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Introduction

Harbours are amongst the most important and remarkable human structures and spaces. They play a crucial role as major centres of exchange, interface, and nodal points in commercial, cultural, and political networks. As such, they provide a unique insight into their contemporaneous world by connecting different aspects of human life, and especially in regions and periods in which human interaction via the sea acquires great importance. This study deals with such a region, the Aegean Sea, and focuses on the Hellenistic and Roman periods, during which seamanship, maritime trade, and mobility became a critical feature of the lives of contemporary peoples.

A key aspect of the function of harbours throughout their history is that successful operation is fundamentally dependent on ships and seamanship. The form and number of the ships that a harbour is required to accommodate, and its ability to do so, largely dictates its importance and allows harbours to develop into significant commercial and urban centres. In turn, the natural and artificial configuration of harbours dictates the form and size of ships that can use them, and the methods mariners will employ for accommodating these ships into harbours. This mutual dependency between harbours and ships constitutes a major field of research that can shed light not only on the operation and evolution of harbours, but also on more general aspects of contemporary commerce, technology, and architecture in a way that has not yet been exploited to its full potential by scholarship. This study examines the case studies of Delos and Kenchreai, two of the most important harbours of the Hellenistic and Roman Aegean in relationship to the ships and cargoes they served, and the role this relationship played in their operation and development. This is done by creating and applying a new methodology based on the principle that harbours are built and operated to predominantly serve ships and their cargoes. The methodology employed includes the use of quantitative methods and introduces the synthesis of a much wider and more inclusive variety of data, handling them through new and up-to-date illustrative methods and the creation of reconstructions of the two case studies.

1.1 The research question and the aims of this study

As noted above, this study targets two Hellenistic and Roman harbours of the Aegean vis-à-vis contemporary ships and seamanship. It focuses on the relationship of the two harbours with the ships of the period and broad approaches to seamanship, and the different ways in which ships, as well as their cargoes, were handled within these harbours. Consequently, the aim of this study is, at a first level, to understand the rapport between specific harbours and the ships that sheltered in them, as well as the cargoes these ships carried and, at a second level, to explore the ramifications in contemporary commercial networks, economy, architecture, and urban planning of the cities related to them. This study combines different aspects of harbour and ship archaeology (Figure 1.1) including, the configuration of ships, seamanship and harbour environments, and the various features of ship and cargo handling within the case study harbours (capacity, circulation, methods of accommodating ships and dealing with the handling of cargoes of various types).

1.2 Why harbours?

Harbours serve various needs and have a multi-level function, from centres of seamanship and thriving markets to coastal settlements and monumental establishments. Their importance lies, as will be explained, in this unique and complex operation that combines different aspects and functions.[1] This is why the study of ancient harbours, and especially of the ones belonging to the Hellenistic and Roman periods, is important and can add considerably to the understanding of the human past.

Harbours are built and operate in a specific geographical position, which essentially constitutes a portal between the land and the sea, the hinterland and the foreland, but also a nodal point in different commercial networks. [2] They also serve the requirements of a given region and of related economies and peoples.[3] It is for these reasons their natural configuration is artificially enhanced to varying degrees, often rendering them some of the most complex and technically advanced structures of their time.[4] Furthermore, and following their prominence as commercial centres described above, they often become the maritime façade and main gateway of the cities, regions, and states they serve, being the first and last thing travellers and visitors experience when they reach or leave a foreign land. Thus, they regularly evolve into spaces where political ideas and symbols are displayed in a unique 'scenography' through lavish and carefully planned monuments and buildings.[5] Finally, harbours as settlements are "autonomous realities",[6] combining a variety of functions and services (commercial, religious, recreational, etc.), all related to the reception and handling of ships, people, and cargoes,

[1] Delano Smith 1979, 327; Rickman 1985, 105; Rogers 2013, 183–96; Reger 2016, 14; Feuser 2020, 2–6.
[2] Horden and Purcell 2000, 392; Karmon 1985, 2–5; Schörle 2011, 93–5.
[3] Bouras 2016; Davies 2006, 78; Hopkins 1983, 85–96; Leidwanger 2013.
[4] Morhange and Marriner 2010; Oleson 1988, 147; Rostovtzeff 1941, 1042.
[5] Bouras 2014, 669–71; Feuser 2020, 305–19.
[6] Reger 2016, 12–5.

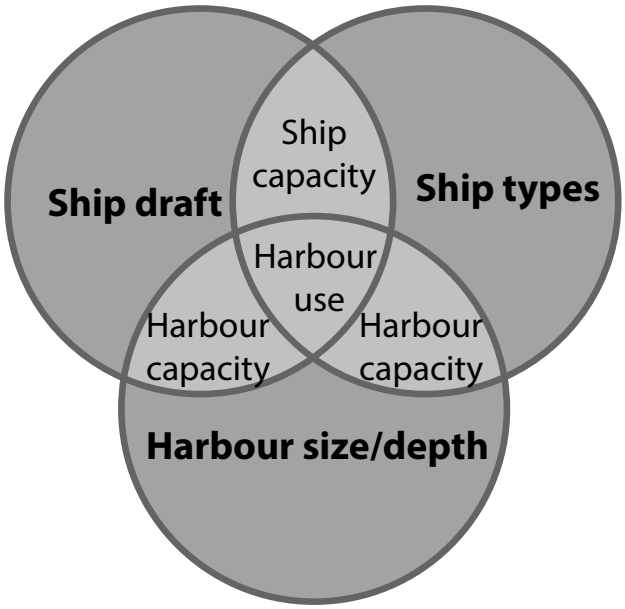

Figure 1.1. Schematic presentation of the various aspects of ship and harbour configuration that relate to this study's research question (drawing by the author).

developing a "nautical economy".[7] They, thus, create an indispensable link between the local populations and the outer world or foreland, as well as their own hinterland and fellow citizens.[8]

Through all these different roles and functions, harbours connect to every aspect of contemporary society. This solidifies their importance as archaeological sites, which is particularly the case for the harbours of the Hellenistic and Roman Mediterranean. This "brilliant, crowded, lively age"[9] was marked by significant changes both in macro and micro levels, especially in economic sectors,[10] largely thanks to the unification of the Mediterranean world that started under Alexander the Great and was completed with the Roman Empire and the *Pax Romana*[11]. Through the establishment of a political, cultural, religious, and commercial *koine*, this unification scheme stimulated commercial growth even more and caused the volume of trade to reach unprecedented levels;[12] the growing volume of seaborne trade had to be served by new, larger, and technologically improved ships (see Chapter 2).[13] This brought new demands to harbours, which were to serve a rising number of merchantmen (often of great tonnage) and variable types of merchandise (from grain and other victuals to works of art, enslaved people, and marble), as well as to house equally variable related facilities and activities (shipyards, markets, storage facilities, lodging of ship crews and travellers, etc.). The crowding of people around harbours, and the importance they acquired, turned many of them into some of the most densely populated and monumental establishments of their period, often under the generous patronage of powerful elites.[14] Old and new technologies were employed in the construction and maintenance of harbours, along with the pre-existing technique of constructing ashlar quays on rubble foundations (conventionally called the 'Greek' method), or of casting blocks from the surface of the water;[15] the ground breaking technology of maritime concrete was also introduced by Roman engineers.[16] Extensive dredging was employed furthermore, from the Hellenistic period onwards.[17]

Nevertheless, and despite the fact that various ways one can approach the operation and development of Hellenistic and Roman harbours exist, the reason why they, as well as essentially all harbours in human history, were primarily constructed, developed, and operated was the accommodation of ships and the handling of their cargoes. A strong dialectic relationship is present between the physical form of a harbour (which is potentially enhanced through human intervention) and the ships and cargoes it has to serve and handle; the configuration of a harbour is what dictates the number, type, and size of ships it can accommodate and subsequently the types and quantity of cargoes that can be handled, or even the number, occupation, and origin of people who dwell in its environs (Figure 1.1). Accordingly, the type and number of ships, and quantity and kinds of cargoes a harbour is required to serve dictates the way it operates, its evolution, and the creation of various harbour works.[18] This is why the research question of this study is so important, and why answering the need and creating a methodological framework for that query, can significantly promote the study of harbours on a wider scale.

1.3 The research of Hellenistic and Roman harbours and ships

The study of Hellenistic and Roman harbours of the Mediterranean is a relatively new field, mainly due to the fact that most ancient harbour sites in the region are partly submerged today and were unreachable by scholars before the development of self-contained underwater breathing apparatus (SCUBA) in the middle of the twentieth century.[19] It has, however, progressed rapidly in a multitude of scientific fields and geographical areas, with a corresponding number of finds, methodologies, and theoretical approaches, many directly related with the

[7] Gibbins 2001, 294–5.
[8] Monge 2004, 229; Reger 2016, 12–5.
[9] Grant 1990, ix.
[10] Archibald 2005, 1.
[11] Chaniotis 2018, 10–30; Horden and Purcell 2000, 27.
[12] Paterson 1998, 150; Temin 2013, 2.
[13] Casson 1974, 121–2.
[14] Boehm 2018, 127; Bouras 2008; 2014; Casson 1971, 366–7; Feuser 2020, 311–2; MacDonald 1986, 262; Oleson and Hohlfelder 2011, 814–6.
[15] Empereur and Koželj 2017, 114–5; Haggi and Artzy 2007, 82; Pritchard 1978, 60.
[16] Brandon et al. 2021; Casson 1971, 367–8; Oleson 1988, 148; Rickman 1996, 285.
[17] Morhange and Marriner 2010.
[18] Boetto 2010, 112–3; Schörle 2011, 94–5; Zarmakoupi 2018b, 31–2.
[19] For general overviews of the history and development of harbour archaeology in the Mediterranean in the twentieth century, see Blackman 1982a, 85–90; Delgado 1997, 187–9; Muckelroy 1978, 75–84; Shaw 1972, 99–100.

scopes of this study. It is, therefore, important, that before proceeding with the examination and analysis of the data of this research, to have a clear and coherent idea of its predecessors, to highlight important similar approaches, underline examples of research that have operated as stimuli and case studies, and to clarify the gaps that this study aims to cover. This literature review does not intend to provide a full account of all developments in the archaeology of Hellenistic and Roman harbours of the Mediterranean, but to present the different approaches to their study and the debates related to the aims of this book, as they have been highlighted in the previous pages.

