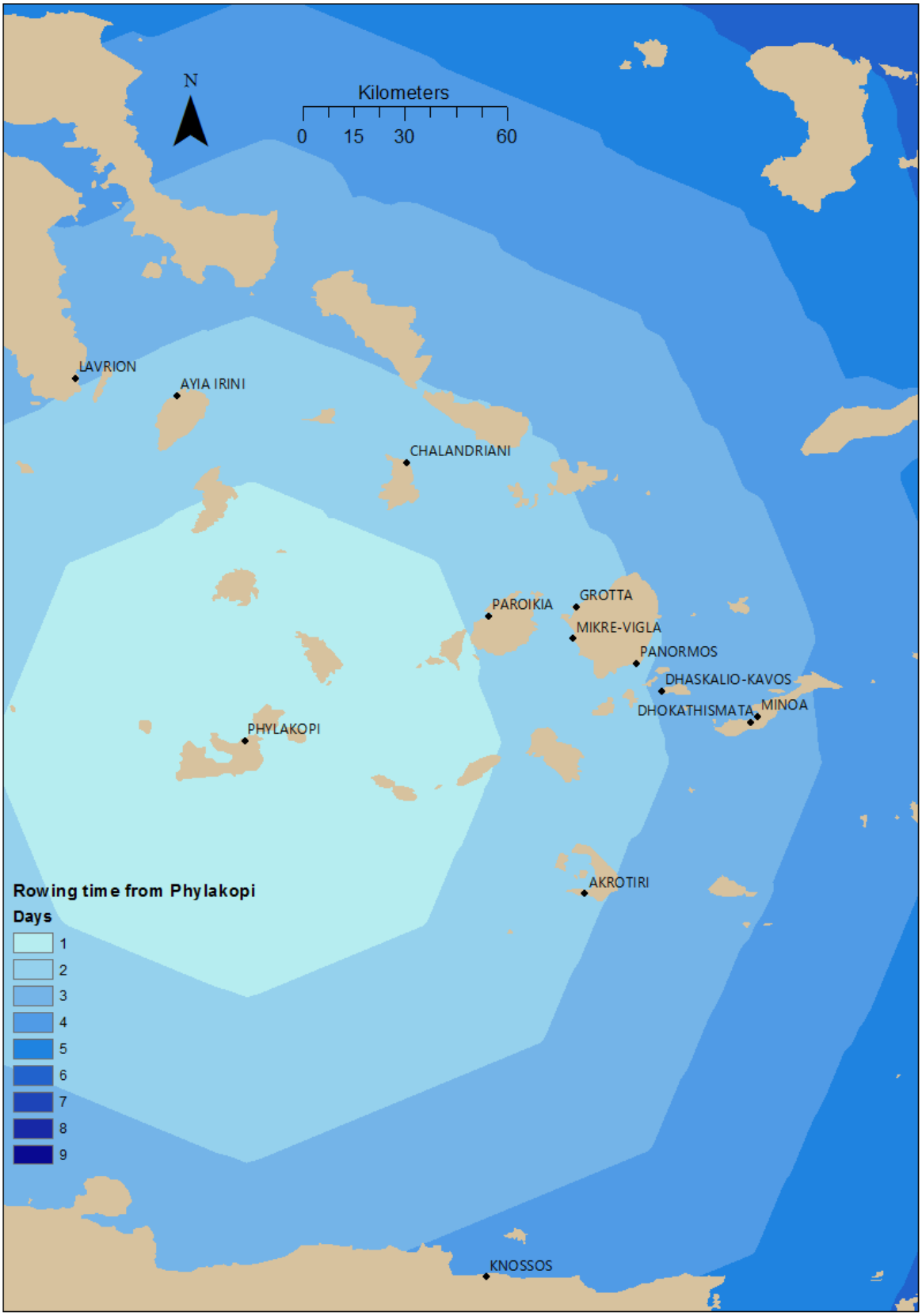
Appendix 4 – Rowing time from Chalandriani.



