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Did Vessels Beach in the Ancient Mediterranean? An assessment of the textual and visual evidence

Gregory F. Votruba

The practice of beaching seafaring ships in the ancient Mediterranean is a widely accepted phenomenon. This paper examines the evidence for beaching and outlines the various methods, tools and technology employed. While habitual beaching for seafaring vessels is testified for the Geometric Period Aegean, for later periods the evidence is primarily negative. With the increasing robustness of the structure and weight of ships, the addition of the ram for naval vessels, and developing economic circumstances leading to the necessity of round merchant vessels, habitual beaching became impractical also in this region. In the Mediterranean, where the low tidal range practically precludes the technique of tide beaching, both galleys and merchantmen were largely restricted to anchoring and mooring.

Key words: Mediterranean, beaching, Homer, trireme, galley, cargo ship

Sailors are often faced with life or death decisions, with those made near shore, particularly in mooring, among the more consequential. Unmoored craft are liable to be driven ashore, and the momentum of several tons of ship being blown upon even soft sediment can cause heavy damage to the hull. Even if a ship merely grounds intact, it can be very difficult or impossible to refloat. Although the Mediterranean is relatively serene, with its shorter fetch in comparison to the oceans, powerful winds and sudden storms are a regular feature.

Anchoring can be problematic. The stone, wood or slender wrought iron anchors of the early ancient world were less reliable for long duration mooring than more modern versions, and anchors can fail without warning. Anchoring systems require regular monitoring and adjustment to the changes in wind and current strength and direction. One might suppose, therefore, that an alternative solution would be to remove the ship from the water altogether through controlled beaching upon the shore.

A wide variety of distinct actions are encapsulated by the simple word 'beaching', so to aid clarity the distinct terminologies are defined as follows.[1] 'Momentum beaching' refers to driving a ship upon the shore with such momentum that the craft partially beaches itself (figure 1 A). Even for small boats momentum beaching would have been hazardous considering the sudden pressure on the end that came into contact with the beach. A safer scenario for achieving the same result may be 'lift beaching', which entails halting the ship a short distance from the shoreline, allowing the sailors to disembark and lift the vessel so that one end sits upon the shore (figure 1

1 Harrison employs the term 'running up on the beach', this term is too similar to the act of a group literally lifting or pulling a craft up a beach, which implies the technique of 'hauling out'. Harrison's second option 'run aground' is also problematic since it implies accidental grounding. Harrison, 'Triremes at Rest', 170; Steinmayer and Turfa, 'Effects of Shipworm', 108–9.

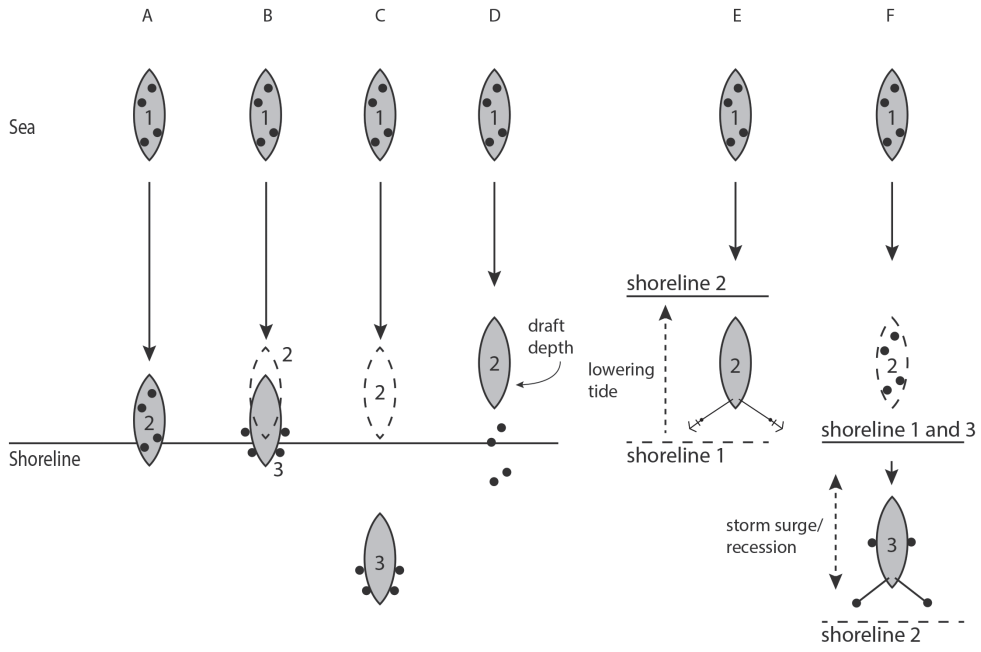


Figure 1 Schematic diagram of various forms of 'beaching.' A: momentum beaching; B: lift beaching; C: hauling out; D: draft beaching; E: tide beaching; and F: storm-surge beaching.

B). This can be facilitated by timing the lifting to coincide with the oncoming waves. A far more difficult procedure, yet feasible in certain circumstances and a necessity in others, is to remove the craft from the water and carry it to rest entirely upon the dry shore. This is accomplished with manual lifting of the hull, dragging with ropes, or the employment of groundways/slipways and machinery. This is termed 'hauling out' (figure 1 C).[2] The hull would be emptied of goods and gear to the greatest extent possible prior to the hauling. Another possible beaching scenario is 'draft beaching', which is to carefully drive the craft into shallow water until the keel touches the seabed. In this case, some stability is produced with one end momentarily resting upon the seabed, allowing disembarkation by wading ashore (figure 1 D).

Other techniques for beaching might employ the changing water levels along the coast. One may halt a ship as far as possible toward dry land at high tide, employing anchors for example, and then wait for the tide to recede, leaving the ship resting upon the now exposed seabed. This is defined as 'tide beaching' (figure 1, E). A similar technique, but with greater reach, is the use of storm surges to bring a vessel further up the shore. This is defined as 'storm-surge beaching' (figure 1, F) and is distinct from uncontrolled but intentional grounding in emergency circumstances at the expense of the hull,[3] regularly to save sailors' lives, which is termed 'sacrificial grounding'.

2 There is modest evidence for the principle of the dry dock in the ancient world (Rankov, 'Slipping and Launching', 104; Blackman 'Ancient Harbours', 207). However, while its objective is comparable to that of hauling out, the use of dry docks should not be conflated with beaching.

3 Parker, 'The Evidence Provided by Shipwrecks', 320; e.g. Acts 27.39–44.

Most vessels were beached or taken out of the water for extended periods to carry out maintenance and repair and at the end of the sailing season.[4] Some vessels beached partially and temporarily as circumstances demanded, for example to load and unload passengers and cargo, or to replenish supplies. However, it is the practice of 'habitual beaching',[5] where vessels were regularly and deliberately taken out of the water for short periods of time, in place of anchoring, as a key component of their design and operational procedures that is the most interesting and contentious.

Despite some uncertainty surrounding this practice, the idea that ancient seafaring craft would habitually be beached has received considerable support. For example, Rankov has recently stated, 'It was common throughout antiquity for both merchant vessels and warships to be hauled up onto a beach as an alternative to mooring, either overnight or for a more extended period.'[6] Similarly Wilson has included beaching for small and medium-sized ships among the practices that existed at all periods before the twentieth century.[7] Wilson here is following Houston's conclusion that beaching was a simple procedure that provided economic advantages and, along with near shore mooring, was standard for many Roman merchant vessels involved in the coastal trade.[8] Illustrating this hypothesis Reddé and colleagues have published within one of their harbour scenes a heavy merchantman being hauled out by haulers pulling on ropes running from the stem post (figure 2). Conversely, Rickman had dismissed the hypothesis of habitually beaching ships of various sizes as an 'old and naïve assumption'.[9] This article investigates the feasibility of beaching ships in the ancient Mediterranean as an alternative to mooring and assesses the evidence to determine how prevalent the practice was.

