

# Ship Losses and the Growth of Roman Harbour Infrastructure

Damian Robinson

Oxford Centre for Maritime Archaeology, Institute of Archaeology, University of Oxford, 36  
Beaumont Street, Oxford, OX1 2PG, UK

Email: damian.robinson@arch.ox.ac.uk

Candace M. Rice

Joukowsky Institute for Archaeology and the Ancient World, Brown University, Box 1837/  
60 George Street, Providence, Rhode Island 02912, USA

Email: candace\_rice@brown.edu

Katia Schörle

Université Côte d'Azur, CNRS, CEPAM, France

Département d'Histoire, Faculté des Lettres, Arts et Sciences Humaines

98, boulevard Edouard Herriot - BP 3209, 06204 NICE, France

Email: katia.schorle@univ-cotedazur.fr

## Abstract

*The purpose of this study is to analyse regional trajectories in Mediterranean coastal developments between ca. 200 BC and AD 200, at the time of a peak in maritime activities as recorded archaeologically through shipwreck evidence. The aim is to test the proposition that the development of harbour infrastructure should be followed by a decline in shipwrecks around coastal areas. Economically speaking, investing in harbours would result in faster and safer transshipment areas, and would enable regions to cope better with intensifying trade while the high costs of harbour infrastructure or lighthouses would be offset by the reduction in the loss of ships, and hence loss of capital. In reality, the relationship between shipwreck data and local harbour infrastructure in the ancient Mediterranean is far more complex. Here we discuss two coastal regions, central Tyrrhenian Italy and southern France. We suggest the realization of a need for the substantial development of infrastructure in order to cope with intensifying trade, is a phenomenon that predates the Roman Imperial period.*

**Keywords:** Roman economic history; maritime archaeology; harbour infrastructure; Gaul; Italy; shipwrecks

## Introduction

The four centuries between ca. 200 BC and AD 200 arguably witnessed the greatest period of maritime trade in the ancient world. The rapid expansion of the Roman Empire to dominance in the Mediterranean region created a particular set of social and economic conditions in which maritime trade could flourish. The now familiar graph of the frequency of known shipwrecks in the Mediterranean (Figure 1) clearly indicates the scale of the increase in maritime ventures, if we accept that the archaeologically visible pattern of vessel loss may be taken as proxy evidence for the frequency of trading voyages (Parker 1992: fig. 3; Wilson 2009; 2011a; 2011b). Similarly, the Roman period also witnessed a substantial growth in both the construction *de novo* and the redevelopment of ports and their associated infrastructure. Roughly 80% of known lighthouses with relatively secure dating information were built between 200 BC and AD 200 (Giardina 2010: 51-120), and the development of maritime concrete in the late third or early second century BC revolutionized harbour building technology, enabling the construction of artificial harbours along coastlines with no natural anchorages (Vitruvius 5.12.1-6; Brandon *et al.* 2014).

>>Insert Figure 1 about here<<

The simple picture of an investment in ports to handle the growing numbers and sizes of ships and their cargoes as the maritime economy developed across the late Republic and into the early Empire is a seductive one, speaking as it does to the general expansion of the Roman economy across this period. Similarly, the increase in shipwrecks between the second century BC and the first century AD is often used by historians to indicate economic growth in the late Republican and early imperial periods (Scheidel 2011: 33-34, n. 65; Wilson 2011a: 33, n. 2; cf. Terpstra 2019: 3-6). The drastic decline in shipwrecks from the first century onwards, however, is much more difficult to interpret. Here Parker's and later Wilson's graphic representations of the numbers of vessel losses (Parker 1992: fig. 3; Wilson 2009; figs. 9.3-9.6; Wilson 2011: fig. 2.5), with their rapid and substantial decline from a peak in the first century AD, is now at variance with the picture of a continually successful maritime economy that we get from both shipwreck *and* land-based archaeology. Indeed, McCormick's collation and analysis of shipwreck data from the period AD 300-1500 suggests that while there is a decline in wrecking during late antiquity it is nowhere near as steep as it first appeared (cf. McCormick 2012: 77-89).

To account for the decline in shipwrecks, numerous explanations have been put forth; some of the most prominent argue that (1) barrels largely replaced amphorae as the preferred container for the shipment of liquids and therefore while maritime trade continued to flourish, we have lost the durable and easily recognizable amphora cargoes that characterize the majority of ancient shipwrecks, (2) larger vessels which used bilge pumps and hence could cope better with storms became more common and simply wrecked less often, and (3) the development of local economies and the replacement of formerly imported goods with locally made ones led to a decline in the absolute numbers of trading voyages and hence shipwrecks (Wilson 2011a: 33-39; McCormick 2012: 74-77; Morley 2007: 589-91).

These explanations touch on some of the difficulties of shipwrecks as a dataset, which range from an overrepresentation of amphorae and stone shipwrecks to an underrepresentation of shipwrecks carrying largely organic cargoes. Furthermore, shipwrecks from particular geographical areas such as North Africa and much of the eastern Mediterranean also appear to be rather scarce in the archaeological record when compared to the economic vibrancy of these areas. Finally, there are also difficulties with dating wreck sites, particularly those whose interpretations were based on amphora with imperfectly understood ceramic chronologies and types with long date ranges. As the argument put forward in this study relies heavily on shipwreck evidence, it is crucial that we acknowledge the imperfect nature of our data from the outset. The problems inherent in the shipwreck data have been discussed in several publications (Parker 1986; 1992; Wilson 2009; Boetto 2012; Rice 2016) and we are aware that we must tread carefully. We feel strongly, however, that it is still possible to make use of the data while keeping these caveats in mind and we have attempted to mitigate the effects of these problems in two key ways. First, with regard to the difficulties of dating ancient shipwrecks, we have graphed according to probability *per annum*, a method put forward by Wilson (2009: 219-29; 2011a: 33-39). This method allows an equal probability that a ship would sink in each year within its date range and the probability is then accumulated by time period, thus avoiding the over-representation of widely dated shipwrecks in any one time period. Secondly, our case study regions, southern France and central Tyrrhenian Italy, were chosen because they are arguably the most robustly documented regions of the Mediterranean in terms of ancient shipwrecks.

Many explanations for the drastic decline in the shipwreck graph have focused on identifying endogenous problems with the shipwreck evidence. While understandable, this has also contributed to other explanations being overlooked. Indeed, the role of the harbour is often largely ignored within this debate. Yet as Oleson and Hohlfelder (2011: 810) argue: ‘... the symbiotic feedback between the economy and technology is particularly marked in the history of harbour construction’. The increasing use of higher tonnage vessels such as the *Madrague de Giens* and *Mahdia*, or the *dolia* ships (ships with *dolia* — large ceramic storage vessels — installed in the central hull) from *Minturnae*, another type of vessel developed in this period (Marlier 2008; Heslin 2011; Rice 2016: 176-80), would have necessitated adequate supporting harbour infrastructure for berthing, loading and unloading, and the storage and forward transport of their cargoes (Wilson 2011a: 46-53; 2011b: 224-31; McCormick 2012: 62-64; Rice 2016: 180). The transport of stone deserves special mention as the Roman stone trade, characterized by demand for a vast array of stone types and particularly decorative stone, rapidly escalated from the end of the Republic (Russell 2013a: 11). Much of this trade involved the transport of incredibly heavy material ranging from column drums to sarcophagi, the loading and unloading of which was both costly and complicated. Quarries often had their own harbours to facilitate the export of stone (Russell 2011: 149-50; 2013a: 135), but importing harbours also needed to be well enough equipped to handle not simply the large size of many of the stone ships, but the heaviness of cargoes which, even in the case of small ships (e.g. *Carry-le-Rouet*), often included items whose weight required the use of a crane (Russell 2013a: 135-40; 2013b).

Investment in harbour infrastructure, such as moles to allow larger ships with deeper drafts to berth and cranes to unload heavy cargo, suggested continued expansion of the maritime economy. Yet throughout the Mediterranean this continued investment in harbours stands chronologically alongside the decline in the numbers of archaeologically visible shipwrecks (Blackman 1982; 2008; De Souza 2000; Oleson and Hohlfelder 2011: 818; Houston 1988).