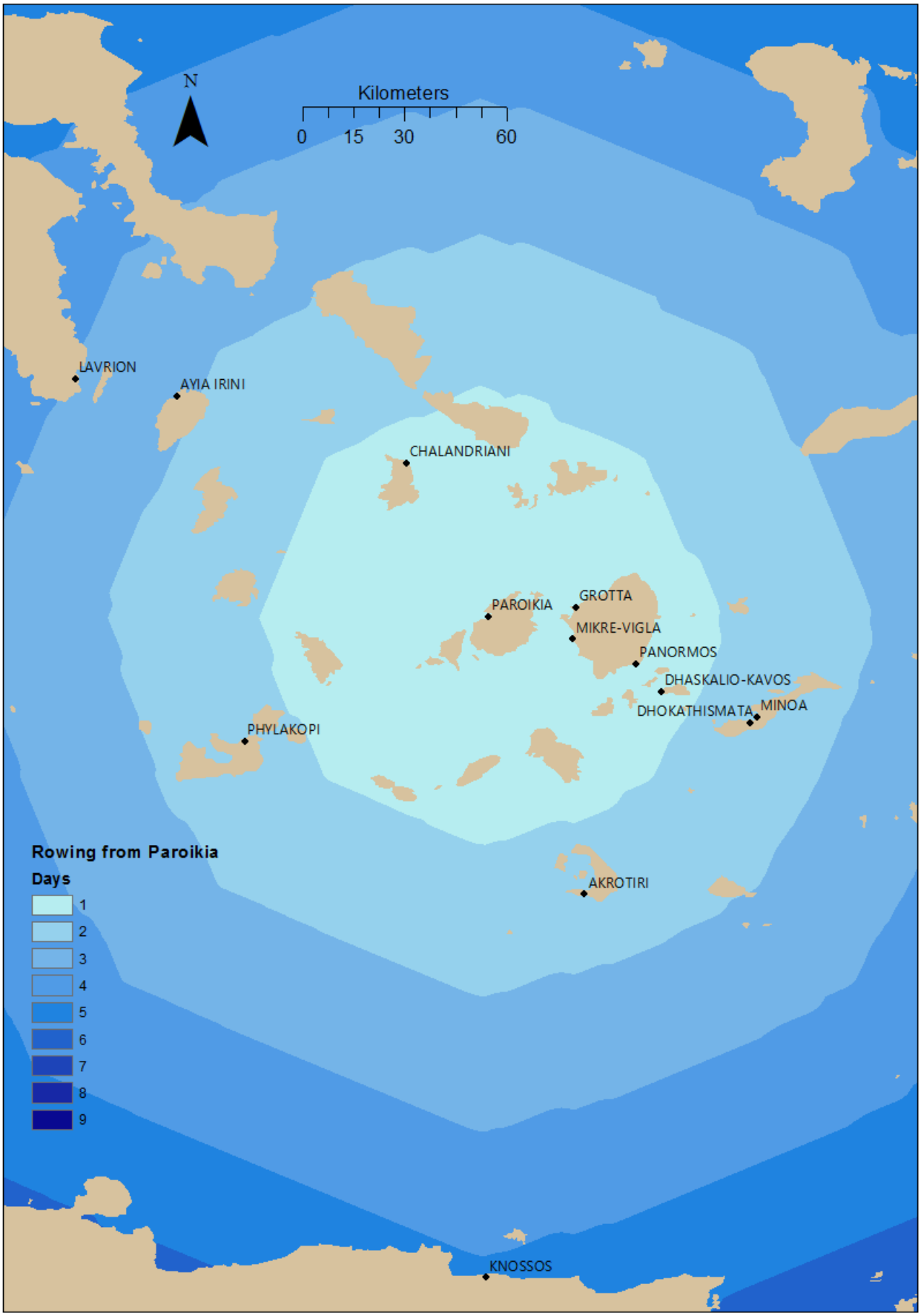
Appendix 5 – Rowing time from Ayia-Irini.