Homer and the Iron Age

It is apparent that some form of habitual beaching for galleys was practised as late as Homer's time. Specifically, the *Odyssey* is rife with references, and an excellent harbour is described as one in which a ship does not need to employ any mooring gear,[10] but can merely be driven upon the shore, and this procedure is accomplished a few lines later, serving as evidence for the practice of momentum beaching: 'nor did we see the long waves rolling on the beach, until we ran our well-benched ships on shore. And when we had beached the ships we lowered all the sails and ourselves went forth on the shore of the sea.'[11] Later, a galley is described as having been rowed so fast that it is momentum beached so that half its length is on to the shore of

4 Cf. Tzamtzis, 'Ships, Ports and Sailors'.

5 Harrison uses the term 'overnight beaching' which matches her studies' focus on triremes, allowing the rowers to rest for the evenings on land, but less so the behaviour of merchant vessels. Harrison, 'Triremes at Rest'.

6 Rankov, 'Slipping and Launching', 102.

7 Wilson, 'Developments in Mediterranean Shipping', 46 and 49; Wilson, 'The Economic Influence', 224.

8 Houston, 'Ports in Perspective', 560–2. Casson and Blackman have also made positive statements toward habitual beaching in the ancient world of ships 'at least 130 tons', based largely on the Thasos inscription. Casson, *Ships and Seamanship*, 171 n. 23; Blackman 'Some Problems', 76–9; cf. 'Triremes and shipsheds', 45.

9 Rickman, 'Towards a Study of Roman Ports', 108.

10 *Odyssey*, 9.136–9.

11 *Odyssey*, 9.146–51.

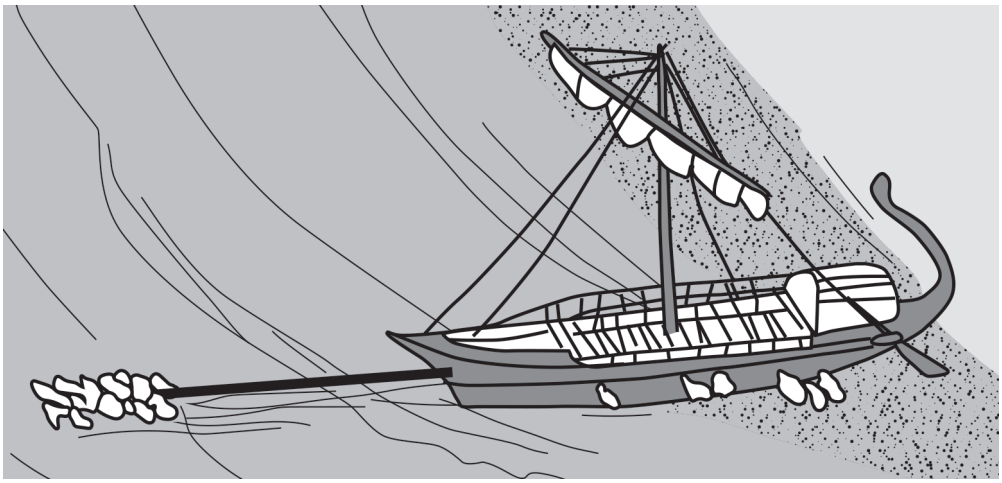


Figure 2 Hypothetical drawing of a merchant vessel being hauled out of the water by human power among a harbour scene (after Reddé, Golvin and Gassend, 'Voyages sur la Méditerranée romaine', 90, detail)

the similarly described harbour of Ithaca: 'The ship ran full half her length on the shore in her swift course, at such pace was she driven by the arms of the rowers.'[12] In these cases some form of the verb κέλλειν (*kellein*, to drive on) is used, and we might therefore presume a similar momentum-beaching action for other less clearly described instances.[13]

This Homeric momentum beaching seems to be supported by the Dipylon Master vase paintings, which often display combined terrestrial and galley ship battle scenes. Chamoux and Kirk have recognized that most of the fighting is concentrated at the bows of the ships, which reasonably illustrates the orientation at which the momentum beaching is accomplished.[14] It is possible that the projecting feature at the bow, while probably a cutwater, could also have been designed in some way to facilitate bow-on momentum beaching if the ships were built particularly lightly with shallow drafts and flat bottoms.[15] It is largely due to this inference of bow-on orientation that the subject of these paintings has been presumed to be piratical activity,[16] which is also well represented in Homer, rather than a standard battle camp scenario such as that of the Greek ships at Troy, where the ships are hauled up stern-first.[17]

It is unlikely that the Homeric galleys were left for long periods only partially beached. For longer than temporary stays, we might assume that the Homeric ships were hauled up completely on to the shore, beyond the breakers. On one occasion

12 *Odyssey,* 13.113–15.
13 *Odyssey,* 9.546, 10.511 and 11.21.
14 Chamoux, 'L'école de la grand amphore du Dipylon', 87; Kirk, 'Ships on geometric vases', 151.
15 Mark, 'The Earliest Naval Ram', 257.
16 Chamoux, 'L'école de la grand amphore du Dipylon', 87.
17 *Iliad*, 15. 716–22.

Homer states that Odysseus' ship is pulled into a cave for protection in a storm.[18] For this and other passages the means of hauling the galleys is literally to drag them onto the shore,[19] or back into the water,[20] employing some form of the verb ἐρύειν (*eryein*, to drag). In another description of a hauled-out ship, the detail is added that props were placed against it for upright support, suggesting that the vessel was not entirely flat-bottomed.[21] That early Iron Age ships were regularly hauled out near coastal cities can be assumed from Homers' description of the well-organized harbour of the Phaeacians, which was lined with craft pulled up onto the shore at designated locations: 'A fair harbour lies on either side of the city and the entrance is narrow, and curved ships are drawn up along the road, for they all have stations for their ships, each man one for himself.'[22]

However, in practice it is apparent that some adjustment to the shore would often be necessary prior to hauling. Rankov has demonstrated that trenches could be dug prior to the beaching to lower the slope of the beach.[23] These were called an οὐρός (*ouros*) by Homer[24], but ὁλκός (*holkos*) by Classical authors. These trenches may have decreased the slope of the beach, from around 1:5, which is standard for Mediterranean beaches, to a more manageable 1:10.[25] Sleeper-beams, called φάλαγγες (*phalanges, commonly meaning round logs*),[26] upon which the keel would more easily slide, were placed within the trenches. Julius Pollux defines these as 'The wooden parts of slipways, which are placed underneath the ships and upon which they are hauled.'[27] Vitruvius must be referring to them when using the word *tigna* (meaning 'timber, beam, etc.'), in stating that they were not always necessary when hauling out a ship.[28] A passage by Apollonius Rhodius is particularly interesting in which such an olivewood sleeper-beam of a ship is placed as a marker upon an Argonaut's tomb,[29] which suggests that these were included among the regular stowed equipment of early galleys.[30]Another Apollonius Rhodius passage describing the virgin launching of the *Argo* has the keel chafing these sleeper-beams[31] causing smoke to rise from the friction, supporting the assumption that the naked (or false) keel was intended to slide upon these beams.[32]

It may not be coincidence that the only specific sediment mentioned upon which the beached galleys rest is sand, perhaps suggesting that sandy beaches were

18 *Odyssey,* 12.312–19.
19 *Iliad,* 1.484–6, 14.30–6 and 14.75–9; *Odyssey,* 6.264–5 and 11.20–1.
20 *Iliad,* 1.308; 9.358; 14.76 and 14.79; *Odyssey,* 4.574–6, 4.778–86, 5.261, 10.400–5, 10.423–4, and 11.1–4.
21 *Iliad,* 1.484–6, see also 2.154.
22 *Odyssey,* 6.264-265.
23 Rankov, 'Slipping and Launching', 102–5.
24 *Iliad,* 2.151–4.
25 Coates, 'Long Ships', 113–14.
26 A plural form, *Iliad,* 2.557–8.
27 Rankov, 'Slipping and Launching', 102.
28 A plural form, *On Architecture*, 10.2.10.
29 νηίου ἐκ κοτίνοιο φάλαγξ, a beam of an olive tree from a ship; 2.843.
30 Rankov, 'Slipping and Launching', 104.
31 φάλαγγας; 1.388–90.
32 Rankov, 'Slipping and Launching', 104.

specifically sought.[33] This would provide the least resistance for digging a trench and hauling, with the sand stably supporting the sleeper-beams. Undoubtedly, hauling out was not limited to sandy shores, but they may have been preferred.

