Hellenistic and Roman republican naval warfare technology

William M. Murray is Professor of History at the University of South Florida, United States

Abstract. *This contribution examines rapid developments in naval warfare technology in the Mediterranean world in fourth and third centuries BC, particularly the evolution of large oared warships, known as 'polyremes' and the creation of naval siege units for assaults on coastal strongholds by the successors of Alexander the Great. It also explains how unsustainable costs and changing strategic priorities led to their abandonment and the introduction of more cost-effective and adaptable vessels and strategies.*

Résumé. *Cette contribution étudie le rapide développement de la technologie des navires de guerre dans le monde méditerranéen des IV^e^ et III^e^ siècles av. J.-C., en particulier l'évolution des grands vaisseaux de guerre à rames connus sous le nom de « polyrèmes », et la création d'appareils dédiés au siège maritime pour l'assaut des bastions côtiers par les successeurs d'Alexandre le Grand. Elle explique également comment les coûts insoutenables et les changements de priorités stratégiques ont conduit à leur abandon et à l'apparition de tactiques et de vaisseaux plus rentables et mieux adaptés.*

Overview

During the last four centuries BC, naval warfare experienced an incredible burst of technological innovation in both the eastern and western Mediterranean.[1] In the span of roughly a century and a half – from approximately 400 to 250 – warships grew in size from triremes or 'threes' to 'thirties,' became broader and heavier, and were armed at the bows with bronze rams of increasing size and weight. The numbers contained in the names describing these new galleys (*triērēs* = 'three,' *tetrērēs* = 'four,' *triakontērēs* = 'thirty') relate to their oar systems, with vessels from the same class having roughly similar dimensions and designs. While we are ignorant of the basic specifications of most classes larger than 'fives,' we suspect they were powered by crews of many hundreds, even thousands of men,

[1] Throughout this chapter, all dates are BC unless noted otherwise.

arrayed at one, two, or three levels, with multiple men to an oar.[2] As a whole, we refer to the vessels that were larger than 'threes' as 'polyremes,' although the ancients preferred to call such warships 'cataphract' (*kataphraktos*) or 'fenced-in' from the rowers' safe placement below the fighting deck. Indeed, the Latin term for such galleys was *tectae* or 'decked.' Thus protected from projectiles, the men below deck provided the muscle that drove their polyremes through harbor barriers, brought catapults and siege machinery up to coastal fortifications, and even shook harbor walls with powerful ramming blows.[3] 'Fives,' with oarcrews of roughly 300, replaced 'threes,' with oarcrews of roughly 170, as the preferred ship of the line for states that could pay the bills and muster the men to row them.[4]

At the same time, we see the brisk development of ranged weapons, which advanced during the course of the fourth century from large, hand-held crossbows to sophisticated torsion catapults relying on twisted skeins of 'spring cord' and hair for their propulsive power.[5] Medium-sized weapons, weighing 2,000 kilograms or more, threw large bolts (i.e., heavy arrows) and small stones as far as 700 meters at tremendous velocity.[6] During the third and second centuries, artillery constructed with heavy timbers, iron plates, capstans, gears,

[2] Over the years, many attempts have been made to determine the crew numbers, beams and lengths of these vessels, which can only be approximated, given our current evidence. See Murray W., *The Age of Titans. The Rise and Fall of the Great Hellenistic Navies*, New York: Oxford University Press (2012), pp. 3–12 for a brief outline of the views behind these classes, and pp. 251–82 for the surviving literary and epigraphical evidence informing us about the various classes and their performance characteristics. A famous exception is the 'forty' built by Ptolemy IV Philometor (reigned 221–204), whose basic specifications were recorded by Athenaeus (*Deipnosophistae* 5.203e–204b). I have excluded this monstrous vessel, likely built soon after 217, from my list because it was not a functional warship; see Plutarch, *Demetrius*, 43.6 and Murray, *The Age of Titans.*, *op.cit.*, pp. 178–85 and 202–205.

[3] See, for example, Philo of Byzantium, *Siege Warfare*, D 22–23 (attacking harbor barriers), 29 (ramming the city wall); and Arrian, *Anabasis of Alexander*, 2.21.4, 22.6–23.3 (siege machinery on warships).

[4] Morrison J., Coates J. and Rankov B., *The Athenian Trireme. The History and Reconstruction of an Ancient Greek Warship*, 2nd edn, Cambridge: Cambridge University Press (2000), pp. 107–108, 111 (170 man oarcrew on an Athenian 'three' of the fifth and fourth centuries); Polybius, 1.26.7 (300 rowers and 120 marines on a Roman 'five' of the mid-third century). The normal complement of marines on a third-century Roman 'five' was probably less than 120, since the warships Polybius describes in this passage were serving as troop carriers for an invasion of North Africa.