1.3.1 Harbours, architecture and urbanism

The relationship of Hellenistic and Roman harbours with their urban environments, as well as their configuration as architectural spaces, is one of the major aspects of scholarship. As early as 1896, Ardaillon, the first excavator of Delos' Main Harbour area, underlined the connection of the harbour with the monuments, agoras, and other buildings lying along the west coast of the island.[20] Pâris continued Ardaillon's study and, in his 1916 pioneering work on the harbours of Delos, focused on the maritime façade of the city and its role as an *ἐμπόριον/emporion*; he considered harbours a special zone of predominantly commercial function, and thus did not move his scope any further inland.[21] This approach was also adopted by Lehmann-Hartleben in his seminal work on ancient Mediterranean harbours in 1923, in which harbours were studied mainly as rather independent annexes of adjacent cities.[22] This independence of harbours corresponded to the notion of their function as distinctive spaces "where the terrestrial zone of consumption and production abuts the maritime domain of redistribution and communication".[23] The existence of this "façade maritime" was already underlined by Günther in his pioneering studies of the coastal remains of Pausilipon near Naples,[24] where through the examination of the local geomorphology, ancient structures (villas, harbours), and finds, as well as of comparative iconographical parallels from Pompeian frescoes, the author focused on the unique maritime cultural landscape and coastal scenography of this specific area in the Roman period. In more recent years, and despite the fact that the importance of harbours as parts of great urbanization projects has been duly recognized,[25] many studies have continued focusing on the existence of a separated maritime façade, or on the strict delineation of harbour space through fortifications, gates, or other monuments.[26] MacDonald, in his seminal study on Roman architecture, even suggested an antagonistic relationship of harbours with the adjoining cities.[27]

This 'wall' between the city and the harbour was breached with recent studies that, based on a better understanding of Hellenistic and Roman cities, suggested a new way of relating the two spaces. An innovative urbanistic approach to the harbour of Delos was attempted in 1981 by the architect Papageorgiou-Venetas. The author, drawing upon the contemporary theories on urbanism and ekistics, used the latest mapping and quantitative methods to assess the development of the ancient city, including its maritime façade, which he considered an indispensable part of the urban fabric. But, despite the importance of the study, the results were problematic; all the evidence was taken from earlier publications, which the author took for granted, and did not proceed from any new fieldwork and little space was left for any detailed discussion of the harbours (see also Section 1.2.6).[28] The complexity of the relationship between harbours and urban hinterlands was also outlined by Purcell,[29] who underlined the complex nature of the urban and rural coast, or *ora maritima*, of the Roman Mediterranean. A similar approach was followed by Karvonis and Zarmakoupi, who meticulously examined the commercial establishments and spaces of Hellenistic Delos (agoras, shops, warehouses) and showed that these were not limited in special areas but dispersed all around the urban fabric.[30] This rendered the whole settlement a true 'merchant city' or an integrated *emporion*, as was suggested by Duchêne and Zarmakoupi,[31] with commercial functions distributed within the whole city and the limits between the maritime façade and the urban hinterland being fluid, their relationship reciprocal and interchanging. A similar approach was adopted in Feuser's recent study on the harbour cities of the Hellenistic and Roman periods in the eastern Mediterranean, although the author there focused primarily on architecture and urbanism, and less on archaeological finds, particularly from the sea.[32]

1.3.2 Harbours as commercial centres

The basic role of harbours of all periods and geographical regions is to serve ship and cargo traffic. Thus, their role as commercial centres and hubs within exchange networks is crucial. Early scholarship was, as discussed above, based on the notion of harbours being *emporia*,[33]

[20] Jardé (1906, 640), who continued the excavation of the Theatre Quarter of Delos, made some interesting observations concerning the difficulty of circulation between the city and the seafront, due to the narrowness of the crooked streets.
[21] Pâris, 1916.
[22] Daum et al. 2014, 11. The integration of coastal cities with harbours was mostly observed through the formers' inclusion within the cities' fortifications, especially military ones (city walls were the only urban features included in Lehmann-Hartleben's plans).
[23] Purcell 1996, 272, 277; cf. Horden and Purcell 2000, 392. The discussion over the form and function of the *emporia* in the Greco-Roman Mediterranean has been a long, complicated, and ongoing one, with various approaches and debates concerning the whole subject (see Bresson and Rouillard 1993; Demetriou 2012; Gailledrat et al. 2018).
[24] Günther 1903; 1913.
[25] Boehm 2018, 127; Feuser 2020; Rougé 1966, 121.
[26] Bouras 2008; Duchêne et al. 2001.
[27] MacDonald 1986, 262.
[28] For generally negative reviews of the book of Papageorgiou-Venetas on Delos, see Scranton 1982 and Bruneau 1984. Amongst others, the author was heavily criticized for uncritically applying modern-era quantitative methods in the study of an ancient city.
[29] Purcell 1996, 276–7.
[30] Karvonis 2008; Zarmakoupi 2013a; 2013b; 2014; 2018a; 2022.
[31] Duchêne 1993, 114–8; Zarmakoupi 2018b, 36–8.
[32] Feuser 2020.
[33] Polanyi 1957, 54; 1963.

something commonly documented in ancient written sources[34] and on which Lehmann-Hartleben dedicated a whole chapter of his seminal study.[35] The commercial function of Hellenistic and Roman harbours was explicitly recognized by the historians of the same period, following the developments in scholarship related to ancient trade and economy. Charlesworth and Rostovtzeff were the first scholars to thoroughly explore the economic history of the Hellenistic and Roman world, in which commerce and harbours played an essential role. Rostovtzeff in particular underlined the importance of Hellenistic harbours as competitive and monumental trading centres and suggested the first general classification for them within contemporary commercial networks.[36] Rougé, in his 1966 work on commerce during the Roman imperial period, saw harbours within their wider economical and geographical context, and also underlined the importance of an extended hinterland for their successful operation, as they functioned as nodal points between "producer" and "consuming cities".[37] The dependence of a successful harbour on a productive hinterland was acknowledged in the 1980s by Hopkins and Karmon and later by Boehm,[38] who all related important commercial networks, and the harbours that served them, with extended hinterlands and large cities that provided both the main goods exchanged (agricultural products), as well as the populations to consume them.[39]

Although such approaches were rather straightforward in harbours serving large and densely populated regions (e.g., Carthage, Alexandria) or "mega cities" like Rome or Antioch (e.g., Portus),[40] recent studies by Reger, Zarmakoupi, and Leidwanger showed the parallel operation of successful harbours lacking a proper hinterland and thus serving relatively small populations, like Hellenistic Delos[41], or hinterlands served by series of rudimentary, "opportunistic" harbours, like Cyprus and Cilicia in late antiquity.[42] In the first case, such harbours could be associated with the operation of long-haul networks and the function of harbours as transit centres and clearing houses,[43] whilst in the second with smaller, but equally important, versatile and more dynamic local networks.

Commercial and seafaring networks have been the focus of a series of harbours studies in the last decades. Network methodology and theory were introduced in the beginning of the twenty-first century by Broodbank for the Early Bronze Age Aegean and by Malkin for the Archaic Mediterranean.[44] Thus, the role of harbours as important parts of such networks was soon recognized, both on a regional scale, as well as a Mediterranean level.[45] Related to the scope of this study was Bouras' study of the harbour network of Roman imperial period in the Aegean,[46] Wilson, Schörle, and Rice's discussion on the division of the Mediterranean into two distinctive harbour networks (east-west),[47] as well as Schörle's discussion of the regional Roman harbour networks of the Tyrrhenian sea.[48] It should, nevertheless, be noted here that a more inclusive study on the operation, or even the existence, of harbour networks in the Hellenistic and Roman Aegean is lacking in the literature.