While Homer provides testimony of short-term beaching, it is also manifest that beaching was standard when long duration stays were intended.[34] The Greek galleys invading Troy were pulled up onto the shore and arranged in two rows.[35] Menelaus' ship is beached for a 20-day stay at Pharos, despite the island having a good anchorage.[36] Circe's request that Odysseus pull his ship on to dry land might be interpreted as the goddess specifically inviting Odysseus for an extended stay, which it was.[37] Another Archaic source, Hesiod, instructs that merchant ships need to be beached and protected for the non-sailing season, with the gear sufficiently cared for, and subsequently relaunched for the sailing season.[38] The Roman poet Horace supports this practice, employing the launching of vessels as a metaphor for the arrival of spring.[39]

Hesiod corresponds with Homer in employing the verb ἐρύειν for hauling out ships. However, to launch the ship Hesiod employs the verb ἑλκέειν (*helkein*), which like Homer's singular use of βάλλειν (*ballein*, to throw or hurl) for the same purpose, is a highly general term meaning draw or drag.[40] Odysseus launches his raft on his own somehow with the help of levers (μοχλοῖσιν, *mochloisin*),[41] but otherwise the general impression given is that the means of hauling and launching ships in this early period was manual, facilitated by large numbers of rowing crew.

It is reasonable to conclude that Homer's galleys were correspondingly lightweight for this early period of economic and technological renaissance. Casson considers them lightweight *because* he assumes they were beached daily.[42] That the ships were largely undecked may have been a deliberate design to preserve their lightness. Further, it may be possible that the early Aegean sewing technique of ship construction may also have helped to keep the ships lightweight.[43] Not employing dense-wood tenons or treenails would have allowed them to be constructed with thinner planks.

However, the question remains to what extent habitual beaching is representative of the entire Mediterranean world, rather than merely in a unique period of Aegean rebirth from Dark Age economic desolation, based upon exceptionally lightweight galleys. It is therefore uncertain what nature of beaching is referred to in the third-century BC fragmentary Thasos harbour inscription, found in secondary context.[44]

33 *Iliad,* 1.486, *Odyssey,* 4.426 and 9.546.
34 Mark, *Homeric Seafaring*, 159.
35 *Iliad,* 14.32–6.
36 *Odyssey,*4.354–60 and 4.575.
37 *Odyssey,* 10.403-404 and 10.423–4.
38 *Works and Days,* 628–36.
39 *Odes* 1.4.1-2.
40 *Works and Days*, 630; *Odyssey,* 4.359.
41 *Odyssey,* 5.260–1.
42 Casson, *Ships and Seamanship*, 44–5.
43 Ibid., 10, and n. 27; Mark, 'Odyssey 5.234–53 and Homeric Ship Construction: A reappraisal' and 'Odyssey 5.234–53 and Homeric Ship Construction: A clarification'; Kahanov and Pomey, 'The Greek Sewn Shipbuilding'; Pomey et al., 'Transition from Shell to Skeleton', 292.
44 *Inscriptiones Graecae* XII Suppl. 348; *Supplementum Epigraphicum Graecum* XVII: 417.

The inscription designates that merchant vessels (πλοῖον) no less than 52 (or 78) tons burden could be hauled out (the verbs are ἀνέλκειν, *anelkein*, and ἀνερύειν, *aneryein*) of one boundary (ὅρος, *oros*) of the harbour area, and those of 130 tons burden from another.[45] Perhaps over simplistically, Launey and Houston suggest that these boundaries had been located within a single harbour complex.[46] Specifically, Launey proposes that it refers to the relatively well-preserved 'closed harbour',[47] however, a recent reconstruction, based on survey and excavation, has this structure entirely surrounded with warship shipsheds.[48] Furthermore, there is at least one other known ancient mole to the east, perpendicularly oriented and dated at least from the Archaic period.[49] The stretch of shoreline around the archaic mole to the closed harbour is both sufficiently spacious (perhaps 400 metres long) and low rising for the beaching of large numbers of vessels.[50] Presumably its perpendicular mole, or some entirely different feature, could act as the boundary. This would be more feasible than having cargo ships hauled up on to the quays of a closed harbour, a practice lacking parallel outside of warship shipsheds.

More significant for this discussion is that the Thasos inscription does not clarify the reason for hauling out. Indeed, most harbours would be ready to accommodate repairs, cleaning, recaulking, and paying, as well as long-term off-season hauling out, and reasonably the administrators of Thasos would have sought to manage such activity. Vitruvius only specifically mentions shipyards (*navalis*) in relation to hauling out ships, which, he says, should include the facility to accommodate the largest.[51] Although the Thasos inscription does suggest that significant beaching would take place along the coastal areas of ancient cities, it cannot be employed to support the argument for habitual beaching of merchant ships.

That ships were beached is also evident from Theophrastus' statement that different types of wood are used for different types of vessels for the purpose of hauling.[52] Specifically, he says that triremes have oak keels, while merchant ships have pine keels, but they place an oak [sleeper groundway?] beneath the merchant ships (ὑποτιθέασι . . . δρυΐνην) whenever they are hauling them ashore.[53] Finally, they

45 Either 2,000 or 3,000 (not certain owing to poor preservation), and 5,000 talents; with the Euboean standard of 1 talent equating to 25.16 kilogrammes. Launey, 'Inscriptions de Thasos', 394–410; Casson, *Ships and Seamanship*, 171 n. 23 and 183; Blackman, 'Some problems', 76–9; Pouilloux and Dunant, *Recherches*, 394 n. 5.

46 Houston, 'Ports in Perspective', 559.

47 Launey 'Inscriptions de Thasos', 400.

48 Simossi, 'Les neoria'.

49 Empereur and Simossi, 'Thasos'.

50 Blackman suggests that light timber structures existed to accommodate the beached ships, but simply supporting them from heeling with ship-specific props and scaffolding may have been sufficient. Hesiod describes building a stone structure around ships hauled out for wintering (*Works and Days*, 624), although this may merely be a foundation layer to help stabilize and hold the ship above the ground. Blackman, 'Triremes and Shipsheds', 45; Mark, *Homeric Seafaring*, 160.

51 *On Architecture*, 5.12.7

52 *Enquiry into Plants*, 5.7.2.