[5] While I characterize the development of catapult technology as 'brisk,' it still took some time for the developments to occur. A recent study of these weapons argues that torsion machines did not quickly replace tension machines (i.e., crossbows of varying size) and, like all new technologies, their designs were perfected over time; see Rihll T., *The Catapult. A History*, Yardley PA: Westholme (2007), pp. 76–90. For the nature of the 'spring cord' or 'sinew cord' (both hair and sinew are attested) imparting the force to a torsion catapult, see Landels J., *Engineering in the Ancient World*, Berkeley: University of California Press (1978), pp. 108–11 and Marsden E., *Greek and Roman Artillery. Historical Development*, Oxford: Oxford University Press (1969), pp. 87–88. For the limitations of weapons fitted with spring cord when used at sea, see Philo, *Belopoeica,* 48 and Murray, *The Age of Titans*, *op cit.*, Appendix F, p. 304.

[6] *Ibid.*, Table 15.1, p. 149.

and toothed firing mechanisms hurled 8.7 to 13.1 kilogram stones (20–30 *minai*) several hundred meters. The largest machine in normal use was more than eight meters tall, seven meters wide, weighed more than 15 tons, and shot 26.2 kilogram stones (60 *minai* or one talent) almost a quarter of a mile.[7] Such a weapon was never taken to sea, although machines one-third to half this size were placed at the entrances to many harbors.[8] Advances can also be seen in other kinds of siege weapons, where teams of engineers perfected new weapons by trial and error and supervised a skilled workforce to build and maintain them. The end result was a period of intense competition, driven by those who felt the new weapons provided them with an advantage over their rivals.

The initial push was provided in 332 by Alexander himself when faced with the need to besiege Tyre, a fortified city built on a small island half a mile off the Phoenician coast. To say Alexander was ready for the attack he unleashed on Tyre is an understatement. His engineers, working from plans they had doubtless prepared for his father Philip II, transformed his fleet at lightning speed, fitting artillery and machinery like battering rams, towers, and assault bridges on the decks of warships and transports. The combination of warships and supporting craft (like freighters and transports of varying sizes) produced what we might call a 'naval siege unit.'[9] Such combinations had been used since the fifth century to attack coastal cities; what was new with Alexander was his placement of land-based siege machinery, like catapults, battering rams, and portable towers, on the decks of his vessels. Then, just as expertly, his men employed these weapons to gain control of the city in about three months after the fleet's transformation.[10] The effect on those present was electric. They saw that by using a naval siege force, it was possible to shorten the siege of a coastal city considerably. Not even an island fortress was exempt. His staff officers were mightily impressed, as we can see by their own adoption of this technology in the years following the great man's death in 323.

Perhaps the most aggressive of those who succeeded Alexander was Demetrius, son of Antigonus 'One Eye.' Demetrius was famous for his personal interest in technology as it applied to weapon systems – the bigger the better, some said.[11] His engineers produced monstrous mobile siege towers, giant covered battering rams, and warships that increased in size from 'sixes' and 'sevens' to an 'eleven,' a 'thirteen,' a 'fifteen,' and finally a 'sixteen' before he died.[12] Although no author describes

[7] According to Josephus, *Jewish Wars*, 5.270, a one-talent catapult could throw its projectile two stades or more, roughly 400 yards (366 meters); see MARSDEN, *Greek and Roman Artillery. Historical Development*, *op. cit.*, p. 90. For the weapon's weight, we can compare the machine built by Carpenter Oak and Woodland (UK) for a 2002 BBC production titled 'Building the Impossible – The Roman War Machine.' The machine weighed 12 tons, and broke after its second shot, presumably because it was underweight; see MURRAY, *The Age of Titans*, *op cit.*, Table 5.1, note 9.

[8] See Philo of Byzantium, *Siege Warfare*, C 56–57.

[9] See MURRAY, *The Age of Titans*, *op cit.*, pp. 132–33 for Philo's understanding of such a force.

[10] *Ibid.*, pp. 95–100.

[11] Plutarch, *Demetrius* 20.1–5, 43.4.