1.3.3 Harbour technology and infrastructure

Infrastructure and technology concern another discourse over Hellenistic and Roman harbours, also related to harbour classifications and hierarchies, as well as with their importance as financial centres as described above. The impressive size and monumentality of several harbours, as documented in written sources (e.g., Vitruvius' descriptions of an ideal harbour),[49] iconography (e.g., the harbour landscape Pompeian frescoes; Figure 2.9)[50] and in a series of archaeological finds (e.g., the Severan harbour of Lepcis Magna or the famous lighthouse of Alexandria)[51] flagged them as "models of really clever and efficient planning and artistic creations of a high order, beautifully laid out and adorned with imposing buildings and decorative sculptures", as eloquently described by Rostovtzeff.[52] The further study of harbours like Lepcis Magna, Portus, Alexandria,[53] as well as the recent study of maritime concrete and dredging technology[54] confirmed the size and technical complexity of harbour infrastructures, and the amount of resources invested in them.[55] This approach relates to one of the longer and most complicated debates over the economic history of antiquity, particularly for the Roman period. 'Substantivists' see the economies of antiquity as predominantly based on subsistence, reciprocity, and "non–market"[56] exchange systems, whereas 'formalists' or neoclassical economists, see ancient economies as universal and highly advanced

[34] For a general discussion on the role and identification of *emporia* in antiquity, largely based on written sources, see Bresson and Rouillard 1993, Demetriou 2012, Gailledrat et al. 2018.
[35] Lehmann-Hartleben 1923, 28–45.
[36] Charlesworth 1926, 76, 115–7; Rostovtzeff 1926; 1941, 1042–3, 1263–8.
[37] Rougé 1966, 121. The terms "producer" and "consuming cities" were introduced by Weber in 1958.
[38] Boehm 2018, 127; Hopkins 1983, 105; Karmon 1985, 1–5.
[39] Horden and Purcell 2000, 105–8.
[40] Boehm 2018, 127; Hopkins 1983, 105; Karmon 1985, 3.
[41] Reger 1994, 51–5; Zarmakoupi 2018b, 31.
[42] Leidwanger 2013; 2020.
[43] Rostovtzeff 1941, 1263; Bresson and Rouillard 1993; Demetriou 2012.
[44] Broodbank 2000; Malkin 2011.
[45] For general studies on exchange networks in the ancient Mediterranean, see Leidwanger and Knappet 2018; Malkin et al. 2009; Malkin 2011; Schäfer 2016. For the *emporia* networks, see Demetriou 2012. For networks in the Cyclades, see Constantakopoulou 2017. For networks in the Red Sea, see Kotarba-Morley 2015.
[46] Bouras 2008, 2016.
[47] Wilson et al. 2013.
[48] Schörle 2011.
[49] Vitr.5.12.1. Cf. Casson 1971, 366; Dubois 1905.
[50] Ugolini 2020.
[51] Bartoccini 1958; Blackman 2008b, 643–9; Empereur 2004; Oleson and Hohlefelder 2011, 814–9.
[52] Rostovtzeff 1941, 1042.
[53] Bartoccini 1958; Feuser 2020, 188–228; Goddio and Bernand 2004; Goddio and Fabre 2008, 266–74; Keay 2012a; Rickman 1996, 2002.
[54] Brandon et al. 2021; Morhange and Marriner 2010; Salomon et al. 2016.
[55] Paterson 1998, 161.
[56] Archibald 2005, 10–7.

"market economies", where utility maximization played a crucial role, much like in modern times.[57] The approach of 'formalists' is in accordance with the refined organization of the large, monumental harbours of the period, as well as with the increased employment of bulkier, more advanced merchantmen, which would correspondingly require larger and deeper harbours, something that culminated within the framework of a "proto-industrial" economy of the Roman world.[58]

A closer look, however, at many harbours of the period revealed a more complex image. Delano Smith, in her important work on the historical geography of the Western Mediterranean, was the first to underline the diachronically successful operation of smaller and shallower harbours, equipped with little (or none at all) harbour infrastructures.[59] Karmon followed by suggesting a clear distinction between less elaborate harbours serving local traffic, and the ones related to long distance, 'great' trade.[60] Such an approach has been productively exploited in more recent years with studies dealing with the parallel operation of short- and long-haul trade networks (see Section 1.3.2)[61] and the corresponding configuration of harbours, even when dealing with specialised cargoes, like marble and stone.[62] This notion most likely reflects the operation of smaller, simpler merchantmen in 'secondary' or local trade networks. The lack of substantial infrastructure has also been thoroughly noted at least for one of the case studies, Delos, by Duchêne, Zarmakoupi and Bresson.[63] Such 'simple' harbours might support substantivist approaches, according to which ancient economy was predominantly tied to its environment and did not involve utility maximisation.[64] The possibility, however, of harbours to serve both types of commerce has been little explored, studies focusing on either the 'great trade' mostly of grain towards the great urban centres, or on local networks and cabotage.[65] The present study sheds light on this issue by clarifying the capacity of harbours in terms of ship traffic, as well as in terms of the cargoes they can handle.

Directly linked to the sophistication and the existence, or not, of harbour infrastructures, as well as to the debate over "primitivism versus modernism", [66] is the advance of the technology of harbour works. A rather linear development was suggested by Blackman, progressing from the relatively primitive "Phoenician" rock-cut harbours to the sophisticated concrete ones of the Roman period, a view followed by later scholars, as well.[67] But this scheme has been challenged; the survival of the "Greek" method, attested by various ashlar moles dating to the Roman period (e.g., Kenchreai, Kyme, Lepcis Magna); the uneven distribution of the use of maritime concrete around the Mediterranean coasts; as well as the simplicity of various harbour sites has shown that the issue of harbour technology development is more complicated than once thought.[68] This is one of the issues discussed in detail in this study.

1.3.4 Politics, patronage, and symbolism

Harbour infrastructures, as well as the development and application of specific construction and maintenance technologies, are both issues related to the role institutions (states, rulers, cities) played in contemporary economy and commerce. Scholars in the past, like Rougé or Morley, recognized only a marginal, usually driven by political and not practical reasons, intervention by the state, especially the Roman one, in the creation of commercial networks and infrastructures.[69] Nevertheless, sources documenting state intervention in the construction of harbours and in the facilitation of trade,[70] as well as the high costs of harbour construction and maintenance,[71] point towards more active and efficient intervention schemes. Neoclassicism and New Institutional Economics, focusing largely on the role institutions played in economy, commerce, and subsequently the operation of harbours in the ancient Mediterranean, have recently tackled these issues through a series of useful analyses.[72] According to them, state intervention, practiced through political and monetary unification, establishing prices of foodstuffs, suppression of piracy[73], introduction of new technologies, and creation of harbour networks,[74] would not only lower the costs of sea transportation but also improve the overall well-being of people, allowing for the intensification of trade and subsequent financial growth, despite the fact that the economy remained largely dependent on agriculture.[75]

But state intervention and patronage had a different impact on harbour construction and maintenance. The study of the interplay of politics with harbours during the Hellenistic and Roman period is a relatively new field of research. Despite the fact that harbour architecture (see above) and iconography had drawn the attention of scholars as early as the time of Lehmann-Hartleben,[76] the actual role of harbour construction in contemporary politics was little explored. Scholars like Lehmann-Hartleben and Rougé focused

[57] Archibald 2005, 3; Polanyi 1957; Reger 2005, 331.
[58] Rougé 1966, 71–3; Archibald 2005, 10; Pomey 2011, 48–9.
[59] Delano Smith 1979, 361–5.
[60] Karmon 1985, 5–6.
[61] Davies 2001, 21–2; Hopkins 1983, 85, 94–6; Lawall 2005, 202; Tchernia 2011, 88.
[62] Russell 2013a, 139–40.
[63] Duchêne 1993, 125; Zarmakoupi 2013b, §5–7; Bresson 2016, 90–1.
[64] Archibald 2005, 3; Polanyi 1957.
[65] Gibbins 2001, 288; Wilson et al. 2013.
[66] Reger 2005, 331.
[67] Blackman 1982a, 1982b, 2008b; Rickman 1996; Wilson 2011b, 46–7.
[68] Brandon et al. 2021, Figure 3.2; Hohlfelder 1985, 85; Leidwanger 2013, 22.
[69] Beresford 2013, 51–2; Morley 2007, 585; Rougé 1966.
[70] Arnaud 2015b; Garnsey 1998, 533–5.
[71] Arnaud 2015b, 66–7; MacDonald 1986, 262.
[72] The most important papers on the application of New Institutional Economics in ancient economy can be found in the Cambridge Economic History of the Greco–Roman World (Scheidel et al. 2007).
[73] Lo Cascio 2007, 226–7.
[74] Morel 2007; Robinson et al. 2020.
[75] Schneider 2007, 169–70.
[76] Lehmann-Hartleben 1923, 217–39. For other early discussions of harbour iconography, see Blackman 1982a, Figures 1, 2, 5; Boyce 1958; Picard 1959.

on the commercial use of harbours, their geographical position, and relationship with markets and hinterlands, but largely avoided discussion of the role of harbour construction in high-state euergetism and competitive politics, especially during the Roman Imperial period, for which more written sources are available. Moreover, the possibility of the use of harbours as symbols of power irrelevant to actual practical use, built primarily to serve political purposes, was not discussed until much more recently, as it will be shown in the following lines.

The role of royal and imperial intervention in harbour construction during the period discussed here became more evident through the recent study of the Roman maritime concrete technology by the Roman Maritime Concrete Survey (ROMACONS) program. The study, through the meticulous examination of the development and diffusion of Roman maritime concrete in the Mediterranean, highlighted the role of central authorities and elites in the creation of such massive and elaborate harbour works.[77] A more thorough study, based mainly on written evidence, was made by Arnaud in 2015.[78] The scholar successfully analysed the interplay between political intervention and harbour construction and maintenance in the Roman Mediterranean, focusing on the complicated and competitive politics behind attempts to create and maintain harbours, as well as on the lack of a cohesive plan to create harbour networks, euergetism being delivered often *ad hoc* and not always corresponding to the practical needs of cities and regions.