53 The key difficult word is δρυΐνην (*druïnēn*, of oak), a singular feminine adjective without a noun; grammatically it harks back to the word τρόπιν (*tropin,* keel). However, it cannot be referring to the keel itself, which is a structural part of the ship. The conjunction ἐπάν (*epan*, whenever) demonstrates that this oak feature is only placed when beaching occurs. The same

use beech for the keels and false keels of smaller boats. For triremes the implication is that they are relatively often hauled ashore, requiring keels of hard oak wood. The use of shipsheds and the practice of removing them from the sea onto natural shores for protection against heavy storms and enemy attack explains the greater frequency of hauling out of triremes. The text also implies that smaller boats, presumably lighters, fishing boats or ship's boats could be hauled out frequently, employing beechwood for keels and false keels, a wood often even harder than oak. However, particularly important is the clarification that merchantmen were fitted with the least durable keels, pine being a soft wood, implying that they were infrequently hauled ashore. When merchantmen did need to be hauled out they required sleeper-beams of oak laid down on the ground to protect the pine keel when sliding.

Therefore, while the Aegean Geometric period evidence is robust for habitual beaching, the post-Archaic textual evidence suggests that only the lightest vessels continued this practice. However, to better understand the circumstance for Classical periods it is best to examine the evidence for galleys and cargo vessels individually.

Galleys

It is often claimed that triremes were regularly beached.[54] Among the suggested reasons are to dry out and make the ship lighter and for 'reducing the rate and extent of shipworm infestation by killing off larvae in the first few hours that they attempt to enter the wood.'[55] Perhaps the reason Lipke believes that the latter could not be avoided simply by applying a coating of pitch or resin is the circular argument that these ships were being hauled out regularly, and therefore pitch coating would have been redundant and even regularly abraded off. Yet the use of pitch is documented for both warships and merchant vessels.[56] Harrison furthermore has recently produced two notes of historical studies demonstrating that triremes were only exceptionally beached in place of anchoring.[57] Harrison indicates that the only testimony among the robust textual evidence for beaching triremes on natural shores

complication exists if one chose to interpret a 'false keel' here. Furthermore, Blackman has made a compelling argument that the translation for the word *chelusma* (literally 'protective sheathing') in the subsequent clause, informing its presence on small boats, is to be 'false keel'. Blackman 'Triremes and Shipsheds', 45. This is, therefore, further argument that *druinēn* should be interpreted as something other than a 'false keel'. However, Blackman's proposals that *druinēn* be translated perhaps as, 'an (obscure) reference to a cradle? or simply to a timber runner laid on the slip, possibly in a "keel slot"', are problematic because these are both untestified features for Mediterranean merchant ships, and their permanent nature, be they shore architecture, again conflict with the significance of *epan*. Rather, the most suitable meaning is 'oak [sleeper groundway]' since there is robust evidence for the use of wooden sleeper-beams for this purpose (e.g. Vitruvius's *tigna*, *On Architecture*, 10.2.10). That the adjective is a singular form indicates that Theophastus is, reasonably, referring to the temporary (likely ship-specific) groundway itself, rather than a single sleeper beam. It is upon this oak groundway that the pine keel would slide, hence the association of the two. Cf. Rankov, 'Slipping and Launching', 116–17.

54 Lipke, 'Triremes and Shipworm', 205 and citations there.

55 Ibid.

56 Harrison, 'A Note', 82–3. Casson, 'More Evidence', identifies the commonality of ship iconography which displays the upper portion of the hull in a light hue and the lower dark. Heavy and fragile lead sheathing on merchant ships, albeit less common, is also incompatible with beaching.

57 Harrison, 'Triremes at rest' and 'A Note'; Whitehead, 'Mooring', 95.

is limited to maintenance or protection, while statements relating to anchoring are ubiquitous. Coates has demonstrated that hauling triremes, which weigh around 20 tons empty, even up well-designed shipsheds with a stable foothold, on oil-slicked timbers, would have approached the limits of human capabilities (140 men pulling in heaves of around 50 kilogrammes), a figure which helps to explain why mooring at anchor is the rule for triremes outside of shipsheds.[58]

Harrison highlights an apparent momentum-beaching manoeuvre of a trireme by the Spartan Brasidas, recorded by Thucydides, the only known post-Archaic example.[59] Unfortunately, Thucydides is not explicit about what actually transpired, but Harrison reasonably suggests that the ship never made it to dry shoreline, since when Brasidas was shot by an arrow on disembarkation his shield fell into the sea. Therefore, the most informative portion of this passage may not be the description of the manoeuvre itself, but the dialogue that Brasidas engaged in with the other captains of his accompanying fleet immediately prior to the event. Brasidas had implored the other captains to land[60] their vessels on the shore with him, for a surprise attack on an Athenian garrison positioned near a favourable (but unfortunately unspecified) portion of the shoreline. Crucially, however, Brasidas admits that the manoeuvre would cause the timbers of the ships to splinter, resulting in the triremes' complete destruction. It is due to this admission that Brasidas ends up attempting the manoeuvre on his own. This passage suggests, therefore, that while Brasidas' choice to momentum beach a trireme was courageous, it was broadly considered foolhardy. The only known example of a Classical warship beaching for attack is therefore a sacrificial grounding.

Further evidence is provided in Polyaenus' description (*Strategems* 3.9.63) of a fourth-century BC warship fleet attacking a Phoenician army by approaching the flat shore in unison, dropping anchors from the stern, and the soldier/rowers jumping out and wading to land. The action was considered so audacious that the enemy was intimidated and fled, giving the impression that naval ships even approaching the shore bow first to attack was exceptional. In contrast to the bow-first momentum beaching evident in the Geometric period, it is apparent that late and post-Archaic galleys largely remained afloat. Specifically, it seems that they would approach the shore sternwards (figure 3).[61] Theseus' ship depicted on the François vase displays an arrival scene with the ship backing water towards the shore, with the celebrating sailors looking sternwards and two particularly eager men swimming from the stern (figure 4). Harrison has reasonably suggested that the shallow curve of the stern would have facilitated this approach.[62] Perhaps the ram located at sea level, with its lower portion below it, would have hindered bow-on momentum beaching, catching the rising sea floor rather than sliding along it. Indeed, the development of the ram,

58 Coates, 'Long ships', 107–9. Rankov, suggests heaves perhaps up to 70 kilogrammes would be required. Rankov, 'Slipping and Launching', 117–18.

59 *History of the Peloponnesian War*, 4.11–12.

60 The verb for the action employed is ὀκέλλειν (okellein), which employs the same root as Homer for momentum beaching.

61 This is also the orientation of Homeric ships when they would anchor offshore. Mark, *Homeric Seafaring*, 154. For a similar Roman illustration, see Morrison and Coates, *Greek and Roman Oared Warships*, fig. 40.

62 Harrison, 'Triremes at Rest', 170–1.



Figure 3 A representation from a fourth-century BC Greek vase, including the stern of a galley with its landing ladder fitted and the rudders raised; waves of the swash zone are present beneath the ship and the ladder (after Svoronos, 'Stylides', figure 6)



Figure 4 The arrival scene of Theseus' ship on the François Vase; the ship is apparently backing water, with two sailors particularly eager to land swimming (highlighted) from the stern (after Kirk, 'Ships on Geometric Vases,' figure 10)

apparently sometime after the Geometric Period,[63] may have dramatically altered naval aggression tactics, since the design handicapped any ability to momentum beach for a land attack. It may not therefore be a coincidence that evidence for successful momentum beaching is only present in the centuries prior to the adoption of the ram.