Consequently, this study investigates the twin phenomena of the development of harbour infrastructure and the decline in the numbers of shipwrecks during the early Empire. As mentioned above, the paper focuses on two case study regions — Italy's central Tyrrhenian coastline and southern France — and systematically analyses the development of their harbour infrastructure. In addition to anchoring our study on strong datasets, this regional approach also enables a more detailed examination of these coastlines that can be tied into both regional and empire-wide narratives of the Roman maritime economy (Parker 1996; 2008; Tchernia 1983; 1997). We present a brief summary of our analyses of each coast, suggest possible interactions between them, and explain wider trends in the light of harbour developments and ship losses.

### **The Maritime Infrastructure of the Tyrrhenian Coast**

The scarcity of natural harbours on the central Tyrrhenian coastline posed serious problems for the maritime development of Rome (Strabo 5.35; Pliny the Younger 6.31), with Dionysius of Halicarnassus (3.44) noting that ships with more than 3000 amphorae had to anchor out at sea. In order to land goods from these larger vessels, they would need to anchor in the shallows and transship their cargo onto lighters for the journey to shore, a sometimes risky and hence costly process (Casson 1965). Ships could also make use of suitable rivers, and during the Republican period river mouth harbours were important; Ostia is the best example, though other harbours, such as Minturnae, were also significant. Sheltered bays on the Tyrrhenian coast also developed under the right set of economic circumstances. The Bay of Naples, and Puteoli in particular, served as the major harbour of Rome until the construction of port facilities at Portus under Claudius and Trajan. Geoarchaeological research at Ostia has now made clear the fact that the river harbour basin had silted up by the early imperial period (Goiran *et al.* 2014; 2017), necessitating the imperial expansion to nearby sites.

**>>Insert Figure 2 about here<<**

Along the coast between Cosa and Puteoli, there was a boom in the construction of maritime villas equipped with harbour or docking faculties between the second century BC and the second century AD, peaking in the first century AD (Marzano 2007). Town harbours also thrived. The port at Cosa was at its busiest in the second and first centuries BC, when it enabled businesses such as that of the Sestii to develop, which can be linked to increasing commerce with Gaul (Gazda 1987). Similarly, the construction of a mole by M. Aemilius Lepidus close to Terracina in 179 BC (Livy 40.51.2), must have had a considerable impact. The famous Caecuban wine from the area of Fondi could have been exported in larger ships

directly from Terracina. In fact, the Dressel 1B amphorae found in the 40 m long Madrague de Giens wreck, a mid-first-century BC ship found in the waters off southern Gaul, were identified as having been produced in this region (Tchernia *et al.* 1978; Hesnard 2012).

In the first century AD, key harbour structures were developed along the Tyrrhenian coast between Naples and Rome. The creation of Portus Iulius on the Bay of Naples (see Figure 2, above) under Agrippa probably set the trend for large man-made harbours and investment in maritime infrastructure. Other areas developed shortly thereafter, such as Lago di Paola, which was connected to the Mediterranean in the Augustan or Neronian periods by a canal (Schmiedt 1972: 120). This was simply an alternative approach to constructing a seaport *de novo*. It is tempting here to remark that of the five ancient shipwrecks off the Monte Circeo (southern Lazio), four occur before the construction of the canal, and hence before the presence of a potentially safe anchorage place on that particular cape.

Often discredited as a folly, Nero's harbour at Anzio represented a major investment in both the physical structures and the regional economy. Recent studies have shown that the ancient harbour was between 25 and 30 ha in extent, making it third in size after Portus and Puteoli (Felici 1995; Felici 2001; Schörle 2011: table 5.1; Wilson *et al.* 2012: table 20.11). With the construction of its harbours and canals begun under Claudius, Portus was the largest artificial harbour structure of the Mediterranean and probably could host some five hundred ships in its basins. It is striking to realize that shortly after AD 50, or under Nero, the formerly harbourless coast of Italy between Naples and Rome had been provided with a set of harbours located at a distance of 50 km, or about one day's sailing, from each other.

Trajan made significant improvements to this coastline in the second century AD through both the significant redevelopment of Portus and the construction of the harbour at Centumcellae (Civitavecchia). The harbour at Centumcellae considerably enhanced the maritime infrastructure to the north of Rome, servicing Trajan's villa and naval detachment, and perhaps also stimulating the economy of the wine-producing areas in the vicinity of Centumcellae. Trajan also enhanced both land and sea access to Terracina through improvements to its 11 ha harbour and construction along the Appian Way, potentially with the intent to add another satellite harbour for the supply of Rome.

This brief survey of the maritime façade of the Tyrrhenian Sea demonstrates the development of ports and their infrastructure from the second century BC onwards. Initially this was associated with the growth of the Italian economy and expansion abroad, particularly marked by the export of wine to southern Gaul, and subsequently by the development of the imperial infrastructure to support the growing city of Rome. Looking specifically at the construction of lighthouses (Table 1), however, it becomes clear that they are overwhelmingly a feature of the first to third centuries AD. During that time, a number of substantial and regularly spaced harbours along the Tyrrhenian shore were also completed. The dramatic decline in the numbers of shipwrecks in the Circeo area following the construction of a safe anchorage could certainly be taken as an indicator of the success of the network of ports and lighthouses in the reduction of ship losses and a general increase in overall maritime safety; this is clearly expressed in the contemporary quote from Valerius Flaccus (7.83-86), where he describes a skipper looking gratefully towards the lighthouse and the safe haven of Ostia in the face of an oncoming storm.

>>Insert Table 1 about here<<

### **The Maritime Infrastructure of Southern Gaul**

The region of Gaul under discussion here includes the Roman provinces of *Gallia Narbonensis* and *Alpes Maritimae* that both face the Mediterranean along a coastline of some 400 km. This coastline is geologically complex and includes numerous landscapes, ranging from the marshy lagoons of Languedoc, to the large alluvial plain of the Camargue delta at the mouth of the Rhône River, to the mountainous stretches of Provence Alpes-Cote d'Azur, where the western extent of the Alps meets the sea. The Rhône River, one of the most important rivers of the western Roman Empire, bisects the study region with the marshy Camargue delta, an alluvial plain of approximately 1450 sq km. This river facilitates crucial inland connections, linking the coastal cities of *Narbonensis* with those of the rest of Gaul. East of the Rhône the landscape changes as the low plains give way to more mountainous ranges where the Alps meet the sea, creating a dramatic coastline. This varied landscape necessitated a range of harbour styles with varied building techniques. In the relatively flat western half of the region, the harbours were located roughly a day's sailing distance apart, while east of Massalia, the density of harbours increased as the landscape grew more rugged.

Artificially constructed or enhanced harbours in southern Gaul predate the Roman period, though they were far fewer and less substantial. Dating information can only be obtained from seven of the harbours in the region: Narbo Martius, Lattara, Fossae Marianae, Massalia, Telo Martius, Olbia and Forum Julii (Figure 3). Pre-Roman harbours include the small harbour at Lattara, the probable lagoonal structures near Narbo Martius and, of course, the harbour of Massalia. The absence of a built harbour does not, of course, mean that sites did not make use of natural setting for harbours.

>>Insert Figure 3 about here<<

Lattara (modern Lattes), an indigenous Celtic site inhabited since ca. 525 BC, is a particularly good example. From the beginning, the site's importance stemmed from its trading connections. Etruscan artefacts are very common during the early period of occupation, and the site was perhaps home to an Etruscan trading post. Trade with Massalites and Greeks is also well documented (Luley 2014: 36). Despite this, artificial harbour structures were not constructed until the second century BC, and the peak in harbour construction did not occur until the first century AD (Garcia 2008). The largest number of improvements to the port facilities were made between 25 BC and AD 75. The harbour continued to be used until the end of the third century AD, which is particularly interesting as the city of Lattara itself was no longer inhabited to any visible extent at this stage (Garcia 2008: 146). It appears that the port continued to be used as a point of transshipment following the cessation of habitation in the city itself. This was perhaps due to the fact that Lattara was situated at the halfway point between the ports of Narbo Martius and Fossae Marianae. Without Lattara, the distance between ports on this stretch of coastline was greater than a day's journey and therefore not ideal if a problem were to arise at sea.

Similar to Lattara, artificial harbour construction on the southern French coast significantly increased following the Roman conquest. The small port of Olbia, a fortified maritime colony of Massalia founded in the fourth century BC, existed with no purpose-built port structures until the Roman period, when a very small mole and landing stage were added in the first century AD (Pasqualini 2000: 36; Bats 2006: 22).