Related to the politics of harbour construction and maintenance is the issue of their emblematic role as symbols of power and authority and the creation of a specific "façade maritime" or an *ora maritima* (maritime coast), representative of a city, a state, or a region.[79] This notion of harbours was evident through the well-known pictorial art of the late Hellenistic and especially Roman period (e.g., various sacro-idyllic Pompeian frescoes or mosaics around the Mediterranean) and it was Günther who related Pompeian harbour iconography in his study on the maritime façade of Pausilipon district near Naples, drawing parallels between the architecture documented in art with archaeological finds. [80] Nevertheless, the scholar did not realise the discrepancy of these images with actual archaeological finds and the fundamentally illusive, idyllic nature of such artworks, as later scholarship showed.[81] A more inclusive study on Hellenistic and Roman harbour symbolism in iconography was published in 2020 by Ugolini, who, collecting nearly all harbour iconography of the period, addressed the ways harbours were visualised within contemporary art and explored the conveyance of a series of meanings (imperial power, prosperity, and euergetism). The author, unfortunately, used little archaeological evidence and focused mainly on the art historian perspective.[82] Bouras, in an article in 2016, and Feuser, in his 2020 study, also addressed the issues of political and religious symbolism of harbour environments basing their studies on iconography, as well as on archaeological finds, especially from the eastern Aegean (Rhodes, Kos, Ephesus).[83]

1.3.5 Harbours and geosciences

With harbours being fundamentally natural spaces, exposed to geomorphological changes, often abrupt and radical, the discussion over their original configuration based on the data of geosciences is a crucial aspect of the literature review. The basic problem affecting both harbours studied here, as well as the rest of the Mediterranean coastline is the rise of sea level. As early as 1900, geologists like Negris and Cayeux debated over the issue, using archaeological data from the submerged structures in Delos and Rhenia, the first supporting the rise of sea level since antiquity and the latter rejecting it.[84] The lack of precise data on the actual sea level of antiquity has lead to many misinterpretations of harbour works, particularly of quay structures, which have been wrongly considered to have been actual docks on which ships could directly berth, despite the fact that in antiquity they were built on dry land and at a distance from the sea (e.g., the early reconstruction of the coast of the city of Delos as a continuous dock by Pâris; Figure 3.7).[85] The debate was settled in the 1960s and 1970s by the meticulous studies of Flemming in sites of the Aegean (Crete, the coasts of Asia Minor, eastern Peloponnese, etc.) and North Africa (Apollonia), and of Schmiedt in the Roman fish tanks of Italy.[86] Both scholars established with accuracy the fact of sea-level rise in the Mediterranean, something proven many times by later studies in various coastal sites, such as Delos, where the study of beachrock formations has been crucial (see also Section 3.1.1).[87]

Nevertheless, the established sea-level rise in the Mediterranean is not the only important factor of change in harbour environments. Tectonic movement, tsunamis, uplift and subsidence, and siltation have puzzled researchers as early as the nineteenth century (e.g., Spratt's observations on the great uplift of the harbour of Phalassarna in Western Crete),[88] but their understanding remained largely empirical, due to the lack of scientific methods that allowed the establishment of a chronological sequence

[77] Brandon et al. 2014, 233–5.
[78] Arnaud 2015a.
[79] On the introduction of the term "façade maritime" in historical geography (concerning the example of Albania), see Ducellier 1981. On the first use of the same term, as well as in relationship to the Latin term *ora maritima* in the context of Hellenistic and Roman coastal environments, see Purcell 1996, 272–4.
[80] Günther 1903, 503–7, Figs.1, 2. 3.
[81] Hinterhöller-Klein 2015, 175–80; Ling 1977, 4–5; Zarmakoupi 2020, 152–3.
[82] Ugolini 2020; for a review of the book see Nakas 2021.
[83] Bouras 2016, 206–14; Feuser 2020, 328–40.
[84] Cayeux 1907; Negris 1904a, 1904b; 1907.
[85] Pâris 1916, Pl.I–IV.
[86] Flemming 1960; 1965; 1971; 1978; 1980; Flemming and Czartoryska 1969; Schmiedt 1970; 1975; cf. Marriner and Morhange 2007, 142.
[87] Dalongeville and Fouache 2005; Dalongeville et al. 2007.
[88] Spratt 1865, 230.

in harbour basins, either still in the sea or on land.[89] The dynamic nature of coastal environments required a multi-disciplinary approach that was made possible towards the end of the twentieth and especially in the early twenty-first century by the development of new methods that combine field survey and coring, with laboratory examinations. Geophysical prospection of different kinds (e.g., electrical resistance and magnetometry) combined with coring and subsequent analysis of the stratified data (soil compaction, particle size, organic content, artefact content, burning and moisture retention, palynology) furthered harbour archaeology by providing hard data concerning the evolution of a truly long series of Mediterranean harbour basins,[90] many from the Aegean coasts of Asia Minor (Ephesus, Troy, Priene and Miletus).

In general, two schools have developed in the study of ancient harbours in relationship to geoscience.[91] The first has focused on validating ancient written sources concerning the configuration and positioning of harbours (e.g., the Homeric harbours of Troy, or the harbour of Late Bronze Age Byblos)[92] and the second on a more "geocentric" approach, dealing with the transformation of whole regions, like Ephesus or Akarnania, without targeting specific ancient sites or assessing written evidence.[93] More recent studies have sought to escape such limited scope, and have actively tried to create multi-disciplinary approaches to take advantage of progress in all branches of science through collaboration and communication.[94]

An important issue of the development of all these methods in relationship to harbours is the lack of direct connection between them, with each method providing specific data on a specific issue, but rather isolated with the rest, often contradicting each other. This issue was partly solved by the development and application of the Palaeoenvironmental Age-Depth Model (PADM) chart in the harbours of Ostia and Portus. [95] The importance of the PADM chart lies in its ability to visualise integrated data (stratigraphy, sea-level rise, sediment texture, and palaeoecological context) in a combinative and comparative way, allowing for a "useful transdisciplinary dialogue"[96] between specialists of all fields. At the same time, it incorporates the discussion over ship draught, which, as will be seen in the following chapter, formed one of the most important aspects of harbour operation during the period being presented in this analysis

Nevertheless, and as correctly put by Marriner and Morhange, the geological record is by no means "a talisman by which to heal all ills".[97] The inability of geophysical research to offer precise chronological evidence, the discrepancy between calendrical and radiometric chronologies, the lack of archaeological data to support its finds, and vice versa, has generated a series of debates amongst archaeologists and geomorphologists concerning the original form, depth, or even sheer existence of some ancient harbours. Examples related with such debates are the harbour of Kition-Bamboula in Cyprus, where three different positions for the harbour's basin have been suggested between 1975 and 2000,[98] as well as Delos' Main Harbour, which has been reconstructed as a functional harbour basin by one group of geologists and as a totally silted bay by another (see Section 3.1).[99] Such discrepancies show the margin of different interpretations of data in geophysics approaches and the need to have a more holistic and inclusive approach to harbour archaeology.

1.3.6 Ships and harbours: towards a combined study

As discussed above, scholarship has predominantly engaged harbours in relationship to their commercial role, as well as their connection with the hinterland, the urban fabric around them and their architecture, but has rarely explored the connection between ships and harbour spaces. Ships, on the other hand, have been meticulously studied in terms of shipbuilding, operation, and cargo, but not in relationship to the places where they were bound to sail to and from. Several attempts of such a combined study have been attempted, some of which have provided stimulus for, and are important predecessors of, this study.

The first scholar who studied harbours and ships in a common context was Pâris. The pioneering archaeologist calculated a maximum of 100–150 merchantmen docked side-first on what he considered as a series of continuous docks on the west coast of Delos' city.[100] This was a totally arbitrary number, since Pâris lacked data on the actual configuration of both the ancient and the original form of the harbours and the coastline. But Pâris also proceeded in other relative fields of study, by addressing Delos' geographical position, ancient sea routes and climatic conditions, protection from the prevailing winds, and by also using ethnoarchaeological parallels (from the nearby harbour of Mykonos) concerning the beaching of ships and the possible use of quays. Pâris laid down the guidelines of a proper interdisciplinary approach, in which all available data would be combined to reach a comprehensive understanding of a harbour's function and operation, especially concerning ships and seamanship.

Casson was the first to recognise the importance of specialised service vessels for ancient harbours, initially in his 1965 study of the harbour and riverboats connecting

[89] Marriner and Morhange 2007, 143.
[90] It is quite futile to give a full list of all ancient harbours studied through geoarchaeological methods in the last 30 years. For a general overview of geoscience applied in ancient harbours, see Marriner and Morhange 2007 and Salomon et al. 2016, 1–3.
[91] Marriner and Morhnage 2007, 144.
[92] Francis-Allouche and Grimal 2016, 2017; Kraft et al. 1980; 2003.
[93] On Ephesus, see Brückner 1997; Delile et al. 2915; Stock et al. 2013. On Akarnania, see Kraft et al. 2003.
[94] Marriner and Morhnage 2007, 144; Morhange et al. 2005.
[95] Goiran et al. 2010, 2014; Salomon et al. 2012; 2016.
[96] Salomon et al. 2016, 19.
[97] Marriner and Morhange 2007, 184.
[98] Gifford 1978; Morhange et al. 2000; Nicolaou 1976.
[99] Dalongeville et al. 2007, Figure 8; Mourtzas 2011, Figure 12.
[100] Pâris 1916, 33.

Portus/Ostia with Rome, and then in his 1971 seminal work on ancient Mediterranean ships and seamanship.[101] In the former, harbours and ships of all types were discussed in adequate detail, but little was done towards an inclusive account of how they interacted and influenced each other. This approach was also followed by Shaw in his 1972 discussion on Hellenistic and Roman harbours; he did not consider the practical issues of the operation of ships and cargoes within harbour environments, either.[102] The issue of ship handling within harbours was briefly but aptly discussed in 1979 by Delano Smith, who underlined both the limited size and lack of infrastructure of various harbours (see above Section 1.3.3), as well as the importance of ship draught and harbour depth. Although the geographer did not discuss the issue in detail, she thoroughly flagged the complex nature of harbour configuration and ship operation within them, as well as the need for a combined study of the subject.[103] Delano Smith's overall approach was implemented in studies in the following decades, but these mostly targeted the harbours' natural and human geography,[104] whereas others addressed the important issue of size and tonnage of ancient ships,[105] without properly combining the two fields within a common framework.