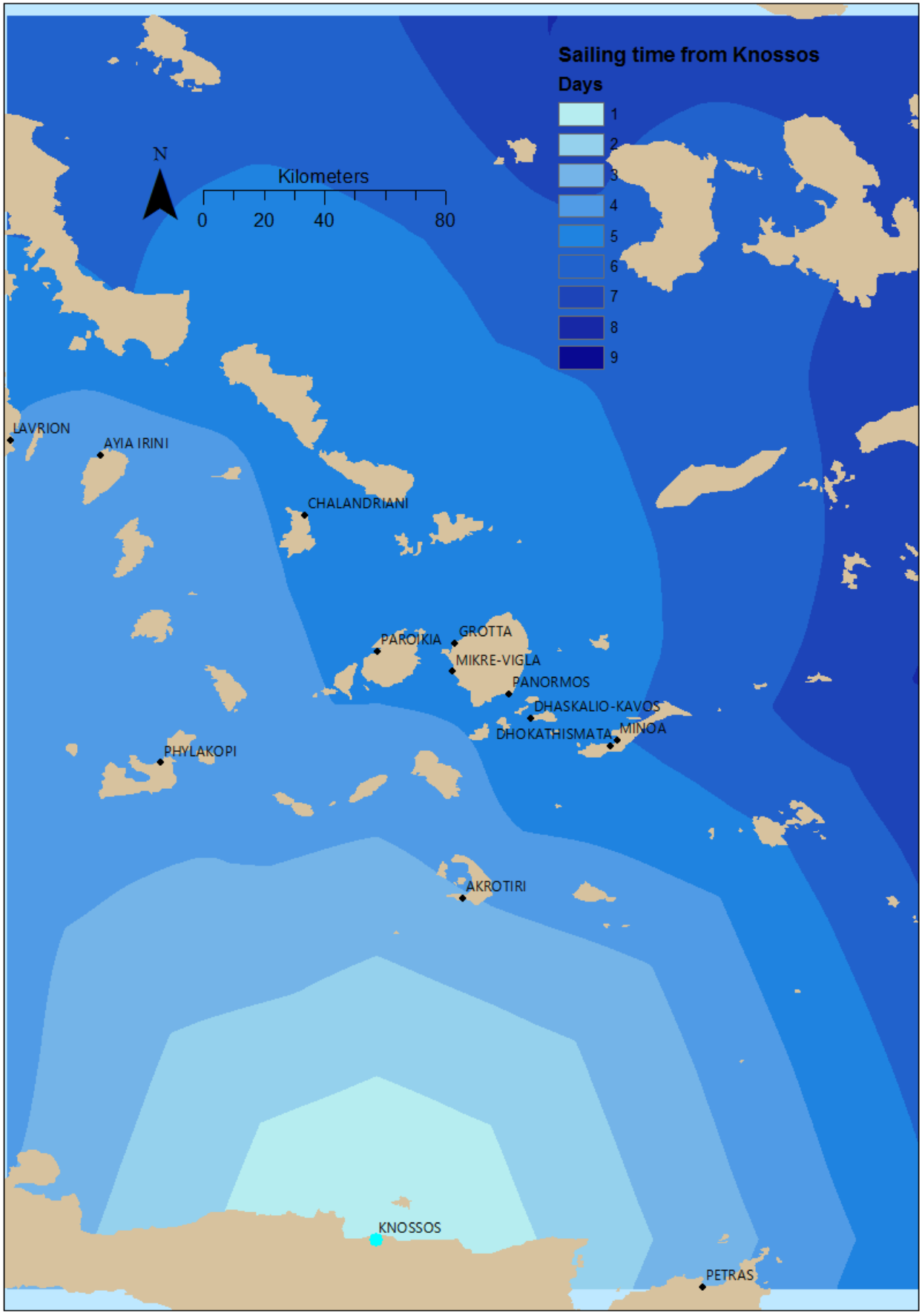
Appendix 6 – Rowing time from Phylakopi.