Momentum beaching of galleys bow-first, reminiscent of Geometric practice, for amphibious attack may not reappear in the textual record until later Byzantine times,[64] long after the ram has disappeared from use. Lewis and Runyan propose that such tactics were novel and included the employment of uniquely modified galleys. Nevertheless, the beaching of galleys may not have achieved standard practice even in this period since Leo VI advises that fleets arriving at a harbourless sandy shore moor by casting bags filled with sand over the sides.[65]

For mooring of galleys in the ancient world, Harrison identifies several instances in Herodotus and Thucydides where it is clear that the fleets were moored at the

63 Mark, 'The Earliest Naval Ram'.

64 Lewis and Runyan, *European Naval and Maritime History*, 30–31 and 76–7; Pryor and Jefferys, *The Age of the* ΔΡΟΜΩΝ, 307.

65 Leo VI, *Tactica* 20.196; Wheeler, 'Notes on a Stratagem', 157–60. Polyaenus (*Stratagems* 3.9.38) had made a comparable statement.

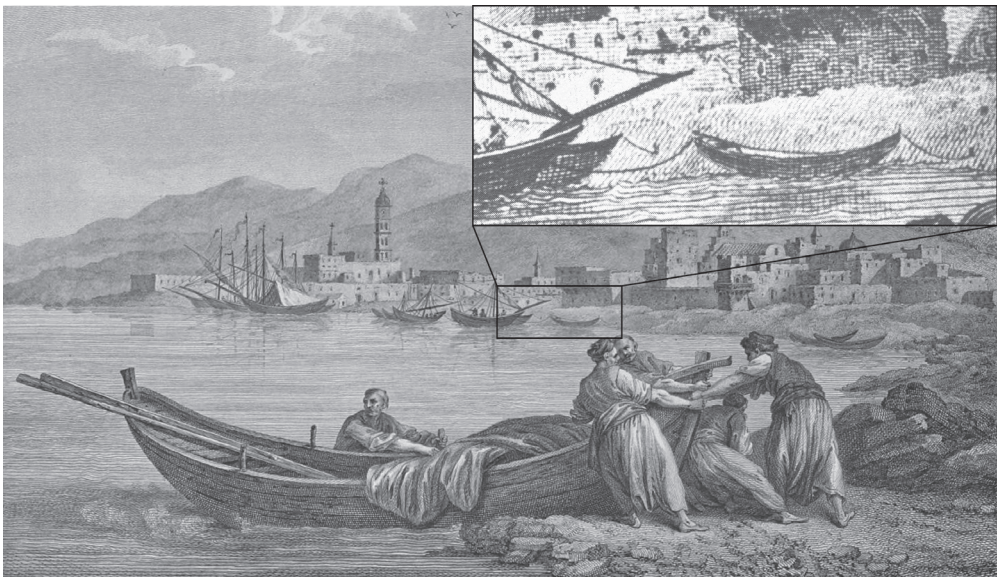


Figure 5 An eighteenth-century engraving of Tinos town; a sieve net rowboat is being launched into the sea, and several modest vessels are moored to mooring-stakes in the background (Choiseul-Gouffier, Barbié du Bocage, and Letronne, 'Voyage Pittoresque de la Grèce', plate 29, detail)

shore.[66] There are frequent references to 'stern cables' (πρυμνησία, *prymnēsia*, or Latin *rectinacula puppis*),[67] which are always mentioned in plural suggesting that they were employed from port and starboard bitts to provide some side-to-side stabilization. Aeschylus states specifically that war fleets seek secure mooring with anchors and cables, the latter carried to the shore.[68] Virgil writes of mooring galleys, 'an anchor is cast from the prow, and the sterns stand to the shore'.[69] The stern cables could have been attached to natural features, or more likely perhaps, to mooring stakes. Pacuvius mentions the use of a *tonsilla* to moor a vessel;[70] and Festus defines them as hewn stakes tipped with iron that are inserted into the shore for fastening ships.[71] It is apparent that standard galleys throughout most periods, despite their great numbers of rowers and possibly lighter construction, were equipped and designed to moor in front of, as opposed to being beached upon, the seashore, even for offensive attack.

66 Harrison, 'Triremes at Rest', 171.

67 For example, Athenaeus (*Deipnosophistae*, 15.12); Apollonius of Rhodes (*Argonautica*, 1.912–13); Euripides (*Iphigeneia in Tauris,* 1352); Homer (*Odyssey* 9.137, 12.32, 15.286 and 15.498); Ovid (*Metamorphoses* 14.547); Polyaenus (*Strategems*, 4.6.8); Definitions by Joannes Zonaras (*Extracts of History*, 1.436.12) and Hesychius (*Lexicon*, 5.4691) also incidentally have them in the plural. Polybius (*Histories*, 33.9.6) uses the term ἐπίγυα (*epigya*, lit. to the land) and Hesychius and Joannes Zonaras specifically equate ἐπίγυα with πρυμνησία.

68 *Suppliants*, 764–6.

69 *Aeneid*, 3.277.

70 *Medus*, 231. Close examination of the vessels moored near the shore in figure 5 demonstrates the common use of mooring stakes in later medieval practice.

71 *Breviarium*, 538.28.



Figure 6 A nineteenth-century small coastal vessel tide beached and transferring cargo into a cart at Lochranza on the isle of Arran, Scotland; it is clear from its broadside orientation that it was not hauled out (from Houston, 'Ports in Perspective', figure 1)

'Round' cargo vessels

If naval galleys, with their streamlined form and high manpower to ship-weight ratio, were not habitually beached, then what is the possibility that 'round' cargo vessels were themselves beached? To investigate this question, we must return to George Houston's 1988 article, 'Ports in Perspective', in which Houston devotes several pages to the likelihood of regular beaching in place of mooring in the ancient world. The most conspicuous support for Houston's argument is a nineteenth-century photograph of a small coaster from Scotland, sitting fully out of the water and seemingly unloading cargo into a horse-drawn cart (figure 6). Similar images from various locations around Great Britain abound, serving as testament to the commonplace nature of this practice.[72]

However, the beaching technique employed in these cases is not hauling-out but tide beaching. For this practice high tidal ranges are necessary, making the coastline of Britain particularly suitable, with an average tidal range of 6 metres.[73] This scenario is not feasible for the Mediterranean, however. Despite cyclical tidal regimes being highly variable due to the geographic terrain, depth of the sea and other factors, the Mediterranean displays a low tidal range overall, only rarely

72 Bouquet, *No Gallant Ship*, 117–24 and figs 1, 2, and 21; Greenhill and Giffard, *The Merchant Sailing Ships*, 78, 81–2 and nos 53, 89, 91; McGrail, *Ancient Boats*, 267–9 and fig. 22.

73 McGrail, 'Medieval boats', 23; McGrail, *Boats of the World*, 170; McGrail, *Ancient Boats*, 259. Caesar, *Gallic War* 3.13, reports that the ships of the Veneti of north-western France were designed for tide beaching, but the invading Roman ships were not.