An effort to relate ship and cargo traffic with the harbours of a 'port-city' was attempted by Papageorgiou-Venetas in 1981. The author incorporated data on late Hellenistic and early Roman merchantmen and calculated the number of ships that could use the harbours and the storage facilities of Delos in relationship to the total amount of imports of the settlement. His conclusions were, however, problematic. By not taking into account the change in sea level, despite it having been already confirmed by geologists,[106] the author basically replicated Pâris' plans, considering the quays of the Main and Merchant Harbours as proper docks where ships of any draught could berth. As for the handling of cargoes, his calculations were based on the assumption that all merchantmen of the period were *myriophoroi* (10,000 amphorae carriers; see Chapter 2) and not ships of any other capacity. No alternative methods of using the island's harbours were considered and, although bathymetric data were thoroughly included in the maps produced, the connection with the draught of ships using the harbours of the island was not discussed.

With the renewed interest in the commercial history of the Hellenistic and Roman Mediterranean, and the introduction of quantitative methods in scholarship at the beginning of the twenty-first century, a series of new studies fruitfully explored the relationship of ships and harbours. Rickman and Brand discussed the cargo volume and handling in the harbours serving Rome, also relating it with ship tonnage and loading/unloading practices, but not ship draught and alternative methods beyond docking.[107] Votruba followed, with his studies on the anchoring techniques, as well as of various beaching methods in the ancient Mediterranean, without, however, addressing the issue of draught in detail.[108] Draught was briefly mentioned by Marlier and Dell' Amico in relationship to the ability of the small-draught *dolia* carriers to navigate shallow estuaries and rivers,[109] but it was Boetto who, in her 2010 article, for the first time approached a Roman harbour as "seen from the sea" ("vu de la mer").[110] The scholar suggested a model for how ships would have used Portus, mainly its best-known Trajanic extension and the surrounding channel network. She did so by exploiting all available material on the site, drawing upon data from ships lost at sea or scuttled (especially of the local Fiumicino harbour/river ships) and proposing a division of zones, based on an updated division of ship types according to their tonnage and draught. Boetto explored the possibility of specific harbour areas to accommodate and serve ships of certain size and draught, including the *statio marmorum* (marble sector) and underlined the variability of ships of different types and tonnage using the harbour. Although the article did not include any bathymetric data,[111] as well as alternative ways of using the harbour, it illustrated a holistic, multidisciplinary approach to the problem of harbour capacity and ship/cargo handling, an approach that is also an essential part of the methodology of my analysis. Boetto's work was included in the application of the PADM chart in Ostia and Portus, which, as mentioned above, also incorporated the issue of maximum ship draught in the operation of these harbours.[112] The role of ships in the creation and development of a harbour was also studied in length by Kotarba-Morley on her study of the Berenike Troglodytica on the coast of the Red Sea, where extended data on local ship typology, configuration, and methods of use was fruitfully incorporated in the discussion over the operation of a specific harbour.[113]

1.4 Methodology

What becomes evident through the analysis of the research question and the literature review presented above is the need to design and implement a new methodology that can answer this study's research question. The lack, with few exceptions, of more detailed and inclusive studies on the role ship and cargo handling played in the operation and

[101] Casson 1965; 1971, 329–43.
[102] It is quite interesting that Shaw, although using more detailed and up-to-date data, did not properly address the issues of ship accommodation and harbour function, and did not include any bathymetric data in the plans he published, whereas in the cases of Delos and Lechaion, he reproduced the obsolete and highly inaccurate plans of Ardaillon and Georgiades.
[103] "The full story of the coastlands, the coastal cities, and the ports of Mediterranean Europe, has not yet been told" (Delano Smith 1979, 327). The author also correctly speculated that the maximum draught of most of the Roman-period merchantmen did not exceed 3 metres.
[104] Horden and Purcell 2000, 392–3; Karmon 1985, 2–5; Rickman 1985, 106–11; 1988; cf. Schörle 2011, 93.
[105] Houston 1988; Nantet 2016; 2020c.
[106] Flemming et al. 1973, 5; Flemming 1980, 176–7.
[107] Rickman 2002; Brandt 2005.
[108] Votruba 2014, 2017.
[109] Dell' Amico 2011; Mariler 2008.
[110] Boetto 2010, 112.
[111] The studies on the original depth of Portus and Ostia were only published later (Salomon et al. 2016, 17–8; Vittori et al. 2015, 378–80).
[112] Salomon et al. 2016, 8, Figures 5, 8.
[113] Kotarba-Morley 2015, 291–355.

development of ancient harbours was caused not only by the lack of interest of early scholars, but also by the lack of a suitable methodology that could be applied to more than one case study.

1.4.1 Methodological principles and tools

This study is based on a fundamental principle that connects its research question, aims, and methodology as follows: harbours are spaces and structures whose function and success is founded on their relationship with the ships and the cargoes that are handled within and through them. To comprehend their operation and development, one needs to have a clear understanding of the ships that use these spaces, as well as the form these harbours have and the possible ways ships and cargoes can be handled within. Thus any analysis of ancient harbours must begin with a solid knowledge of their original form and operation in relation predominantly to ship and cargo traffic, as these are documented through all available sources. Harbours must be seen 'through the eyes of the mariners' and in an inclusive and holistic way.

Basic concepts and principles

This study was developed around the concepts of inclusiveness, collectiveness, quantification, and standardization. This is due not only to the multilevel function of harbours as centres of shipping, commerce, and other human activities (see Section 1.2), but also to their complex dual character as natural and anthropogenic "amphibious" spaces.[114] Harbours combine natural features such as size, depth, exposure to the sea, and types of seabed and coastline, with human interventions of various forms, such as protective works, dredging operations, and commercial infrastructures.[115] They are also commonly related to coastal cities, with which they develop a reciprocal relationship, especially within common schemes of financial growth and urban planning (e.g., Delos, Miletus, Ephesus),[116] but also with other cities located further inland whose trade routes they serve (e.g., Kenchreai with Corinth, Portus with Rome, Elaia with Pergamon).[117] As a result, a variety of data (ship capacity, harbour configuration and infrastructure, climatic conditions, etc.) must be examined and synthesised to reach a reliable reconstruction scenario (or scenarios) of the original configuration of harbours and of the ship and cargo traffic that occurred.[118]

Standardization is required to produce results that are comparable and relatable to each other, and this is done

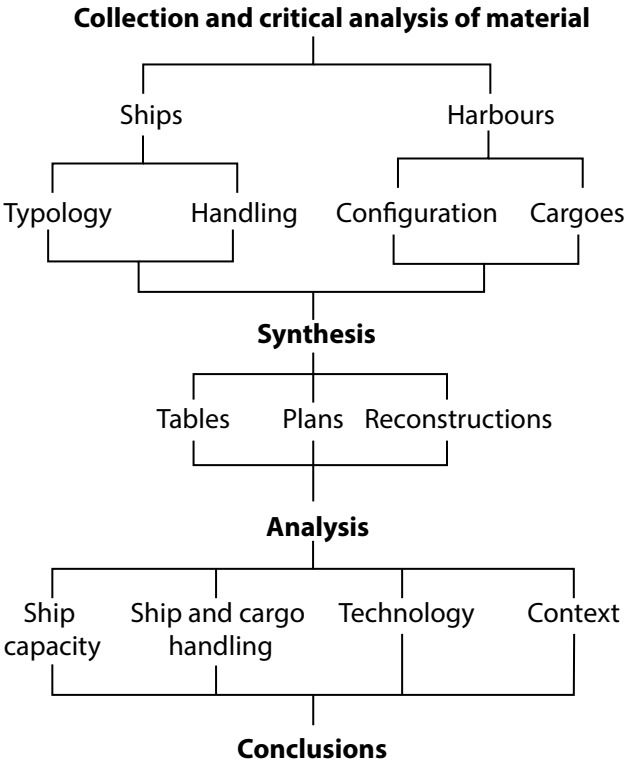

Figure 1.2. Flow diagram describing the methodology and stages of this study (drawing by the author).

through the creation of planar reconstructions that highlight the same aspects of harbour operation: shore configuration, depth, seabed types, size and form of harbour works, and land infrastructure. This is also achieved via the creation of comparative tables that concern the characteristics of the ships of the period (size, tonnage, draught, cargo), as well as the size of the case study harbours and of other contemporary ones and the number and typology of ships that could be accommodated. This codification of data through plans, reconstructions, and tables provides a platform for further analysis and facilitates the extraction of conclusions and the answering of the current study's research question. It also organizes the data used in a coherent way for use by future scholars.

Quantification is another important principle of this study, directly related with standardization. The operation of harbours is, as already outlined, fundamentally dependant on the practicalities of ship and cargo handling, both elements of material culture that can be properly studied through quantification methods. Such methods have already been employed not only to the study of the ancient economy and commerce,[119] but also to seamanship and harbour archaeology (see also Section 1.3)[120] and have offered important results, based on finds and not on often vague and fragmented historical sources. Such a methodological tool can also greatly assist the organization of material used in this study, as well as strengthen analysis

[114] Delano Smith 1979, 326–7. See also the use of the term "amphibious" for the inhabitants of the coasts of the Mediterranean by Strabo: "for we are in a certain sense amphibious, not exclusively connected with the land, but with the sea as well" (1.1.16; translated by H.C. Hamilton, and W. Falconer).
[115] Wilson 2011b, 46–51.
[116] Feuser 2020, 9–20.
[117] Keay 2012b, 39–52; Salmon 1984, 31–7; Steksal 2014.
[118] Kotarba-Morley 2015, 356–61.
[119] Scheidel and von Reden 2002; Wilson 2009.
[120] Boetto 2010; Brandt 2005; Kotarba-Morley 2015, 229; Parker 1992a.

by providing tangible, precise, and comparable results, essential for the best understanding of any material object or space, such as ships and harbours. The material used includes ship size and draught, harbour size and depth, as well the capacity of harbour infrastructures (warehouses, agoras, etc.) to handle ship cargoes of various kinds (grain, stone, enslaved people, etc.).