The harbour of the important Greek trading centre of Massalia was completely redeveloped following the conquest of the city by Caesar, though little is known about the Caesarian harbour structures as an Augustan period reorganization of the port obliterated the previous remains (Hesnard 1994: 207). The major changes were generalized redevelopment, the construction of docks and warehouses and the dredging of the harbour basin (Hesnard 1994: 207). In the first century AD, at Place Jules-Verne, two quays were constructed around a harbour basin of approximately 1.5 m in depth, as well as a large pier, a substantial quay or jetty, which jutted out some 30 m into the water and allowed ships to dock on both sides of the platform. As the end of the pier was so far out into the sea, it could accommodate very large ships with significant drafts. During the second century AD, a hull of a ship was used to extend the pier. An additional, but smaller, pier was constructed to the west of the main pier in the third century. By the fourth century, the port had silted up considerably, was no longer dredged and the piers went out of use (Hesnard 1994). Nearby at the La Bourse site, harbour structures had existed since the Archaic period (Guery 1992: 111), but as at the Place Jules-Verne, significant reorganization occurred during the Roman period. The first and most significant renovation was the cutting of an internal basin, with a stone wall of more than 4 m in height and enclosed an area of some 2000 sq m (Guery 1992: 111; Euzennat 1969: 426). Coins of Vespasian date the completion of this construction to AD 75-80 (Euzennat 1980: 136). By the fourth century, siltation had reduced the depth of the basin to less than 2 m (Euzennat 1969: 426). Two other major structures were added in the first half of the second century AD, a large decantation basin and warehouses. The basin seems to have had a dual purpose; it served as a source of fresh water for ships and other harbour needs and for this purpose it was equipped with a water-lifting wheel. As a decantation basin, it also served to settle some of the silt from the stream before it entered the harbour basin (Euzennat 1969: 426; Euzennat and Salciat 1968: 155). The basin silted up by the end of the second or beginning of the third century AD and went out of use (Euzennat and Salciat 1968: 155).

In addition to expansion and/or redevelopment of harbour infrastructure at pre-Roman sites, there was also harbour construction at new sites. The earliest datable Roman infrastructural intervention related to harbours is the Fossae Marianaë; in 102 BC, Marius ordered the construction of a canal linking the Mediterranean and Arelate in order to circumvent the difficulties of navigating the mouth of the Rhône (Long and Duperron 2016). The harbour at the mouth of the canal, Fossae Marianaë, has been positively confirmed at modern Fos-sur-Mer (Provansal *et al.* 1999: 131; El-Amouri *et al.* 2015), and a seven km segment of the canal itself has been located northwest of Fos-sur-Mer at Vigueirat (Badan 2013; Leveau 2017: 53-55). Very little is known of the port structures at Arelate (but see Long and Duperron 2016); in 49 BC, Caesar (1.36) used the shipyards at Arelate to construct ships for the siege against Massalia during the Civil Wars, and the city was apparently known for its pontoon bridge depicted in a mosaic from the Piazzale delle Corporazione at Ostia

(*Notizie degli scavi di antichità* 1914: 286).

The first Roman colony in Gaul was established in 118 BC at Narbo Martius, modern Narbonne. Strabo (4.1.6) records that by the Augustan period, Narbo was the greatest emporium of the region. Narbo Martius was served by a number of lagoon harbours between the city and the Mediterranean. Excavations within the lagoons are ongoing and revealing particularly interesting facets of the ancient harbour structures (Sanchez *et al.* 2015; Ginouvez *et al.* 2016; Carayon *et al.* 2018). The earliest harbour structures uncovered thus far date to the Augustan period and include a waterway, a quay wall and a canal located at Saint-Loup, as well as two *dolia* warehouses at La Nautique (Carayon *et al.* 2018: 157). Parallel dykes and a breakwater designed to ensure ease of access between the lower Aude and Narbo Martius were located at the site of Le-Castélou-Mandirac (Carayon *et al.* 2018: 159-60).

Forum Julii, modern Fréjus, is thought to have been founded as a colony by Julius Caesar around 49 BC. It was the site of one of the three most important naval bases in the western Roman Empire from the Augustan period through to the end of the second century AD (Reddé 1986: 171-77). The harbour was enhanced in the Augustan period with a seamark and potentially two additional lighthouses in the first century AD (Gébara and Morhange 2010: 863). The last mention of the port occurs in the Antonine Itineraries; the harbour was probably severely silted up by the sixth and seventh centuries and was no longer connected to the sea but was simply a freshwater pond. Nearby, Telo Martius, modern Toulon, was founded at the very end of the first century BC when a quay and landing stage were built as well as substantial artisanal quarters. The site peaked in the mid-second century AD (Brun 1992: 123).

Figure 4 illustrates the harbour chronology of the seven dated sites; the columns illustrate the phases during which the harbour was in use while the line graph illustrates the main harbour building activities. For example, Massalia had a harbour since the Archaic period (sixth century BC); as a result, harbour occupation for Massalia is marked for all centuries, but the Roman harbour restructuring and building began in the first century AD and continued into the second century AD — the line graph marks those activities. As is clearly apparent from the chart, harbour construction peaks in the first century AD. While there are several sites for which earlier harbours could have existed, the primary building surge occurs after the first major peak in trade over the last two centuries BC. Lighthouses provide a particular insight into this activity, and while there are fewer than on the Italian coastline, they largely date to the first century BC/AD, in line with other harbour developments (Table 2).

>>Insert Figure 4 and Table 2 about here<<

### The Reduction in Shipwrecks

The above overview of the development of harbour infrastructure on the shores of central Tyrrhenian Italy and southern France offers a way into a comparative discussion of the regional development of infrastructure and the social and economic processes by which it was driven. While small-scale trends can be seen in both regions, it is the coherent phase of development in the first century AD that is perhaps most striking, as well as the continued investment in infrastructure in some cases, such as with the lighthouse at Narbo Martius, into the third century AD (Giardina 2010: 111-12). But when compared to the evidence presented



by the patterns of shipwrecks, this is rather intriguing as investments in harbour infrastructure continue while the number of shipwrecks appears to fall.

The question that we must therefore ask ourselves is whether there was any relationship between the provision of good harbours and a reduction in ship losses: can we move from correlation to causation? Here Bascom's (1976: 71-72) study of the Lloyds of London shipping registers during the mid-nineteenth century is particularly useful. It should be noted that the Lloyd's figures relate to ships from the last great era of wooden sailing vessels when the ships themselves were 'probably better designed, built and sailed than ever before', but were of comparable size to vessels in the early Empire (Bascom 1976: 84). The figures used by Bascom suggest that 42% of the vessels lost in 1871 were less than 100 tons, i.e. less than 25 m in length, 36% were between 100-300 tons, i.e. less than 35 m in length, and 14% between 300-600 tons, i.e. less than 45 m in length (Bascom 1976: 78). Bascom noted that about half of the ships recorded in the Lloyds registers sank, with about 80% of those doing so because of some coastal obstruction. Clearly, then, the risks of sailing close to the shore were high, an observation dramatically borne out through even a casual observation of Parker's (1992: fig. 2) distribution map of ancient shipwrecks and their predominantly coastal location. While we acknowledge that the majority of survey work related to ancient shipwrecks has been coastal with deeper waters largely not investigated, coastlines were particularly dangerous. Even today, grounding due to striking the seabed, shore, or underwater shipwrecks is the second most common cause of sinking (Allianz 2019).

In his ethnography of a voyage on an Arab trading dhow sailing from Kuwait to Zanzibar in 1939, Villiers (2010: 170-71) writes about a morning spent reading in the port office in Mombassa:

In this casualty book were accounts of strandings, dismastings and other losses of vessels set out in precise handwriting as if they were entries in a merchant's ledger ... I was impressed by a curious similarity of many of the accidents. It was amazing how often some hard wind just 'suddenly came up', or some rocks suddenly got beneath the vessel ... Consider for example, the case of the Lamu dhow Amantualla, outward from Mombasa to Dar-es-Salaam. Everything was going well, according to the sworn testament of her *nakhoda*, when 'all of a sudden a terrific gale swept over our dhow and dashed it against a rock'. She was lost.

Loss figures from the Lloyd's registers also highlight the scale of the danger from the wind to sailing ships. In the registers, stress of weather is the most common cause for vessel loss and ships are three times more likely to sink due to weather than to the next most likely cause, inattention. Indeed, the wind itself does not need to be particularly stormy; in 1871 more than half of the ships that went down due to the weather did so at wind velocities of force 6 and under, 'when the wind did not exceed a strong breeze' (Bascom 1976: 77).