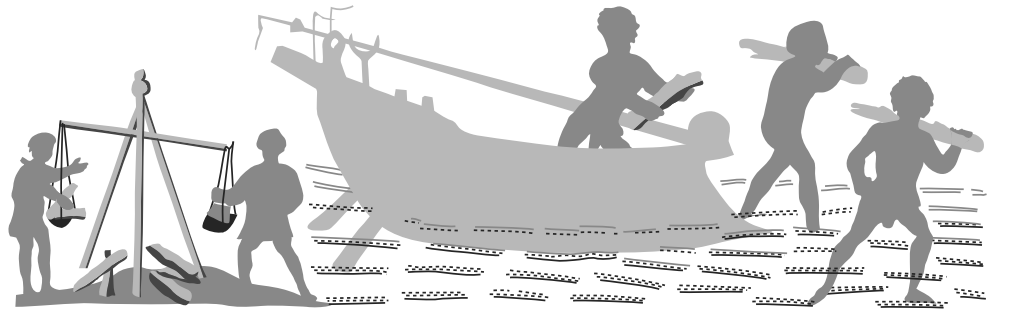


Figure 7 Scene of unloading wood pieces from a cargo vessel and wading to the shore where it is weighed, from a mosaic at Sousse, Tunisia. The dashed lines represent blue tesserae, indicating seawater (after Ben Abed, 'Tunisian Mosaics', fig. 2.14)

surpassing 30 centimetres.[74] Only the Gulf of Gabès (nearly 2 metres), the northern end of the Adriatic Sea and a few locations in the Aegean (80 centimetres) have appreciably greater ranges. These measurements of celestially influenced tides are of course separated from additional global factors such as air pressure, which can adjust the local sea-level height perhaps by a metre.[75] Such effects are impossible to anticipate and it is therefore invalid to base arguments regarding beaching ships in the Mediterranean on records from the United Kingdom and elsewhere.[76]

The only possible iconographic evidence for beaching cargo ships from the Classical Mediterranean is a mosaic from third-century AD Sousse which is indeed employed by Houston and Wilson as testimony of such (figure 7).[77] However, being surrounded at both ends by blue tesserae representing water, it is clear that the vessel is depicted in the sea. Despite the craft reasonably being a modest provincial vessel, with a cargo of firewood (?), it is important that there was no attempt to haul it out. It could, however, represent draft beaching, where the ship enters as shallow as possible for the keel to rest on the seabed. Yet, it is difficult to be certain of the water depth. The waders are depicted in shin-high water, but this does not conform to the rudders not having been raised, giving the impression that the vessel is floating in deeper water. It is reasonable that the artist truncated the scene so that deep water is displayed side by side with shallow. Conceivably the small ship could be anchored and floating in waist deep water, which would still allow the removal of cargo by wading.

Other classical and later ancient world iconography related to mooring displays

74 United Kingdom Hydrographic Office, *Mediterranean Pilot, vol. 1*, 25; *vol. 2*, 16; *vol. 3*, 17; *vol. 4*, 13; *vol. 5*, 21.

75 McGrail, *Boats of the World*, 170.

76 Mark, *Homeric Seafaring*, 155, has made a similar mistake in which an ethnographic report of a 100-foot-long merchant ship in the Indian Ocean is cited as being beached through kedging and pulling on ropes around stable objects on shore. What Mark omits is that the report clarifies that such procedure only occurs 'where there is a big rise and fall of the tide', i.e. tide beaching. Villiers, *Sons of Sinbad*, 215.

77 Houston, 'Ports in Perspective', fig. 2 and 561. Wilson, 'Developments in Mediterraenan Shipping', fig. 2.23 and 49.

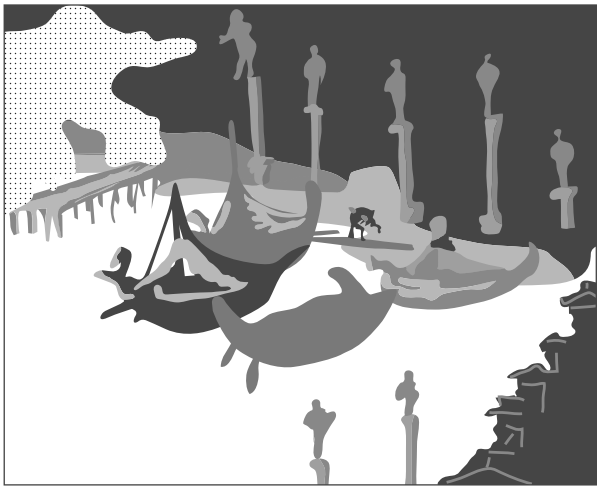


Figure 8 An interpretative illustration of a first-century AD fresco from Stabiae, Naples, showing a harbour scene; with several vessels moored in the harbour basin adjacent to a seemingly unbuilt low-rising shoreline pierced with wooden piers (after Spathari and Karageorghis, 'Sailing Through Time', fig. 199)

ships moored in the water, not hauled out. For example, a first-century AD fresco from Naples seems to display four ships moored floating, even though they are adjacent to the shoreline (figure 8). There are also examples of moored vessels floating from a sixth-century AD mosaic from Ravenna.[78] Other early representations display ships moored, transferring cargo or embarking people. Several appear to be able to access the shore with a landing ladder,[79] including one of the vessels closest to the shore in figure 8. Others have the landing ladder apparently leading to quays.[80]

The same appears to be true of the more numerous and detailed iconographic evidence from the late medieval and early modern periods.[81] David Roberts has illustrated scenes at Akko, Tyre and Sidon with the primary focus being coastal craft of around 10 to 15 metres moored floating and being tended to by small lighters (figure 9).[82] However, a particularly interesting Roberts lithograph depicts two similar ships with masts standing and rigged, apparently fully beached upon the open sandy shore to the north of Tyre (figure 10). We must assume that such beaching was possible with relatively beamy, flat-bottomed, low draft vessels as they appear to be,

78 Spathari and Karageorghis, *Sailing Through Time*, fig. 213.

79 A third-century AD stone relief from Salerno, Italy (Casson, 'Harbour and river boats' pl. 5 no. 1); fourth-century AD bronze bowl decoration at the Musée de Louvre (Spathari and Karageorghis, *Sailing Through Time*. fig. 171); second- to third-century AD mosaic from Kos (ibid., fig. 204). It is unlikely that a ladder could actually reach dry land. Although these representations are not entirely accurate, they do nevertheless display moored ships floating. If that of fig. 204 is a ship's boat, as it appears, that is more feasible.

80 A third-century AD relief from Portus (Casson, *Ships and Seamanship*. fig. 174); a second-century AD relief from Narbonne (Gianfrotta and Pomey, *La Navigation*, pg 127 upper); the Torlonia relief, about AD 200 (ibid., 82).

81 Tzamtzis, 'Ships, Ports and Sailors', 58 and 103.

82 The other two are scenes at Acre (Akko), dated 23 Apr. 1839, and Sidon, dated 28 Apr. 1839.

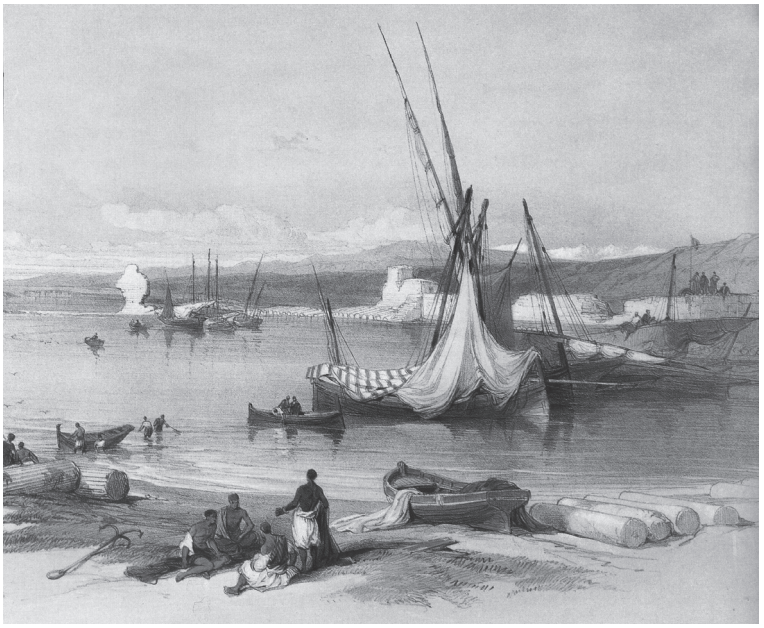


Figure 9 Detail of a lithograph of the Tyre enclosed harbour by David Roberts, whose original sketch was completed on 27 April, 1839; larger ships are moored within the harbour basin with the closest communicating with the shore through small boats, but a small fishing sailboat can be seen having been hauled out in the foreground



Figure 10 A detail of a separate lithograph by David Roberts, also sketched 27 April 1839, of a beach scene north of Tyre, with two ships seemingly fully beached

employing sufficient storm surge provided by the uniquely large fetch to the west of the Levant.[83] Although the sea as drawn was apparently calm, Roberts reports that the previous day had been stormy with large waves.[84] It is feasible that storm surge-beaching would be a regular technique at this time for protecting the ship during storms along the exposed and relatively sandy-shored Levant.