Reconstructions

Within this framework, reconstruction is a fundamental tool of analysis. Two reasons make reconstructions important and they correspond to two levels of research and analysis respectively: on the one hand, the great dynamics of the coastal environment of the Mediterranean (sea level rise, subsidence and uplift incidents, and siltation), as well as human intervention (reclamation, dredging, and destruction of ancient remains),[121] have severely altered the form ancient harbours have today, including the two case studies, as will become evident in Chapter 3. To understand the original function and capacity of these harbours, it is necessary to reconstruct their original natural configuration, as well as the original form of harbour works and infrastructure (jetties, quays, lighthouses, urban landscape, etc.). On the other hand, the reconstruction of harbour capacity and operation in terms of ship and cargo traffic, based on the aforementioned reconstruction of the harbour environment, tackles one of the main questions of this study, which concerns the number and type of ships that could fit inside harbours and the methods that were used.

Several questions appear during the creation of different reconstructions of the harbours discussed (size, original form of coast and harbour works, depth, seabed, etc.) and must be sufficiently answered through this process. This greatly improves the level of understanding of each harbour's form and function, and helps when combining and comparing different datasets within the same working context. It also allows the presentation of the results of this study in a comprehensive way for the reader, clarifying the points made by the research. A series of mapping and illustration software tools were used, as discussed below, in combination during this research (Autodesk CAD, ESRI ArcGIS, Adobe Illustrator), always according to the aims of the study in each phase and to the best representation and analysis of data.[122] An important criterion for the choice of software was its ability to recreate harbour landscapes, and include and represent all the data considered necessary.

The basis for every reconstruction is updated using metrically accurate surveys of the harbours studied, which are found in various publications of these sites. The archaeological remains are naturally included, as these are documented in topographical surveys (e.g., the inclusive and highly detailed Atlas of Delos by the École Française d'Athènes, or the detailed plans created by the Kenchreai excavators in the 1960s).[123] Older surveys, despite their possible topographical inaccuracies, are also important for the documentation of structures and features now obscured by modern development (e.g., the early twentieth-century plans of Delos' Main Harbour).[124] Equally important is the bathymetry of the harbours discussed. This has been documented in detail in previous publications, with data either taken from the maps of the Hydrographic Service of the Greek Navy (Kenchreai) or by special fathoming surveys (Delos).[125] Further data can be found in naval maps of the eighteenth and nineteenth century, which, although not always as accurate as more recent surveys, document not only features today lost or obstructed (coast configuration, ancient remains) but, very importantly, also the use the harbours by sailing ships in the past (particularly in the case of Delos).[126] Finally, satellite and aerial photography provided further information on the configuration of the harbours today, of various natural and anthropogenic features of the coastline and seabed, and recent changes not yet documented in scholarship (e.g., the movement of the northern rubble jetty at Delos' Main Harbour due to wave and drift action; see Section 3.1).

After the collection and initial evaluation, the data described above was digitized and combined with the use of AutoCAD software. Maps and aerial photographs were inserted in AutoCAD files and georeferenced in accordance with the topographical data included in them or, when these are absent, in accordance with various features of buildings and the coastline, as accurate as possible. This could be a tedious process, especially for early plans of the harbours studied where survey data are inaccurate and several features had to be incorporated with a certain degree of acknowledged inaccuracy (e.g., the first plan of Delos' Main Harbour published by Ardaillon).[127] With different maps, plans, and photographs placed at their right position, new maps were created by tracing the old ones into AutoCAD.

An important part of the reconstructions is bathymetry. The available material documents bathymetry rather roughly, in certain cases with contours spaced at a distance of up to 5 meters (Delos) and often along sporadic soundings (Kenchreai). To create a more detailed bathymetric relief of the harbour sites' seabed, this data was imported into ArcGIS and new, more-detailed contours were produced, which were used for a better calculation of the ancient

[121] Kotarba-Morley 2015, 25–6; Marriner and Morhange 2006; 2007, 146–62; Marriner et al. 2014.

[122] Although adequate topographic and architectural data exist for the case study sites, allowing for the creation of intricate virtual reality models, these have been considered unnecessary for the purposes of this study. Simpler and more convenient mapping schemes have been chosen since it is beyond the scope and potential of this study to make 'realistic' recreations of whole urban areas (for a critical approach on the use of virtual reality in archaeology see Favro 2006, 326 and Gillings 1997, 253).

[123] Moretti et al. 2015; Scranton et al. 1978, Figure 4.

[124] Ardaillon 1896, Pls.II–III.

[125] Duchêne et al. 2001, 36–9; Georgiades 1907, Pl.I; Scranton et al. 1978, Figure 4.

[126] Gallois 1910.

[127] Ardaillon 1896, Pls.II–III.

sea level and accordingly harbour depth. [128] Finally, the maps created were rendered in Adobe Illustrator to be more clear and comprehensive to the reader, as well as to facilitate their handling as vector files. Colours and special hatching were also added at this stage to make the final reconstructions easier to read and understand, especially concerning the different depth zones and types of coast (beaches, rock, reefs).

These maps form the basis of the reconstruction of the harbours studied as they were during the Hellenistic and Roman period. The first task is to adjust the sea level according to the geophysical data and to move the shore accordingly. In both harbours, the sea level has risen considerably (2–2.5 meters), and siltation has affected the configuration of the basins. The change in the sea level affects also the bathymetric contours that have to be similarly adjusted. Another important task is to remove any modern structures and recreate the original bathymetry beneath them (namely the rubble moles around Delos' Main Harbour where contours are available thanks to soundings undertaken before the construction of the modern moles). Harbour works and structures along the coast are also reconstructed with caution to indicate clearly the parts added and recreated even when this is done with great probability. Finally, a series of cross-sections of the harbour basins were created, based on the previous plans. This was done not only to make the harbours' configuration clearer, but also to test, in the following stage of analysis, the ability of ships of various types, sizes, and draught to approach and use these areas, how close they could approach the shore and harbour works, and the ability of people to approach them through walking in shallow water.

A final tool of analysis of the evidence and presentation of the results of this study are freehand drawings that constitute the final stage of the reconstruction process. They, on the one hand, serve the comprehensive presentation of the results of this study to the reader and, on the other, they constitute part of the analysis. To create these drawings, different kinds of data concerning the harbours (landscape, architecture, use by ships, etc.) were combined, as in the previous planar reconstructions, but through these drawings new challenges appear concerning the form of harbour works and land infrastructure, the stationing and movement of ships, as well as the configuration of the whole urban landscape around the harbours. By creating these drawings from rough sketches to final inked and detailed reconstructions, all data examined are combined, including the natural and urban landscape of the harbours, along with a suggestion of how these spaces could have functioned during the period studied concerning ship accommodation and traffic, and the image they would have presented to the people arriving via ship. It should, however, be underlined here that such reconstructions form a basic form of interpretation and assessment of data collected and should be seen as such, offering wide margins of criticism and discussion, especially concerning harbours for which archaeological or geophysical evidence is debatable.

Ship capacity and handling

Having reconstructed the original configuration of the case study harbours, the next task was to insert ships into these spaces. This was done in two steps: the first one was to divide the sea areas in and around harbour basins into zones according to the spaces that ships of different draughts could use according to the reconstructed bathymetry (or bathymetries in case of different scenarios) and the draught these ships would have, which is presented in Chapter 2. The second step was to calculate the number of ships that could fit in these spaces, as well as the docks and beaches of these harbours. Due to the reconstruction of the harbour basins in AutoCAD, it was easy to calculate the areas each depth zone covered and by using the maximum space ships of various kinds would occupy, as this was assessed through the study of shipwrecks and texts in Chapter 2, it was possible to calculate the maximum number of ships each zone could accommodate. An issue that arises here is the discrepancy between the maximum number of ships that could theoretically fit into harbour areas and the actual number that could be accommodated, while allowing enough space for ship circulation and handling. The aforementioned method allows for the calculation of a theoretical, maximum number of ships that could be accommodated within harbour basins, a highly unlikely scenario since cramping ships next to each other would leave little space for the circulation of other vessels and could also be dangerous in case of an abrupt change of wind. To suggest a more functional number and typology of ships that could use the case study harbours, an empirical method was employed: the figures of ships of different sizes were inserted into the reconstructed plans of the harbours studied according to the areas that were approachable by these ships. This allows for the creation of a more credible scenario of how these harbours could have functioned, with respect to the size of ships, harbour depths, and the protection offered by natural or artificial features.[129]

1.4.2 The case studies

A multitude of Hellenistic and Roman harbours have been known in the Aegean and the Mediterranean, and many

[128] It should be noted here that ArcGIS software has been used only for this purpose in this study and not for the inclusion of all available data. This has been done because it has been considered easier to create CAD files that incorporate all available data, since this data concern mainly the topography and structures of the harbours discussed and not excavation data, whereas the various analytical tools offered by ArcGIS software (e.g. visibility, distance, hydrology) are not useful for the purpose of this study, addressing issues related with the land and not the water area.