If we can use the Lloyds figures as even a rough proxy for ancient wooden ships and their rate of loss, we can see that the rate of 'natural predation' would have been very high, particularly for ships sailing close to shore. This scale of loss across ships of all sizes would have been a powerful deterrent to maritime trade. The very real perils of seafaring and the

financial implications of this are brought home in a clear albeit humorous fashion in the *Satyricon*, in which the loss of five ships filled with cargoes of wine cost Trimalchio thirty million sesterces (Petronius 76).

The ability to lower the rate of natural predation by improving the safety of the highly risky coastal zone through the construction of a network of safe havens would have important economic consequences for maritime trade through the overall lowering of transaction costs. Certainly, later periods demonstrate a rise in harbour and port development in periods of increased maritime trade. During the Medieval period in both the marine republics of Italy and the cities of northern Europe's Hanseatic League, the rebirth of large scale ship-borne commerce also saw a renewed interest in port design and the provision of maritime infrastructure aimed at increasing safety (Hague and Christie 1975: 10-13; Giardina 2010: 42-47). The modern container ship revolution and the corresponding redevelopment of worldwide ports offers an extreme, but not dissimilar parallel (e.g. Ducruet *et al.* 2018).

Consequently, it would seem logical to suggest that the provision of a network of safe havens was crucial in mitigating potential disaster when sailing close to the shore, and we can return to our case studies with this idea in mind. We have collected our data on ship losses along the southern French and Italian coasts from Parker's catalogue of Mediterranean shipwrecks, augmented by Strauss's updates (Parker 1992; Strauss 2007); we have also separately graphed all shipwrecks for the central Tyrrhenian coast, encompassing the area just north of Cosa to slightly south of the Bay of Naples, and the entirety of southern France. In defining our study regions, we were careful to analyse approximately the same length of coastline for both areas — ca. 400 km — with a comparable number of harbours in order to avoid the introduction of further biases into the analysis. The numbers of shipwrecks were graphed according to Wilson's method of probability *per annum* discussed above and sorted according to 50-year intervals. Although clearly not an unbiased sample of the total numbers of ancient ships lost along these shores, the data allow us an insight into the number of known shipwrecks from particular periods.

For Italy (Figure 5), the graph of 201 shipwrecks shows a steady increase in the number of shipwrecks per half century, leading to a dramatic peak in the first century AD. When compared to the pan-Mediterranean picture of shipwrecks, the rise in ship losses along the Tyrrhenian coast with the development of the maritime trading economy leading up to the first century AD peak is even more acute, perhaps suggesting a greater volume of trading voyages along this coast than the 'average' Mediterranean picture. The decline in shipwrecks during the second century AD — and between AD 100 and AD 150 particularly — is even more pronounced than the pan-Mediterranean picture: ship loss is now at levels even lower than the first and even second century BC. In other words, we see a gradual increase of shipwrecks from 200 BC onwards, with a peak in the first half of the first century AD, as we might expect, and then a surprising drop between AD 50 and AD 100, and an even more drastic one after AD 100. Such a pattern correlates well with the picture of the development in maritime infrastructure presented earlier. Ship losses fall dramatically just at the time when the Neronian harbour interventions occur, and again at the same time as the harbours at Portus, Civitavecchia, and Terracina are either created or amplified/restructured.

>>Insert Figures 5-6 about here<<

Turning to France, our sample includes 391 shipwrecks. When graphed, again using the method of probability *per annum* sorted by 50-year intervals, an intriguing pattern arises (Figure 6). To some extent, this follows the basic pattern of the Mediterranean-wide graph as already discussed above, but given the more specific dataset, more distinct patterns can be distinguished. Before discussing them, it is essential to give a brief overview about known trading patterns in the region.

Over the course of the Republican and early Imperial periods, three major trends in maritime trade may be highlighted. The first is the wine trade between Italy and Gaul; the second is the late first-century BC and early first-century AD wine trade between Gaul and *Tarraconensis* primarily visible in western *Narbonensis*; and the third is the mid-first century AD rise of local wine production in southern Gaul, which occurs in conjunction with the northerly-aimed Baetican oil trade. Large-scale Roman trade with Gaul predated the first official Roman urban establishment in the region and the majority of the harbour infrastructure. This of course included but was not limited to the well-known and often discussed wine-for-slaves trade between Italy and Gaul, which occurred over the late second and first centuries BC (Diodorus Siculus 5.26.3; Cicero 6.2; Tchernia 1983; 2016: 277-96; Poux 1999; 2004; Loughton 2003; Loughton 2009; Fentress 2011). The late Republican period, in fact, accounts for the two largest shipwrecks known from the Roman period, the 500-600 ton Albenga wreck (100-90 BC, located off the coast of Albenga, Liguria, Italy) and the 375-500 ton Madrague de Giens wreck (70-50 BC, located off the coast of the Giens peninsula, southern France), both ships that were carrying Italian Dressel 1B wine amphorae. In western *Narbonensis*, the sites of Lattara and Narbo Martius provide good chronological resolution for the decline and near cessation of Italian wine imports by the beginning of the first century AD. At Narbo Martius, Italian wine was thoroughly supplanted by Tarraconensian wine around 30 BC. The late first century BC and particularly the early first century AD marked the rise of Spanish imports across southern Gaul. Tarraconensian wine was imported until around the mid-first century AD, when local wine takes over. Baetican olive oil imports began in the first century AD and continued until the third century (Sanchez 2004; 2009: 122-53).

The patterns are slightly different east of Massalia, particularly during the first half of the first century AD. Italian wine was still the dominant import of the first century BC, but there are fewer Tarraconensian wine imports during the early first century AD. Instead, wine from the region around Massalia was briefly prevalent, as evidenced by the assemblages at Olbia (Bats 2006) and the Porquerolles (Pellegrino 2010). By the mid-first century AD, however, the more widespread Gallic wine bottled in Gauloise amphorae became the most common. Baetican oil imports were also common, though slightly less so than in western *Narbonensis* (Rice 2012).

To return to the graph (Figure 6), a substantial increase in shipwrecks in the Republican period is evident, exactly in line with the well-documented wine trade between Italy and France. This is to be expected. A greater increase during the first 50 years of our era might also be expected. This traffic is no longer largely dependent upon trade with Italy but comes

at a time when Tarraconensian wine and Baetican oil dominate the ceramic assemblages of southern France. What is of course surprising is the initial drop around AD 50 followed by the drastic drop in AD 100, because this is precisely the period in which the economy of southern France reaches its peak. The decline in the number of shipwrecks along the French coast thus occurs at precisely the same time as the peak in harbour construction and the rise of the local wine industry. We might consider three possibilities:

1. The local wine industry means that fewer amphorae were being imported and we are therefore seeing fewer shipwrecks.
2. The fact that the majority of the exports of southern Gaul are going northwards as opposed to into the Mediterranean means that the export side of the Mediterranean shipwrecks is missing, thus greatly reducing the overall Mediterranean traffic.
3. Better harbours result in fewer shipwrecks.

While all of these are likely to contribute to the overall decline in the number of shipwrecks, the construction of harbours is in many ways the most convincing explanation. Although less wine is being imported overall, the amphora assemblages still show a variety of imported vintages. Furthermore, the number of Baetican oil amphorae that were being both imported and transhipped remains very high, and we would expect them to show up in the wreck evidence if ships were lost frequently (Rice 2012). While it is true that the majority of exports were moving northwards, the wine and the amphorae in which it was shipped were produced over a relatively large part of southern Gaul; in many cases it would have been shipped by sea to the Rhône; for example it would have been more efficient to ship the products from the production sites around Forum Julii via sea rather than overland.

It would seem, therefore, that the initial rise in trade in the late Republican period occurs prior to the construction of most harbours. That this trade flourished is clear from the terrestrial evidence, but the wreck evidence also proves that it involved substantial risk. This seems to have spurred the development of a more sophisticated network of harbours aimed at the reduction of ship losses. Given the drastic decrease in the number of shipwrecks so far discovered after the first century AD, it would seem that the venture was successful. The site of Saintes-Maries-de-la-Mer provides a contrasting example in support of this argument; this site marks the location of what was the mouth of the westernmost branch of the Rhône. While the branch was navigable, no harbour structures have been found, perhaps because of the investment of the canal and harbour at Fossae Marianae, the easternmost branch. Fossae Marianae was a full day's sail from Saintes-Maries-de-la-Mer, however, and this apparently encouraged ships from the west to attempt to sail up the nearer branch. Over thirty shipwrecks, dated predominantly to the early Roman period (Pagès *et al.* 2011; Coustures *et al.* 2006: 244), have been found at this location; these vividly illustrate the hazards of attempting to navigate an area without artificial harbour works.