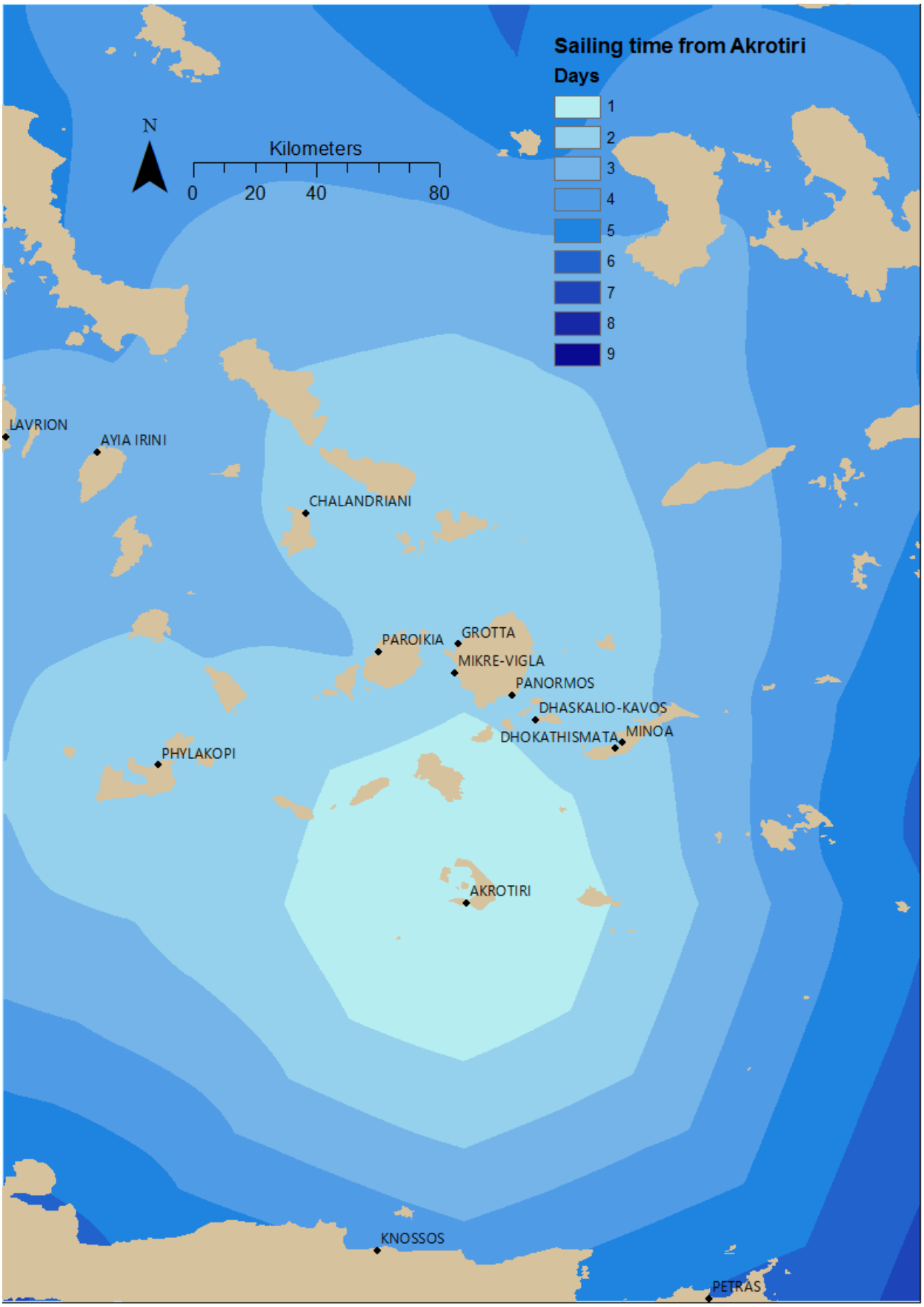
Appendix 7 – Rowing time from Paroikia.