[129] For a similar method of inserting ship figures in scale in the reconstruction of an ancient harbour see Kotarba-Morley 2015, Figures 7.50–1. Nevertheless in Kotarba-Morley's study no dathymetric data was included, neither any different type of ships than ships covering an area of 25x7 metres.

have been excavated and studied (Figure 1.3). Various catalogues have been compiled concerning harbours of specific regions[130] or of the Mediterranean, in general.[131] It is not within the scope of this research to create another almanac of Hellenistic and Roman harbours. This is not simply due to the large number of harbour sites known, but also because the aims of this research require the thorough and extended application and testing of the methodology designed to specific sites with the inclusion of all available data. Therefore, two case study harbours were selected, Delos and Kenchreai, two sites which can be sufficiently examined within the extent of this research and that fulfil certain criteria defined for addressing the principal research question: historical importance, availability of material, and variability of site configuration.

Historical importance and availability of material

As outlined above, the methodology of this study focuses on inclusiveness, collectiveness, standardization, and quantification; thus, every source, from archaeological remains to geomorphology and from iconography to written evidence, has to be used. However, to examine various datasets, these need to be available to scholarship. In other words, it is essential for the aims of this research to target sites for which data is available through written sources, archaeology, geosciences and iconography. Harbours of great importance for which adequate information do not exist, either because archaeological and written sources are scarce or because the sites have been distorted by modern development, are not ideal for the methodology of this research (e.g., Piraeus' Kantharos, Eretria, or Rhodes). The availability of data is secured, on the one hand, by the historical importance of harbours, thanks to which more plentiful and variant written sources (historical texts, literature, inscriptions) document their operation and commercial role and, on the other, by the existence of published material through archaeological and geomorphological research, which also depends on the historical importance of harbours that has drawn the attention of researchers.

The case study harbours and the cities they served, Delos and Corinth, played a major role in the Aegean during the Hellenistic and Roman period, and had a parallel and often antagonistic history. Delos was the archetypal port-of-trade of the Hellenistic and early Roman Mediterranean.[132] During the period of Independence (314–167 BCE),[133] the city had begun to establish itself around commercial activities, transforming from an important but small sanctuary settlement to a thriving cosmopolitan trade centre. Prosperity was further stimulated by the establishment of the free port by the Romans in 166 BCE[134] and the city witnessed a swift and unprecedented commercial and urban development, until its two destructions during the Mithridatic Wars (88 and 67 BCE), after which the settlement shrank dramatically and lost all its previous importance.[135] "Wealthy Corinth"[136] was essentially Delos' commercial rival and successor, and its importance as a sea power was considered to have been similar to that of Carthage by Cicero.[137] The city was annihilated by the Romans in 146 BCE[138] and was largely substituted as a commercial centre by Delos, who witnessed its most lucrative years in this period.[139] After a century of desolation (referred to as the 'interim period'),[140] Corinth emerged as an administrative and commercial centre after its rebuilding as a Roman colony in 44 BCE.[141] This included the total reconstruction of the city's harbours, Lechaion and Kenchreai, and Corinth was to replace Delos as a trade centre through the entire Roman Imperial Period.[142]

The significance of Delos and Corinth as two of the most important cities of ancient Greece triggered the early interest of archaeologists and the beginning of large-scale, long-term excavations and other research (since 1872 in Delos and 1896 in Corinth), which also included the local harbours. This research accumulated an abundance of material (archaeological, epigraphic, geomorphological, etc.), which has offered the necessary hard evidence that is used in this research.[143] The combination of different sources of information (written evidence, excavation results, geophysical research, etc.) allows for better

[130] See Schörle 2011 for the Tyrrhenian coast or Mauro 2017 for the Aegean.
[131] de Graauw 2020; Lehmann-Hartleben 1923.
[132] The significance of Hellenistic and Roman Delos as a commercial centre is explicitly underlined by a series of ancient authors: Pausanias (3.23.3–6) mentions Delos as the emporion (trading station or market) of all Greece. Pliny (*Nat*.34.9) reposts that the market of Delos is frequenred by "all the world". Lucilius referred to the busy harbour of Puteoli as "a lesser Delos" (*Satires*, cited in Paulus, ex Festo 88.4), underlining the proverbial importance of the Delian market. Pliny (*Nat*.34.9) and Cicero (*S.Rosc*. 133) also report on the high quality of the Delian bronzes. Cf. Lawall 2005, 214 and Zarmakoupi 2013b, n.4.
[133] On the beginning of the Delian independence and the foundation of the Nesiotic League, see Diod.19.62.9; *IG* XI, 2, 135. Cf. Tréheux 1948.
[134] Plb.30.20; Strab.10.5.4. Cf. Roussel 1916.
[135] App.*Mith*.5.28; Paus.3.23.3–4; Strab.10.5.4. Cf. Hatzfeld 1919, 34, 36; Green 1990, 384–5; Rauh 1993.
[136] Hom.*Il*. 2.570; Strab.8.6.20.
[137] Both Thucydides (1.13.2) and Strabo (8.6.20) underline the importance of Corinth as a commercial hub because of its geographical position between Italy and the Aegean, as well as the control over the Isthmus, while Thucydides also notes the long shipbuilding tradition of the city. Cicero states that by destroying Carthage and Corinth, the Romans had "put out those twin eyes of the sea–coast" (*N.D*.3.91; translated by H. Rackham), whereas he also reports that prior to the destruction of 146 BCE the Corinthians were so focused on trade that they had abandoned agriculture (*Rep*.2.7). Cf. Gruen 1984, 299 and Purcell 1996, 271.
[138] Diod.32.4.5 and 32.27.1–2; Paus.2.1.2; Liv.*Periochae* 52; Strab.8.6.23. Cf. Engels 1990, 197.
[139] According to Strabo (10.5.4) the resettlement of many merchants from Corinth, after its destruction in 146 BCE, to Delos greatly contributed to the commercial development of the island towards the end of the Hellenistic period.
[140] Despite the proverbial desolation of Corinth during the Interim Period (see Cicero's lament over the city's ruins related to his visit in 79–77 BCE; *Tusc*. 3.53), archaeological finds suggest that Corinthia was still a nodal point in commercial traffic, although no longer a "viable political entity" (James 2010, 221).
[141] On the reconstruction of Corinth as a Roman colony, see App. *Pun*.20.136, Plut.*Caes*.57.5 and Dio Cassius, 43.50.3–5. On Corinth as the capital of Roman Achaea, see *Acts* 18.12–7, Apul.*Met*.10.18, Kent 1966, n.153; Meritt 1932, nos.75–6, 80–3; West 1931, nos.53–75.
[142] Engels 1990, 33; Rougé 1966, 152.
[143] For an overview of scholarship on Delos, see Bruneau and Ducat 2005, and especially on issues concerning commerce and shipping, Zarmakoupi 2015; for Corinth and Corinthia see Williams and Boukidis 2003 and Kissas and Niemeier 2013.

Figure 1.3. Map of the Aegean region, with the main Hellenistic and Roman harbours mentioned in the text (drawing by the author).

understanding through their reconstruction and analysis. Underwater investigations have also been undertaken at all three sites and have provided first-hand evidence for their form and function.

Diversity

The case study harbours were also chosen because of their differences. Delos is a small, arid island at the centre of the Cyclades. It was served in antiquity by a number of harbours dispersed around its coasts, all connected with the dense urban fabric of the prosperous late Hellenistic city. This was equipped and embellished with various buildings related to its commercial function, but had few harbour works.[144] Kenchreai can be considered in a way a 'model' harbour; located in a sandy, deep natural bay, it was protected by two moles and surrounded by ashlar quays and a well-planned settlement, equipped with all the necessary facilities useful for an important harbour of the Roman Imperial Period.[145] Each site presents a unique configuration, and offers the opportunity to explore how, on the one hand, ancient mariners tackled different harbour spaces and, on the other, how contemporary engineers and harbour administrators faced the challenges of creating and maintaining harbours in different natural environments, as

[144] Zarmakoupi 2018b; Zarmakoupi and Athanasoula 2017.
[145] Scranton et al. 1978, 39–79.

well as how their choices affected the ship traffic and vice versa.

1.4.3 The selection and handling of the material

As underlined in the previous pages, to understand the complicated nature of harbours as centres of seamanship, commerce, and human interaction, it is essential to combine a variety of different sources: archaeology, geomorphology, written evidence, and iconography. The different types of material studied in this book were selected not just because of their availability but, more importantly, for the information relatable to the research question and aims of this research these sources offered. As different datasets, each presents specific characteristics and must be approached differently and critically, with respect both to its potential and limits.

Archaeology

Archaeological data forms the main source of information of this study. As first-hand evidence, it constitutes the most reliable testimony on the original form and operation of harbours and ships and, thus, provides the most solid data for any further analysis. However, it also presents certain limitations and requires critical assessment, as well as different handling, since it covers two considerably different fields, harbours and shipwrecks. Ship remains, including vessels lost or scuttled in the sea, coastal areas, and inland waters, can reliably document the types, size, and equipment of ancient vessels but also their cargoes, provenance, as well as the ways they were handled. Fortunately for this study, the period under investigation marks a great peak in the number of shipwrecks discovered and excavated in the Mediterranean, reflecting the intensification of maritime mobility and allowing for an advanced knowledge of ship construction and seamanship.[146] Nevertheless, several implications must be taken into account: the preservation of ancient wooden hulls is, mainly due to the action of the *teredo navalis* shipworm, problematic in the Mediterranean and various portions of them survive, depending on the protection of the wood by sediments and cargoes, from largely intact hulls to a few pieces of wood. This diminishes the actual number of ship finds that can deliver precise data on ship configuration and construction.[147] Moreover, the survival of ships and cargoes is greatly affected by salvaging and looting, both common since antiquity,[148] as well as by the different progress of underwater research in various countries that impairs the creation of more inclusive statistics on ancient shipwrecks.[149] Nonetheless, ship finds remain the most direct source of information on ancient seamanship; thus, they have been extensively used for the formulation of the basic comparative tables developed in this study, but always after a thorough scrutiny of their reliability as evidence (see Chapter 2 and Appendix I). These tables predominantly include data that can be safely confirmed by research, with the necessary indications of their accuracy; all statistics are considered with a certain degree of reservation and different scenarios are suggested.