## Discussion

Even when considered collectively, the explanations typically put forward to explain the dramatic decline in ship losses remain unsatisfactory. There were undoubtedly technological developments in ship construction and techniques of navigation from the Hellenistic period onwards and into the empire that allowed bigger, stronger, and perhaps safer vessels to be

constructed and sailed (McGrail 2004: 154-60, Pomey and Rieth 2005: 155-72, Wilson 2011a; 2011b; Nantet 2016). Yet the rate of loss, as seen in our graphs detailing the numbers of visible shipwrecks, also continued to increase into the first century AD. While individual vessels may have been safer, this would have been effectively offset by the increasing number of trading vessels at sea and thus in potential peril. Barrels are only widespread in some parts of the western empire and are perhaps better viewed as replacements for *dolia*, rather than amphorae (McCormick 2012: 74-77; Rice 2016: 180). Even the most encompassing of explanations — those related to the uneven geographical spread of known shipwrecks and the over-representation of durable cargoes such as amphora-borne goods and stone — do not fully explain the dissonance in our evidence. The concomitant evidence for continued and even increasing maritime trade visible in terrestrial evidence, the marked development in harbour infrastructure, and the decline in ship losses needs further explanation.

Thus we come to the proposition that the provision of a network of safe harbours contributed to the dramatic decline in ship losses. The correlation between the development of harbours and the decline in ship losses seems clear. But to what extent can we argue that harbours were a cause, or even a primary cause of this reduction? There is, of course, no doubt that harbours should reduce ship losses and there is ample evidence that the Romans strongly associated the presence of harbours with increased safety. Roman textual sources are full of references to harbours, highlighting the danger of harbourless areas (e.g. Strabo 5.3.5; Pliny the Younger 6.31), the felicitous nature of coastlines amply supplied with harbours (Strabo 14.3.2), and the overwhelming relief experienced by sailors in peril when they reach a safe harbour (*Greek Anthology*, 9.674-75; Valerius Flaccus 7.83-6; Juvenal 12). Emperors built, expanded, and adorned harbours and issued coins highlighting these projects (e.g. Trajan's Portus coin, Antoninus Pius' coin of Soli-Pompeiiopolis). While the storm that sunk some 200 ships inside the Claudian basin at Portus illustrates that even a flagship harbour did not guarantee safety (Tacitus 15.18.2), the expectation was that they did so and that was the more common reality.

Roman sailors traversed the Mediterranean without modern navigational aids, relying instead upon experience and intimate knowledge of the maritime landscapes that they sailed and the facilities and opportunities that they provided. Such navigational knowledge presumably was passed on orally amongst seafarers (Harris 2011: 18-19) rather than written down in manuals. Even long-distance trading voyages on sailing vessels could be composed of multiple journeys of relatively short distance (Villiers 2010). The importance of stopping to take on board fresh supplies of water and food or to pick up or set down passengers, or perhaps to buy and sell elements of cargo should not be overlooked. It is through such considerations that the conceptual geography of the Roman sailors' view of the coast along which they were sailing would have been formed. Such geographies would also, of course, have mentioned where safety might be sought in bad weather. This may have been particularly pertinent at either end of the maritime sailing season when storms could certainly endanger shipping (Beresford 2012); Lucian's (1-13) description of the storm and the troubles that befell the Alexandrian grain ship the *Isis*, which resulted in it taking shelter in the Piraeus, is a case in point (Casson 1950). In a less extreme situation, it is more likely that

the crew would simply have put in at the nearest harbour that could have provided shelter from the storm.

Juvenal, writing in the late first and early second centuries AD, provides an amusing but particularly informative view of the perils of sea travel and salvation by harbour; his *Satire* 12 tells the story of a skilled mariner by the name of Catullus who is besieged by a storm while at sea and has jettisoned his cargo to no relief, when finally the winds calms, the sun appears and the harbour at Portus comes into view:

And now at length the ship comes within the moles built out to enclose the sea. She passes the Tyrrhenian Pharos, and those arms which stretch out and meet again in mid-ocean, leaving Italy far behind ---- a port more wondrous far than those of Nature's making. Then the skipper, with his crippled ship, makes for the still waters of the inner basin in which any Baian shallow may ride in safety. There the sailors shave their heads and delight, in garrulous ease, to tell the story of their perils.

Harbours were quite literally havens and ancient texts and images make frequent reference to harbour and lighthouse terminology and artistic depictions of breakwaters, ships, and lighthouses to conjure ideas of safety literally, figuratively, and metaphorically. The image of the harbour as a place of security and protection is by no means limited to the Romans and should be seen as part of a much longer tradition encompassing Euripides' *Medea* (768-770), who refers to Aegeus, king of Athens, as her harbour when he offers her sanctuary in Athens to Gregory of Nyssa (1.13) who specifically compares the light of god to that of a lighthouse, guiding the soul into the port of salvation.

Well-constructed harbours facilitated maritime safety and reduced ship losses and many such harbours existed around the Mediterranean well before the first century AD decline in the ship losses. Why the sudden change in the first century AD? It seems to be a matter of scale. In the seascapes of southern France and central Tyrrhenian Italy, the increase in harbour construction in the early Imperial period created a network of harbours at regular intervals. This greater density of harbours increased the likelihood of finding a safe haven quickly when dangerous conditions arose at sea and this increased the security of ships and their crews and surely resulted in fewer shipwrecks.

It is particularly important to note here that the construction of artificial harbours — an activity made possible by the uptake of maritime concrete technology — was crucial for developing the harbour system along coastlines that were devoid of natural harbours, of which the majority of southern France and Tyrrhenian Italy can be included. A similar situation can be observed along the North African coast. Stone's (2014) synthesis of Roman harbours in North Africa definitively identifying artificial harbour structures in 29 cities or towns. Of these 23, or 79%, were newly constructed between the first and third centuries AD with an additional three, or 10%, modified between the first and third centuries AD after earlier initial construction (Stone 2014: 585). This is a staggering increase in the number of artificial harbours and drastically altered a coastline which was commonly described by earlier Roman authors as harbourless and dangerous (Stone 2014: 567-68). As Stone (2014: 595) points out, this surge in harbour construction occurs alongside the rise of North Africa in

the production and export of agricultural and marine products from the second to fourth centuries AD. Given the paucity of shipwrecks along the North African coast from all periods, we cannot assess the impact of these harbours on ship losses, but it is striking to note the marked increase in harbour facilities.

## Conclusions

In this study, we have taken an explicitly regional approach to a maritime landscape in order to consider the chronological patterns for the development of harbour infrastructure and how they may reflect the regional economy and potentially the patterns that we see in ship losses. Unsurprisingly perhaps, developments in harbour infrastructure prefigure, promote, and support increased maritime trade and facilitate maritime safety. This approach, which considers the maritime cultural landscape as the network of sea routes and harbours as seen both above and below the water, is a productive one for a dynamic regional analysis. While individual harbours or shipwrecks may not be dated as closely as we might wish, and while the shipwrecks for which we have records are not a full representation of the vessels that would have sailed the waters in antiquity, when the data are used sensitively, regional analyses are fruitful.

We have used the available data to trace the growth of a technological improvement — better harbours — within two well-documented geographical settings and compared this to the changing rate of natural predation from the sea. In the case of the waters off southern France and central Tyrrhenian Italy, we are able to reach some level of statistical validity for archaeologically visible shipwrecks: our sample set includes a total of 592 shipwrecks, which is just over one-third of all shipwrecks recorded by Parker (1992) and Strauss (2007).