Therefore, it can be considered that the flat-bottomed hulls characteristic of 'eastern riverine root' ship construction, as defined by Pomey and colleagues dating from at least AD 500, may have been to some extent to enable this storm-surge beaching.[85] These authors suggest that the prevalence of flat-bottoms of medieval date may derive particularly from riverine tradition (particularly Nilotic), where it was a solution to navigating shallow-water.[86] However, DeVries and Throckmorton both suggest that flat-bottomed ships were easier to beach.[87] Congruently, Parker has suggested that the flat-bottomed La Luque A and Cap del Vol ships had been designed for draft beaching.[88] The apparent gradual increase in flat-bottomed hulls in the first millennium AD could be indicative of greater draft- and surge-beaching practice, in addition to the use of rivers, a feasible response to the decline in harbour infrastructure in the post-Roman periods.[89]

Practicalities of hauling out

Perhaps the primary reason seafaring vessel habitual beaching is not testified after the Archaic Period is the greater weight of ships. For example, the relatively small Ma'agan Mikhael ship from around 400 BC is estimated to weigh 4 tons unladen and 19 tons laden.[90] It is believed to be an international coaster constructed in the northern Aegean, that called at Cyprus, but was wrecked in the Levant.[91] For us to consider hauling-out this small ship one would have to imagine needing to drag several tons, even if empty of all cargo and ballast.[92] The great majority of cargo vessels simply would have been too heavy to be hauled out solely by the small crew. Furthermore, any hauling out would also have been tremendously dangerous.

83 See also Pashut et al., 'The Akko 2 Shipwreck', 135. Adjacent to the two ships highlighted is a small boat and a pile of objects. These were presumably removed to lighten the ship as much as possible prior to the storm-surge beaching.

84 Roberts, *The Holy Land*, 242.

85 For several references to Byzantine beaching in response to storm see McCormick, *Origins of the European Economy*, ch. 13, notes 133, 136 and 139.

86 Pomey et al., 'Transition from Shell to Skeleton', 304 and 308; Pomey et al., 'On the transition'.

87 DeVries, 'Greek, Etruscan and Phoenician Ships and Shipping ', 47; Throckmorton, 'Romans on the Sea', 68.

88 Parker, 'Cargoes, Containers and Stowage', 25. See also Caesar, *Gallic War* 3.13, for tide beaching.

89 Blackman 'Ancient Harbours', 199. For an argument for significant beaching and river mouth navigation in the Byzantine Period see McCormick, *Origins of the European Economy*, 419–21.

90 Its reconstructed dimensions are: 13.8 metres length, 4.27 metres beam, 2.65 metres hull depth amidships. Winters and Kahanov, 'Hull-lines, Seaworthiness, and Burden', 131.

91 Kahanov and Linder, 'Conclusions'.

92 Collins (*Makassar Sailing*, 11–13 and 20–7) describes the hauling out of Indonesian seafaring ships, roughly the size of the Ma'agan Mikhael, for the off-season. Even though the haulers numbered in the hundreds, with hands on the hull but also employing attached poles and ropes, it was nevertheless accomplished with difficulty.

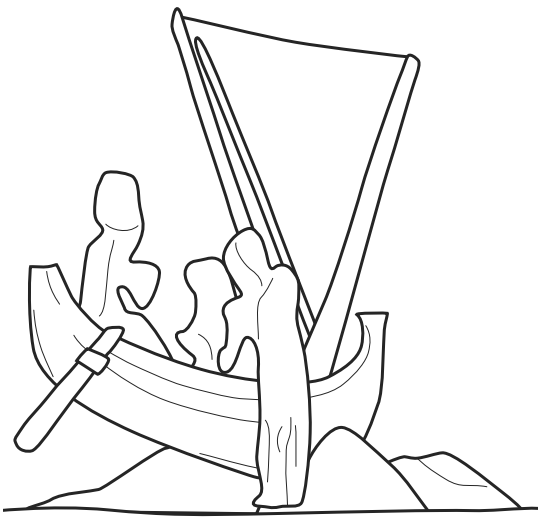


Figure 11 A sketch of the contours of an eroded Roman tombstone relief in the Archaeological Museum, Thessaloniki, depicting the launch of a small boat with a spritsail (traced from Casson, 'Ships and Seamanship', figure 178)

Rodriques Santamaria for example, when talking of Spanish fishing boats, notes that large waves are known to knock the vessel over and roll it upon the sailors attempting to stabilize it.[93] We must be particularly conscious of stabilization problems with the largely wine-glass hull shapes of the Graeco-Roman Periods.

However, we know from the Theophrastus passage cited above that light boats were often hauled out. Correspondingly, looking again at the Roberts image (figure 9), one will notice that there is a modest fishing boat apparently hauled-out on the shore in the foreground. From the Aegean a similar boat is seen being launched into the water by at least five workers, with its fishing net stowed (figure 5), which might be considered comparable to a small boat with a sprit sail being launched depicted on a Roman tombstone (figure 11). These small craft suggest a modest size of boat, with shallow draft, that could be hauled out regularly. It is therefore reasonable to assume that only light hulls, likely including ship's boats, could or would have been habitually beached in any period.

It is possible that early penteconters, particularly the open 'aphract' variety specifically designed to be light,[94] could be readily hauled out. It may have been practical for a shallow draft penteconter with an estimated lightship weight of around five tons to beach in favourable natural conditions.[95] This would require a heaving pressure of about 35 kilogrammes per member of the crew. Such a capability may help explain why these were preferred for the Archaic exploratory and settlement enterprises travelling through little known geography where sheltered anchorage was uncertain to be found. It was the increasing size of war galleys with decks and multiple rower levels and with increasingly robust construction, along with the introduction of the ram, which instigated the need for permanent slipways.

93 Rodríguez Santamaría, *Diccionario de Artes de Pesca*, 346.

94 Casson, *Ships and Seamanship*, 50. That undecked ships were considerably lighter than decked ones may be supported by a passage in Polybius (*Histories*, 5.101) in which a fleet of undecked ships was hauled across the isthmus while the decked ships were ordered to sail around the Cape of Malea.

95 Coates, 'Pentekontors and Triereis', table 2; Coates, 'Long Ships', 111.

Slipways would maximize the performance of hauling out by producing solid and standardized stepping ground for the haulers while minimizing the sliding friction of the hull. It was no longer practical to regularly haul out galleys with simple dugout channels and, possibly, laid down wooden beams. A case in point for this change in mooring behaviour in the Aegean is Athens' decision, in the early fifth century BC to employ the deep water harbours at Piraeus instead of the shallow, sandy, beach at Phalerum that had previously been the city's outport.[96]

For the Classical Mediterranean, when hauling out ships for long duration beaching, winches could have been employed. Their use for hauling vessels is confirmed by Vitruvius and Horace.[97] The use of winches (στρέβλαισι, *streblaisi*), in plural, for hauling a single ship, testified by Aeschylus, suggests that more than one could be employed.[98] What form the winches took is unfortunately not specified, with the exception of Archimedes who constructed a screw windlass to launch the lower portion of the *Syracusia*.[99] Vitruvius claims specifically that ships are hauled ashore using ropes and blocks to supplement the winches.[100] Similarly, a probable variant on the Athenaeus testimony for the *Syracusia* launching includes detail of the employment of a multiple block and tackle.[101] Indeed, ethnographically recorded ship-hauling capstans are shown to function in conjunction with compound pulley blocks to provide adjustment in the direction of the pull and, most importantly, mechanical advantage.[102] The discovery of the compound pulley may therefore have had a significant effect on the capacity and practice of beaching ships. The device is known from at least the Aristotelian discussion of the early third century BC, while Coulton has argued that the tool was first discovered in the sixth century BC.[103] This may have increased the maximum size of ships that could be hauled out, but their relatively slow functioning, and the need to adjust them to the dimensions of individual ships and the characteristics of the shoreline would have made them impractical for habitual beaching of anything but provincial craft.