Similar to shipwrecks, ancient Mediterranean harbours, including the two case studies, have been preserved and excavated to various extents. An important aspect of the assessment of this material is the ability to properly date structures. With many harbours being used before, as well as after, the period studied, it is essential to clarify which structures were operable during these years, something often difficult due to the lack of datable finds. Another methodological issue considers the spatial extent of areas where related material is to be sought and collected. In other words, where does a harbour stop and where does its rural or urban hinterland begin? This forms a challenge for this study, especially in Delos, where the harbours and their commercial functions are incorporated within the city's urban fabric.[150] The current research, however, considers each harbour and its hinterland as an integrated space and avoids drawing boundaries between harbour and non-harbour urban areas. This reflects the conceptualisation of harbours as an extended unified space that comprises commercial, religious, and habitation zones at the same time.[151] The harbour, as a centre of commerce and a gateway to/from the outer world or foreland of each settlement or hinterland, influences every aspect of the surrounding human landscape. Thus evidence of their operation and, more importantly, of their role in their contemporary world should be sought in a much more extended space and the investigation should include any kind of data, from imported goods to road networks and from inscriptions to quarries. This complex, and often laborious, approach gives a unique opportunity to study and understand harbours in their totality, and connect the handling of ships and cargoes within them not only with a demarcated harbour space, but with a whole related hinterland.

Geomorphology

Equally important, and closely related to archaeological data, is the harbour geomorphology, which fundamentally influences the sites' original creation and ensuing operation concerning the size and number of ships they could shelter and their relation with the hinterland.[152] Furthermore, the perpetual change of coastal environments, including human interventions, is the major factor that has created the image ancient harbours present today, in the case of the Mediterranean causing most of them to have become submerged or silted.[153] The thorough scrutiny of the

[146] Gibbins 2001, 288; Nantet 2020c, 76–80; Parker 1992a, Figures 3–5; Strauss 2013.
[147] Boetto 2012; Wilson 2011b, 33–9.
[148] Pomey 1982, 139; Tchernia et al. 1978, 29–31.
[149] Manning 2018, 257–9; Wilson 2011b, 33–9.
[150] Duchêne et al. 2001; Karvonis 2008, 218–9; Zarmakoupi 2018a, 206–7.
[151] Feuser 2020; Purcell 1996, 277–9; Reger 2016.
[152] Delano Smith 1979, 327; Karmon 1985, 2–6; Kotarba-Morley 2015, 36–9.
[153] Marriner and Morhange 2007, 145–85.

geomorphology of harbours makes it possible to 'go back in time', and recreate the form the harbours and their surroundings had in the period studied and suggest possible scenarios on their original configuration, especially in cases where substantial geological changes have occurred.[154] Geomorphological research offers reliable information, being based on solid data collected through field surveys and interpreted through lab analysis. As, however, noted in Section 1.3.5, the main problem with such datasets is, on the one hand, their availability, since they require extended and costly geophysical research that is not always easily undertaken and, on the other, their precision, bearing in mind that their dating can vary greatly, depending on the existence of stratified and datable material, like pottery and organic remains.[155] Therefore, results of such surveys should be thoroughly scrutinised and cross-examined in relationship to archaeological and historical data, and, in some cases, their insufficiency to offer useable results should be plainly acknowledged.

Climatic conditions

Another important and precise dataset is the climatic conditions of each area studied, mostly in relation to the prevailing and seasonal winds, which have hardly changed since antiquity. These would naturally influence the choice of the harbours' location, the handling of ships through them, and the construction of specific protective works around these spaces.[156] An important dataset regarding the operation of the harbours studied here consists of the predominant winds, and their frequency and strength according to the season, as this is codified through wind rose charts.

Written evidence

Written sources constitute another type of evidence related to the scope of this investigation and provide information on almost every aspect of ship and harbour form and operation, especially during Greco-Roman antiquity.[157] They belong to a wide variety of types (historical and geographical texts, poetry, fiction, etc.), come from the whole geographical extent of the Mediterranean world and include important information concerning ships, as well as harbours. The major drawbacks of written evidence are scarcity, indirectness, and vagueness. On the one hand, direct sources (state decrees, archives, registries, etc.) are very rare and often fragmentary, whereas their dispersal is uneven (in Kenchreai, virtually no inscriptions survive concerning the harbour or the settlement, whereas Delos preserves abundant epigraphic material; see Chapter 3). On the other hand, most information on ships and harbours comes mostly from historical, geographical, and literary texts, which are often elusive, offering various clues on ships and harbours, but usually indirectly and compiled by authors with little knowledge or interest in seamanship and harbour operation. Even geographical texts, in which harbours are systematically listed, give too brief information and even replicate older sources (e.g., Strabo).[158] Thus, any approach to written evidence should be undertaken with caution and in, as much as possible, combination with other written and mostly with archaeological sources that can help to assess their reliability. All original ancient texts have been included in Appendix II of this publication, with translations inserted in the footnotes or within the text.

Iconography

Iconography is another important source of information concerning ancient ships and harbours of the Hellenistic and Roman period. Numerous images in a variety of means and qualities, from sculptures to frescoes and from mosaics to graffiti, especially from the Imperial Roman period, document harbours and vessels of different kinds, shedding light on their parallel operation.[159] Despite its richness, however, iconography remains, above all, pictorial art and not a naturalistic reconstruction of reality, its main goal being to convey ideas through artistic means and not to give blueprints of objects or structures.[160] To this, the trend of copying or creatively and often unrealistically interpreting older sources should be added.[161] Although the iconography of ships and of harbours has often been confirmed by archaeological finds (e.g., the hull shape of the Madrague de Giens shipwreck or the depictions of the harbour of Kenchreai),[162] it should be considered as a secondary source basically reaffirming archaeological finds and its value being largely dependent on the existence and reliability of the later.

Nevertheless, iconography often consists of the only kind of evidence on the methods of using harbours and approaching coasts. Anchoring, beaching, and docking are aspects of ship handling that, with few exceptions, seldom leave traces in the field,[163] but are commonly part of iconographical schemes (usually related to mythological scenes), or appear in scenes related to the depiction of harbour activities (e.g., the famous Torlonia harbour relief; Figure 2.10).[164] Although such iconography should

[154] Both the Cyclades, as well as Corinthia, has been the target of numerous geological studies during the last 50 years. Especially in the case of Corinthia, the very dynamic sea environment of the Corinthian Gulf, as well as the multiple seismic faults of the Saronic Gulf, have drawn the attention of various field researches, which have already produced an impressive set of data (see Chapter 3).
[155] Marriner and Morhange 2007, 184.
[156] Beresford 2013, 53–103. Cf. Kotarba-Morley 2015, 233–4.
[157] Blackman 1982a, 79–80; Brandon et al. 2021, 11–36; Casson 1971; Pomey and Rieth 2005, 53–5.
[158] Dueck 2000, 44; Hornblower and Spawforths 1998, 692. An example of Strabo's replication of older sources is the shipsheds of Carthage, which he reports as operating in his time, although archaeological data has shown that these were never rebuilt after the destruction of the city by the Romans in 146 BCE (Hurst 1994, 27–8).
[159] On ship iconography see Basch 1987; Pomey and Rieth 2005, 61–8. On harbour iconography see Boyce 1958; Picard 1959; Blackman 1982a; Ugolini 2020; Zarmakoupi 2020.
[160] Pomey and Rieth 2005, 61–8.
[161] Bruneau 1981, 116–8; Ugolini 2020, 72; Zarmakoupi 2020.
[162] Pomey 1997, 89; Scranton et al. 1978, 148–9.
[163] Votruba 2014, 13.
[164] Blackman 2008b, 651; Felici 2019.

be, as noted above, not taken as a naturalistic recreation of reality, the actual choice by ancient artists of specific ship types and methods of using harbours, especially when these are irrelevant to established iconographic schemes (mythological circles or historical scenes), is a good indication of vessels and practices that these artists would have witnessed in their contemporary harbours and would have portrayed in their artwork.

Ehtnoarchaeology and historical parallels

One final indirect source of information concerning the operation and handling of ships and cargoes in relationship to harbours and coasts is maritime ethnoarchaeology, as well as the use of more recent historical and iconographical data. With various types of ships, especially the smaller ones, having progressed little in terms of size and tonnage even until more recent years, the use of comparative material can be helpful in understand the handling of ships in harbours and coastal environments.[165] Within this study, such parallels mostly relate to the practice of anchoring in the open and using lighters and to the use of shallow harbour basins without deep docks (e.g., a series of photographs of small harbours of the Aegean in the first half of the twentieth century; see Chapter 2). Such data, despite their evident usefulness, should, nevertheless, be approached not as actual documentation or survival of ancient practices, but as possible scenarios; the use of specific techniques in more recent periods or even in modern times should highlight the possible application and implications of certain methods, but not be taken as a proof for their use and exact form in antiquity.

[165] For examples of such approaches, see Delano Smith 1979, 365; Houston 1988; Votruba 2017.