When taken together, these data show a massive drop in shipwreck numbers between the first and second centuries AD, at the exact time when major investments were made in harbour works along the coasts. For the Tyrrhenian coast, this means that ports capable of sheltering large ships were now located within 50 km of each other, i.e. one day's sailing. In the mid-first century AD, Pliny the Younger (6.31) emphasises both the lack of harbours on this stretch of coast and the benefits that Trajan's port at Centumcellae will bring. Again, it is the element of safety that Rutilius Namatianus (1.237–49), writing in the fifth century AD, highlights about the port: deviating towards Centumcellae owing to a strong wind, there he finds ships safely at rest, with neither waves nor winds disturbing them. The example of Saintes-Maries-de-la-Mer at the mouth of the Rhône provides a counter example: here, where there was no harbour at the entrance to one of the Rhône branches, some 30 shipwrecks have been discovered dating largely between the first century BC and the first century AD. Providing a safe harbour at a strategic location on the coast must have been an important consideration for the state — as in the case of the Nero's 'folly' at Antium — as much as for the elites of local port towns who re-invested their harbour taxes in further facilities, perhaps in the hope of capturing a greater proportion of the passing trade.

The data from the harbours are also supported by land excavations, which clearly demonstrate that the decline in shipwrecks does not indicate a decline in maritime trade in the second century AD. While other possibilities have been proposed to explain the decline in wreck numbers, whether due to actual losses or simply to visibility in the archaeological

record, they are largely unsatisfactory. Something else is happening on the shores of southern France and central Tyrrhenian Italy that helps to reduce the number of ships lost here, and we propose that this is the continuing development of maritime infrastructure. We do not suggest that this is the sole explanation, but the evidence suggests that the establishment of a regular network of safe havens resulted in a marked decline in ship losses and this should not be overlooked. This change would have been particularly pronounced for coastal regions lacking in natural harbours, but given the quickly changing landscapes of the Mediterranean and trans-Mediterranean nature of Roman maritime trade, few journeys would have been unaffected by overall improvements.

The implications of these changes for the Roman economy are considerable. Improved maritime infrastructure would have lowered the amount of natural predation by sea, and surely also would have had the knock-on effect of lowering the costs of maritime trade, ‘which depended, among other things, on the ability of vessels and cargoes to reach their destinations’ (Harris 2011: 15).

The loss of ships is a maritime ‘fact of life’ but it is something that is seldom, if ever, really noted in economic analyses of maritime trade in the classical world (Stewart 2011: 1-69 for fatality rates among seafarers during the Age of Sail and the extreme danger of this profession). Scheidel (2011: 24-30), for example, only considers vessel loss through the agency of piracy. To put such losses into some sort of comparative perspective, however, during the Napoleonic War the British Royal Navy lost over 300 vessels by mishap, mainly due to the weather, and fewer than a dozen by enemy action: even in times of global maritime conflict, it was the weather that was the worst enemy of the crew of wooden warship (Bascom 1976: 83-84). Indeed Lewis (1960: 421, 442) notes that only 6.3% of British naval deaths during the Napoleonic Wars were the result of enemy action.

Therefore, the link between a developed network of ports and maritime safety should play a more prominent role in our understanding of the continuing seaborne economy after the second century AD. Crucially, a developed network of ports would have increased investor confidence. While catastrophic losses still happened, an improved network of safe havens and lighthouses to guide ships in when the winds worsened and the visibility dropped, meant that losses happened with less frequency. Investors could therefore have more confidence in getting a return on their loans rather than having them ‘gulped down by Neptune’ (Petronius 76), enabling the maritime economy to continue to flourish through the long years of peace and prosperity in the Mediterranean during the High Empire.



## **Acknowledgements**

We would like to thank the Oxford Roman Economy Project (OXREP), Andrew Wilson, and Julia Strauss for allowing us to use their data on shipwrecks in the Mediterranean. Versions of this paper were presented and discussed with faculty and graduate students at the University of Oxford, University of Edinburgh, Stanford University, Brown University, Aix-Marseille Université and Université Côte d'Azur, and we are grateful for these stimulating discussions, which have helped us to refine and improve this paper. We would also like to thank the anonymous reviewers and the editors of the JMA for their thoughtful comments. All mistakes that remain are, of course, our own.

## **About the authors**

**Candace M. Rice** is Assistant Professor of Archaeology and Classics at the Joukowsky Institute for Archaeology and the Ancient World at Brown University. Her research and publications concentrate on Roman maritime trade and shipwrecks, Mediterranean ports, Roman merchants and trading communities, Roman villas, and Roman economic development. She is also co-director of the Upper Sabina Tiberina Project, focused on the excavation of a late Republican to mid-Imperial villa in the Sabina, Italy.

**Damian Robinson** is the Director of the Oxford Centre for Maritime Archaeology and Associate Professor of Maritime Archaeology at the University of Oxford. He works in collaboration with the *Institut Européen d'Archéologie Sous-Marine* on the excavation and publication of the shipwrecks and sunken cities of Aboukir Bay and Alexandria, Egypt.

**Katia Schörle** is Assistant Professor of Archaeology and History of the Ancient World at the Université Côte d'Azur. Her research focuses on the economy of the Roman world, maritime archaeology, long-distance trade, the Roman military and merchant networks. Her archaeological experience ranges from maritime excavations to land-based surveys and excavations in Italy (Rome), North Africa, France and Spain. She currently co-directs several archaeological projects, in Croatia as well as in Tunisia as part of the European Union Horizon H2020 (SfaxForward).

## Classical Authors and Texts

Anonymous, *The Greek Anthology*.  
Caesar, *Civil War*.  
Diodorus Siculus, *Library of History*.  
Cicero, *In Defense of Publius Quinctius*.  
Dionysius of Halicarnassus, *Roman Antiquities*.  
Euripides, *Medea*.  
Gregory of Nyssa, *The Life of Moses*.  
Juvenal, *Satires*.  
Livy, *History of Rome*.  
Lucian, *The Ship, or the Wishes*.  
Petronius, *Satyricon*.  
Pliny the Younger, *Letters*.  
Rutilius Namatianus, *De Reditu Suo*.  
Strabo, *Geography*.  
Tacitus, *Annals*.  
Valerius Flaccus, *Argonautica*.  
Vitruvius, *On Architecture*.

## References

- Allianz  
2019 *Safety and Shipping Review 2019: An Annual Review of Trends and Developments in Shipping Losses and Safety*. Munich, Germany: Allianz Global Corporate and Specialty.
- Badan, O.  
2013 Sur le traces du canal de Marius. *Bulletin Amis du Vieil Arles* 158: 27-28.
- Bascom, W.  
1976 *Deep Water, Ancient Ships. The Treasure Vault of the Mediterranean*. London: David and Charles.
- Bats, M. (ed.)  
2006 *Olbia de Provence (Hyères, Var) à l'époque romaine*. Aix-en-Provence: Édisud.
- Beresford, J.  
2012 *The Ancient Sailing Season*. Leiden: Brill.
- Blackman, D.J.  
1982 Ancient harbours in the Mediterranean. Part 2. *International Journal of Nautical Archaeology* 11: 185-211.
- 2008 Sea transport, part 2: harbours. In J.P. Oleson (ed.), *The Oxford Handbook of Engineering and Technology in the Classical World*, 638-70. Oxford: Oxford University Press.
- Boetto, G.  
2012 Les épaves comme sources pour l'étude de la navigation et des routes commerciales : une approche méthodologique. In S. Keay (ed.), *Rome, Portus and the*