As alternatives to capstans, along the eastern and southern coast of Spain it is recorded that pairs of oxen, mules and horses could be employed, which could be with or without pulleys for mechanical advantage.[104] Johnstone and Tilley reported that the 15-ton displacement *saveiro* ships of Portugal required 20 oxen to haul them out

96 Garland, *The Piraeus* 18–19; Goiran et al., 'Piraeus', 531–4.

97 Vitruvius, πολύσπαστον (polyspaston), *De architectura*, 10.2.10; Horace, *machinae*; *Odes* 1.4.2.

98 Aeschylus, *Suppliants*, 441

99 Athenaeus, *Deipnosophistae*, 5.207b. That only the lower portion could be launched with difficulty suggests that the ship itself could not be hauled out. Therefore other techniques may have been used for maintenance such as careening.

100 *De architectura*, 10.2.10.

101 Plutarch, *Marcellus*, 14.8; Casson, *Ships and Seamanship*, 195 n. 29.

102 For Spain: Rodríguez Santamaría, *Diccionario de artes de pesca*, 342–47, 351, 355 and 360; for Greece: Tzamtzis, 'Ships, Ports and Sailors', pl. 32. Incidentally, these include the use of a sliding cradle, a tool untestified for the pre-modern world; Rankov, 'Slipping and Launching', 113–15; Tzamtzis, 'Ships, Ports and Sailors', 98-9.

103 Aristotle, *Mechanika*, 18; Coulton, 'Lifting in Early Greek Architecture'.

104 Rodríguez Santamaría, *Diccionario de Artes de Pesca*, 342–6; Rubin de Cervin, 'The Thera Ships', 151.

after they had finished with their job of setting out trawling fishing nets.[105] Evidence from the Indian Ocean testifies to the employment of elephants for beaching, in addition to multitudes of haulers.[106] In the ancient Mediterranean there is testimony only for the use of human labour, rather than animal, when, for example, hauling ships upstream.[107]

It is largely unclear how hauling ropes were attached to the ships.[108] For the prehistoric Mediterranean we have unsubstantiated interpretation of the stern projection on several of the Thera ship depictions as being attachments for hauling ropes.[109] There may be evidence of boring of the keel or lower stern post to allow the passing of hauling line through, as identified and interpreted from several ships dating from the eighth to tenth century AD at Yenikapı in Istanbul.[110]

When hauling out a ship by human power alone, we may consider the minimum requirement of 140 men (and 120 for launching) for triremes stated on a Piraeus inscription.[111] For further detail we must incorporate ethnographic evidence. Rodríguez Santamaría mentions the practice of manually hauling out fishing vessels in Spain and, judging from the images provided, this was done either pulling tug-of-war style, or using the cables fitted with shoulder and waist-crossing straps for greater leverage.[112] An interesting observation about emergency beaching comes from Estepona. When storms arose, the parish bells alerted the local population, including women and children, to congregate on the beach to assist the hauling-out of both local and foreign vessels.[113] We might therefore speculate that the inhabitants of coastal towns in the ancient Mediterranean would have organized themselves to haul out anchored ships during increasingly dangerous storm conditions.

Conclusions

The beaching practices of seafaring ships varied through time and space. Northern European and Indian Ocean sailors could employ tide beaching. In the Black Sea and the Atlantic coast the use of machines to haul vessels ashore was prevalent. However, for the Classical Mediterranean neither warships nor merchant ships were habitually beached in place of anchoring. Despite the benefits to be gained, this would not have been practical because most seafaring craft were far too heavy for the sailors alone to lift or drag, even when cargo and gear was removed. The round hull forms of merchant ships also made them unstable and hazardous when hauled from the water. Habitual beaching may only be testified for Homer's early Iron Age period

105 Johnstone and Tilley, 'An Unusual Portuguese Fishing Boat', 15.
106 Qaisar, *The Indian Response*, 33.
107 Marlier, 'Architecture et espace', n. 132.
108 Blackman, 'Some Problems', 74 and n. 7. Following Vian, *Les Argonautiques Orphiques*, 94 n. 271, allows emendation of the text of the *Orphic Argonautica* (270–1) that places a cable in use for launching the Argo. However, Rankov ('Slipping and Launching', 104) interprets the passage to describe rather the sleeper beams laid in a straight line.
109 Rubin de Cervin, 'The Thera Ships.'
110 Pulak, Ingram and Jones, 'Eight Byzantine Shipwrecks', 52, 3 and 9; Kocabaş, 'The Yenikapı Byzantine-era shipwrecks', 15 and 20.
111 *Inscriptiones Graecae* 13 153.6-9; Rankov, 'Slipping and Launching', 117–18.
112 Rodríguez Santamaría, *Diccionario de Artes de Pesca*, 348.
113 Ibid., 345–6.

in the Aegean, when the galleys with their high rower numbers were designed to be particularly light.

Although we lack direct testimony for the contemporary and Bronze Age eastern Mediterranean, we can interpolate the limited data according to the beaching theory that has been developed here. From the substantial evidence of round large tonnage ships, habitual beaching may not have been uniform practice during the Bronze Age.[114] The apparent mortice-and-tenon joinery construction of the Uluburun and Cape Gelidonia shipwrecks would also suggest heavier construction than Homeric ships, making them less feasible to be beached.[115] This assumption is further reinforced by the multiple stone anchor finds in several Bronze Age and early Phoenician ships and Leo VI's and Polyaenus' comparable assertion that ships moored on harbourless coasts by casting multiple sandbags tied to ropes over the sides. The Thera West House frieze arrival scene may display a scenario similar to that apparent in post-Archaic periods, with small boats beaching and ships moored at anchor.[116]

Generally speaking, only provincial fishing craft, lighters, and canoe-like vessels could have been habitually hauled out in any period. Additionally, flat-bottomed craft could be carefully beached on soft shores as protection from rising storm waves, with the help of the increasing surge and sea-level. Round-hulled ships would primarily only have been hauled out for repairs and maintenance, off season storage, salvage, or during emergency circumstances. This operation would have regularly required wooden sleepers to be laid to minimize resistance and would have required dozens to hundreds of haulers, even for modest-sized ships. From the middle of the first millennium BC winches and compound pulleys could have been employed. Nevertheless, these hauling systems do not appear to have ever developed to a level of ease or efficiency that would have enabled habitual beaching. It is therefore clear that, from the Classical period at the latest, the standard practice was to remain afloat at anchor.

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114 Wachsmann, *Seagoing Ships*, 9, 10, 18–28, 41; Marcus, 'Amenemhet II and the Sea', 154–7.

115 Wachsmann, *Seagoing Ships*, 206, 216–17; Bass, 'The Hull'.

116 Shaw, *Bronze Age*, figs, 18 and 19.

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