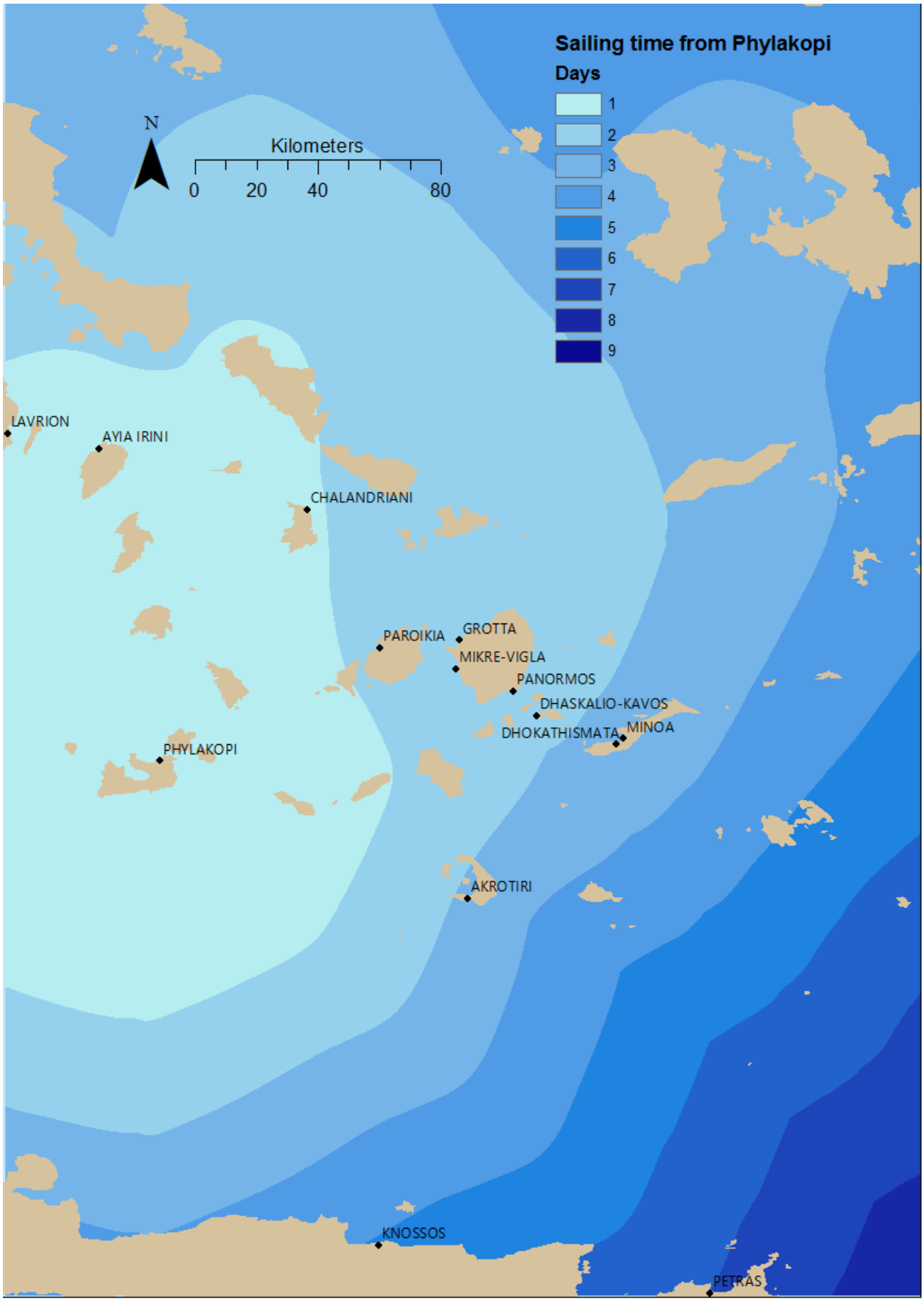
Appendix 8 – Sailing time from Knossos.



Appendix 9 - Sailing time from Akrotiri.



Appendix 10 – Sailing time from Phylakopi.



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