- Mediterranean*. Archaeological Monographs of the British School at Rome 21: 153-73. Oxford: Oxbow Books.
- Brandon, C. J., R. L. Hohlfelder, M. D. Jackson and J.P. Oleson  
 2014 *Building for Eternity: The History and Technology of Roman Concrete Engineering in the Sea*. Oxford: Oxbow Books.
- Brun, J.-P.  
 1992 Les amphores du port antique de Toulon (Telo Martius). In F. Laubenheimer (ed.), *Les amphores en Gaule*, 123-31. Paris: Belles Lettres.
- Carayon, N., S. J. Keay, P. Arnaud, and C. Sanchez  
 2018 The harbour system of Narbo Martius (Narbonne / F) and its facilities during antiquity. In C. von Carnap-Bornheim, F. Daim, P. Ettel and U. Warnke (eds.), *Harbours as Objects of Interdisciplinary Research – Archaeology + History + Geosciences*. Tagungen Band 34: 151-63. Mainz: Römisch-Germanisches Zentralmuseum.
- Casson, L.  
 1950 The Isis and her voyage. *Transactions and Proceedings of the American Philological Association* 81: 43-55.  
 1965 Harbour and river boats of ancient Rome. *The Journal of Roman Studies* 55: 31-39.
- Coustures, M.-P., C. Rico, D. Béziat, D. Djaoui, L. Long, C. Domergue and F. Tollon  
 2006 La provenance des barres de fer romaines de Saintes-Maries-de-la-Mer (Bouches-du-Rhône). *Gallia* 63: 243-61.
- De Souza, P.  
 2000 Western Mediterranean ports in the Roman Empire, first century BC to sixth century AD. *Journal of Mediterranean Studies* 10: 229-54.
- Ducruet, C., S. Cuyala and A. El Hosni  
 2018 Maritime networks as systems of cities: the long-term interdependencies between global shipping flows and urban development (1890–2010). *Journal of Transport Geography* 66: 340-55.
- El-Amouri, M., S. D. Fontaine, and F. Marty  
 2015 Un port maritime d'Arles à l'époque romaine à Fos-sur-Mer. In C. Landuré, C. Vella and M. Charlet (eds.) *La Camargue au détour d'un méandre: études archéologiques et environnementales du Rhône d'Ulmet*, 134-36. Istres: Société Spirale.
- Euzennat, M.  
 1969 Provence-Côte-d'Azur-Corse (région sud). *Gallia* 27: 419-63.  
 1980 Ancient Marseille in the light of recent excavations. *American Journal of Archaeology* 84: 133-40.
- Euzennat, M., and F. Salciat  
 1968 Les fouilles de Marseille (mars-avril 1968). *Comptes-rendus des séances de l'Académie des Inscriptions et Belles-Lettres* 112: 144-59.
- Felici, E.  
 1995 Anzio: un porto per Nerone. *Archeologia Viva* 52: 56-63.  
 2001 Recenti ricerche nel porto neroniano. In P. Gianfrotta and F. Maniscalco (eds.),

- Forma Maris. Forum internazionale di archeologia subacquea*, 121-28. Naples: Massa.
- Fentress, E.
- 2011 Slavers on chariots. In A. Dowler and E.R. Galvin (eds.), *Money, Trade and Trade Routes in Pre-Islamic North Africa*, 65-71. London: British Museum.
- Garcia, D.
- 2008 Le port de Lattara (Lattes, Hérault): premiers acquis sur les phases préromaines et romaines. *Gallia* 65: 131-49.
- Gazda, E. K.
- 1987 The port and fishery: description of the extant remains and sequence of construction. In A. M. McCann (ed.), *The Roman Port and Fishery at Cosa: A Center of Ancient Trade*, 74-97. Princeton: Princeton University Press.
- Gébara, C., and C. Morhange
- 2010 *Fréjus (Forum Julii): le port antique / The Ancient Harbour. Journal of Roman Archaeology Supplementary Series 77. Portsmouth, Rhode Island: Journal of Roman Archaeology.*
- Giardina, B.
- 2010 Navigare Necesse Est: *Lighthouses from Antiquity to the Middle Ages. History, Architecture, Iconography and Archaeological Remains*. British Archaeological Reports, International Series 2096. Oxford: Archaeopress.
- Goiran, J.-P., F. Salomon, I. Mazzini ... C. Pepe and L. Sadori.
- 2014 Geoarchaeology confirms the ancient river-mouth harbour of Ostia (Italy). *Journal of Archaeological Science* 41: 389-98.
- Goiran, J.-P., F. Salomon, C. Vittori... G. Poccardi and A. Pellegrino
- 2017 High chrono-stratigraphical resolution of the harbour sequence of Ostia: palaeo-depth of the basin, ship draught, and dredging. In T.V. Franconi (ed.), *Fluvial Landscapes in the Roman World*, 68-84. *Journal of Roman Archaeology Supplementary Series 104*. Portsmouth, Rhode Island: *Journal of Roman Archaeology*.
- Ginouvez, O., C. Carrato and C. Sanchez
- 2016 Les entrepôts de Port-la-Nautique à Narbonne. In C. Sanchez and M-P. Jézégou (eds.), *Les ports dans l'espace Méditerranéen antique. Narbonne et les systèmes portuaires fluvio-lagunaires*. *Revue archéologique de Narbonnaise Supplément 44*: 71-86. Montpellier: Presses Universitaires de la Méditerranée.
- Guery, R.
- 1992 Le port antique de Marseille. In M. Bats, G. Bertucchi, G. Congès and H. Treziny (eds.), *Marseille grecque et la Gaule*, 109-21. Lattes: A.D.A.M. éditions.
- Harris, W. V.
- 2011 Introduction. In W.V. Harris and K. Iara (eds.), *Maritime Technology in the Ancient Economy: Ship-Design and Navigation*, 9-20. *Journal of Roman Archaeology Supplementary Series 84*. Portsmouth, Rhode Island: *Journal of Roman Archaeology*.
- Hague, D.B., and R. Christie
- 1975 *Lighthouses. Their Architecture, History and Archaeology*. Dyfed: Gomer Press.
- Heslin, K.

- 2011 Dolia shipwrecks and the wine trade in the Roman Mediterranean. In D. Robinson and A. Wilson (eds.), *Maritime Archaeology and Ancient Trade in the Mediterranean*, 157-68. Oxford: Oxford Centre for Maritime Archaeology.
- Hesnard, A.
- 1994 Une nouvelle fouille du port de Marseille, place Jules-Verne. *Comptes-rendus des Séances de l'Académie des Inscriptions et Belles-Lettres* 138: 195-217.
- 2012 L'épave la Madrague de Giens (Var) et la plaine de Fondi (Latium). *Archaeonautica* 17: 71-93.
- Houston, G. W.
- 1988 Ports in perspective: some comparative materials on Roman merchant ships and ports. *American Journal of Archaeology* 92: 553-64.
- Lewis, M. A.
- 1960 *A Social History of the Navy, 1793-1815*. London: Allen and Unwin.
- Leveau, Ph.
- 2017 Environmental risk in the Lower Rhône valley: high water levels and floods. In T.V. Franconi (ed.) *Fluvial Landscapes in the Roman World*. Journal of Roman Archaeology Supplementary Series 104: 47-67. Portsmouth, Rhode Island: Journal of Roman Archaeology.
- Loughton, M.
- 2003 The distribution of Republican amphorae in France. *Oxford Journal of Archaeology* 22: 177-207.
- 2009 Getting smashed: the deposition of amphorae and the drinking of wine in Gaul during the late Iron Age. *Oxford Journal of Archaeology* 28: 77-110.
- Long, L., and G. Duperron
- 2016 Navigation et commerce dans le delta du Rhône durant l'Antiquité: bilan des recherches sur le port fluvial d'Arles et ses avant-ports maritimes. In C. Sanchez and M-P. Jézégou (eds.) *Les ports dans l'espace Méditerranéen antique. Narbonne et les systems portuaries fluvio-lagunaires*. Revue archéologique de Narbonnaise Supplément 44: 199-217. Montpellier: Presses Universitaires de la Méditerranée.
- Luley, B.
- 2014 Cooking, class, and colonial transformations in Roman Mediterranean France. *American Journal of Archaeology* 118: 33-60.
- Marlier, S.
- 2008 Architecture et espace de navigation des navires à dolia. *Archaeonautica* 15: 154-73.
- Marzano, A.
- 2007 *Roman Villas in Central Italy: A Social and Economic History*. Leiden: Brill.
- McCormick, M.
- 2012 Movements and markets in the First Millennium. Information, Containers and Shipwrecks. In C. Morrisson (ed.) *Trade and Markets in Byzantium*, 51-98. Washington DC: Dumbarton Oaks Research Library and Collection.
- McGrail, S.
- 2004 *Boats of the World: From the Stone Age to Medieval Times*. Oxford: Oxford University Press.

- Morley, N.
- 2007 The Early Roman Empire: distribution. In W. Scheidel, A. I. Morris and R. Saller (eds.), *The Cambridge Economic History of the Greco-Roman World*, 570-91. Cambridge: Cambridge University Press.
- Nantet, E.
- 2016 *Phortia: Le tonnage des navires de commerce en Méditerranée du VIII<sup>e</sup> siècle av. l'ère chrétienne au VII<sup>e</sup> siècle de l'ère chrétienne*. Rennes: Presses Universitaires de Rennes.
- Oleson, J.P., and R.L. Hohlfelder
- 2011 Ancient harbours in the Mediterranean. In A. Catsambis, B. Ford and D. Hamilton (eds.), *The Oxford Handbook of Maritime Archaeology*, 809-33. Oxford: Oxford University Press.
- Page, G., P. Dillmann, P. Fluzin and L. Long
- 2011 A study of the Roman iron bars of Saintes-Maries-de-la-Mer (Bouches-du-Rhône, France). A proposal for a comprehensive metallographic approach. *Journal of Archaeological Science* 38: 1234-52.
- Parker, A. J.
- 1986 The evidence provided by shipwrecks for the ancient economy. *Thracia Pontica* 3: 30-45.
- 1992 *Ancient Shipwrecks of the Mediterranean and the Roman Provinces*. British Archaeological Reports, International Series 580. Oxford: Archaeopress.
- 1996 Sea transport and trade in the ancient Mediterranean. In E.E. Rice (ed.) *The Sea and History*, 97-109. Stroud: Sutton Publishing.
- 2008 Artefact distributions and wreck locations: the archaeology of Roman commerce. In R.L. Holfelder (ed.), *The Maritime World of Ancient Rome*, 177-96. Ann Arbor: University of Michigan Press.
- Pasqualini, M.
- 2000 Les ports antiques d'Olbia (Hyères) et Toulon, environnement historique et géographique. *Méditerranée* 94: 33-38.
- Pellegrino, E.
- 2010 Le mobilier céramique du site de la rue de la Douane à Porquerolles (Hyères, Var), de l'époque augustéenne au Ve s. après J.-C. *Bulletin Archéologique de Provence* 33: 49-90.
- Pomey, P., and E. Rieth
- 2005 2005 *L'archéologie navale*. Paris: Errance.
- Poux, M.
- 1999 Les amphores et la chronologie des sites Bâlois (Bâle-Gasfabrik-Bâle-Münsterhügel). Nouvelles données. In M. Tuffreau-Libre and A. Jacques (eds.), *La céramique précoce en Gaule Belgique et dans les régions voisines: de la poterie gauloise à la céramique gallo-romaine*. Nord-Ouest Archéologie 9: 385-416. Berck-sur-Mer: CRADC.
- 2004 *L'âge du vin: rites de boisson, festins et libations en Gaule indépendante*. Montagnac: Editions Mergoïl.

- Provansal, M., P. Leveau and C. Vella  
 1999 Le canal de Marius et les dynamiques littorales du golfe de Fos. *Gallia* 56: 131-39.
- Reddé, M.  
 1986 *Mare Nostrum: les infrastructures, le dispositif et l'histoire de la marine militaire sous l'Empire romain*. Bibliothèque des Écoles Françaises d'Athènes et de Rome 260. Rome: École française de Rome.
- Rice, C.  
 2012 Port Economies and Maritime Trade in the Roman Mediterranean: 166 BC to AD 300. Unpublished D.Phil. thesis, University of Oxford.  
 2016 Shipwreck cargoes in the western Mediterranean and the organization of Roman maritime trade. *Journal of Roman Archaeology* 29: 165-92.
- Russell, B.  
 2011 *Lapis transmarinus*: stone carrying ships and the maritime distribution of stone in the Roman Empire. In D. Robinson and A. Wilson (eds.), *Maritime Archaeology and Ancient Trade in the Mediterranean*, 139-55. Oxford: Oxford Centre for Maritime Archaeology.  
 2013a *The Economics of the Roman Stone Trade*. Oxford: Oxford University Press.  
 2013b Roman and late antique shipwrecks with stone cargoes: a new inventory. *Journal of Roman Archaeology* 26: 331-61.
- Sanchez, C.  
 2004 La céramique: étude du mobilier des rues A et C, des maisons IV, VI et de l'espace VII. In M. Sabrié and R. Sabrié (eds.), *Le Clos de la Lombarde à Narbonne: Espace publics et privés du secteur Nord-est*, 146-82. Montagnac: M. Mergoil.  
 2009 *Narbonne à l'époque tardo-républicaine: chronologies, commerce et artisanat céramique*. Revue Archéologique de Narbonnaise: Supplément 38. Montpellier: Editions de l'Association de la Revue Archéologique de Narbonnaise.
- Sanchez, C., N. Carayon, G. Dupéron and S. Mauné  
 2015 Les ports de Narbonne antique. *Revue Archéologique/Bulletin de la Société Française d'Archéologie Classique* 2015: 137-45.
- Scheidel, W.  
 2011 A comparative perspective on the determinants of the scale and productivity of maritime trade in the Roman Mediterranean. In W.V. Harris and K. Iara (eds.), *Maritime Technology in the Ancient Economy: Ship-Design and Navigation*, 21-37. *Journal of Roman Archaeology Supplementary Series* 84. Portsmouth, Rhode Island: Journal of Roman Archaeology.
- Schmiedt, G.  
 1972 Parte prima. Considerazioni sull'indagine svolta. In G. Schmiedt (ed.), *Il livello antico del Mar Tirreno. Testimonianze dei resti archeologici*, 3-236. Florence: L.S. Olschki.
- Schörle, K.  
 2011 Constructing port hierarchies: harbours of the central Tyrrhenian coast. In D. Robinson and A. Wilson (eds.), *Maritime Archaeology and Ancient Trade in the Mediterranean*, 93-106. Oxford: Oxford Centre for Maritime Archaeology.
- Stewart, A.J.

- 2011 *The Sea Their Graves. An Archaeology of Death and Remembrance in Maritime Culture*. Gainesville: University Press of Florida.
- Stone, D.
- 2014 Africa in the Roman Empire: connectivity, the economy, and artificial port structures. *American Journal of Archaeology* 118: 565-600.
- Strauss, J.
- 2007 Roman Cargoes: Underwater Evidence from the East. Unpublished PhD dissertation, University College London.
- Tchernia, A., P. Pomey and A. Hesnard
- 1978 *L'Épave Romaine de la Madrague de Giens (Var)*. Paris: CNRS.
- Tchernia, A.
- 1983 Italian wine in Gaul at the end of the republic. In P. Garnsey, K. Hopkins and C.R. Whittaker (eds.) *Trade in the Ancient Economy*, 87-104. London: Chatto and Windus.
- 1997 Le commerce maritime dans la Méditerranée romaine. In P. Pomey (ed.) *La navigation dans l'Antiquité*, 116-45. Aix-en-Provence: Édisud. 2016 *The Romans and Trade*. Oxford: Oxford University Press.
- Terpstra, T.
- 2019 *Trade in the Ancient Mediterranean. Private Order and Public Institutions*. Princeton University Press: Princeton.
- Villiers, A.
- 2010 *Sons of Sinbad*. London: Arabian Publishing Ltd. Wilson, A.I.
- 2009 Approaches to quantifying Roman trade. In A. Bowman and A.I. Wilson (eds.) *Quantifying the Roman Economy – Methods and Problems*, 213-49. Oxford: Oxford University Press.
- 2011a Developments in Mediterranean shipping and maritime trade from the Hellenistic period to AD 1000. In D. J. Robinson and A. I. Wilson (eds.), *Maritime Archaeology and Ancient Trade in the Mediterranean*, 33-60. Oxford: Oxford Centre for Maritime Archaeology Monograph Series.
- 2011b The economic influence of developments in maritime technology in antiquity. In W.V. Harris and K. Iara (eds.), *Maritime Technology in the Ancient Economy: Ship-design and Navigation*, 211-33. Journal of Roman Archaeology Supplementary Series 84. Portsmouth, Rhode Island: Journal of Roman Archaeology.
- Wilson, A. I., K. Schörle and C. Rice
- 2012 Roman ports and Mediterranean connectivity. In S. Keay (ed.), *Rome, Portus and the Mediterranean*. Archaeological Monographs of the British School at Rome 21: 367-91. Oxford: Oxbow Books.





## List of Captions

### Figures

- Figure 1 Mediterranean shipwrecks graphed by half-century (Wilson 2011a: fig. 2.5, total n=1646).
- Figure 2 Tyrrhenian harbours discussed in text (C. M. Rice).
- Figure 3 Southern Gallic harbours discussed in text (C. M. Rice).
- Figure 4 Graph of southern Gallic harbour occupation and building phases (C. M. Rice).
- Figure 5 Shipwrecks off the Tyrrhenian coast of Italy (data from Parker 1992 and Strauss 2007).
- Figure 6 Shipwrecks off the French coast (data from Parker 1992 and Strauss 2007).

### Tables

- Table 1 Lighthouses of the Tyrrhenian coast (data from Giardina 2010).
- Table 2 Lighthouses of the southern Gallic coast (data from Giardina 2010).