[12] These are the classes for which we possess concrete information. For the evidence, see MURRAY, *The Age of Titans*, *op cit.*, Appendices C and D, pp. 267–82.

precisely how he used ships larger than 'sevens' in battle, he built his 'eleven' and 'thirteen' soon after his failed siege of Rhodes, so they were probably designed to break into harbors as part of his naval siege unit. Despite our ignorance about them, these larger classes must have been effective, for his rivals followed suit and built their own large vessels in response.[13] The same strategic objectives that drove Demetrius also drove the second Ptolemy to build the largest fleet of polyremes ever known, containing multiple numbers in the range of 'fives' to 'thirteens,' a single 'twenty' and two 'thirties,' which probably served as floating siege platforms.[14]

Advances in naval technology and the money to pay for it clearly drove the gigantism we see in the eastern Mediterranean, and when the money ran out, fleets and warships decreased quickly in size, complexity, and in numbers. As this occurred and the pace of new technology slowed a bit, less wealthy powers who relied on smaller warships refined their designs and added galleys like *lemboi*, *hēmioliai*, *triēmioliai*, and *liburnae* to their fleets as support ships. As a group, these ships were classed among the aphract (*aphraktoi*) or non-cataphract galleys, something Latin speakers characterized as *apertae* or 'open.' Already by the late fourth century, such galleys were reinforced with extra planking and used in siege and counter siege operations, or placed between and around larger galleys to discourage attacks on their sides.[15] Some states adapted these smaller designs for specific purposes. The Rhodians, for example, enlarged the *hēmiolia* to produce a smaller version of the trireme, which they called a *triēmiolia* and used for anti-piracy operations.[16] The Roman *liburna* provides another example of such a vessel. This small open galley was often identified with Octavian (the future Augustus), who famously preferred such smaller craft to the larger units in his fleet, presumably for their speed and greater maneuverability.[17]

Other signs of 'cost effective' technology can be seen in a host of economical devices like the famous *corvus* or 'raven' developed by the Romans. This device was essentially a boarding bridge, rigged with line and pulley to an upright pole at the bow and fitted with a long, downward pointing spike on its outboard end. The crew dropped the bridge on the deck of an opponent who approached too closely, and then found himself impaled and unable to back away. By this means, the Romans captured many ships during the early battles of the First Punic

[13] For Lysimachus' 'extraordinary '8,'' named *Leontophoros,* see *ibid*., pp. 171–78.

[14] Athenaeus, *Philosophers' Dinner Party*, 5.203D (5.36.11–21); the monarch was Ptolemy II Philadelphus (reigned 283–246). For an attempt to explain how Ptolemy used his fleet of big ships, see MURRAY, *The Age of Titans*, *op cit.*, pp. 188–200.

[15] During the late fourth century Demetrius used such galleys for his siege of Rhodes (Diodorus Siculus, *Library of History*, 20.85.3); during the following century Philo (*op. cit.,* D 21, 38) advises their use in the naval siege unit; and Philip V deployed a mass of small galleys around and between his 53 cataphracts in the battle line at Chios in 201 (Murray, *The Age of Titans*, *op cit.*, p. 210).

[16] See Casson L., *Ships and Seamanship in the Ancient World*, revised edn, Baltimore: The Johns Hopkins University Press (1995), pp. 129–31.

[17] See Murray W. and Petsas P., 'Octavian's Campsite Memorial for the Actian War', *Transactions of the American Philosophical Society* 79.4 (1989), 143–51 (especially 145 n. 61 and 147 n. 67).

War (264–241).[18] Another device was the 'little ape' or *pithakion*, a weight rigged between two yoked vessels that supposedly increased hull stability when carrying siege machinery.[19] This instability of yoked hulls was a repeated problem for Demetrius in 305 when rough seas and strong winds hindered his use of them at Rhodes.[20] Vessels placed side by side tend to rock in opposite directions as waves pass underneath and this breaks or loosens the fasteners holding the beams laid across the decks of both ships. Those with deep pockets might solve this problem, as did Ptolemy II, by building '20s' and '30s' with double or twin hulls (see below), while those of lesser means might try the *pithakion*. Then we have the braziers of blazing coals that the Rhodians rigged off their bows in 190 to deter frontal attacks by larger warships.[21] If an enemy got too close, a foredeck man unhinged the brazier's bottom, spilling both fire and coals into the enemy's bows.

Cost effective submarine attacks were carried out by divers who slipped in under water to cut a ship's anchor lines or drill through its hull.[22] Measures to stop such attacks involved stationing guards on rafts who tried to spear incoming divers with long tridents.[23] A century and a half later at Sicilian Naulochus (36) the Romans shot grappling hooks called 'grabs' (*harpagones*) at their enemies' topsides and rigging. The hooks were mounted on long poles reinforced with iron bands, which were then attached to lines. After these were shot onto enemy vessels, the Romans pulled the lines to 'set' the hooks, and then dragged their foes alongside for boarding, with the length of the pole and iron bands preventing those struck from cutting the line.[24] And finally, an inexpensive way to elevate one's archers and light arrow-shooting catapults was to place them on collapsible towers that

[18] This device was called a *korax* in Greek and is described in detail by Polybius (1.22.4–11). In general on this device, see Wallinga H., *The Boarding Bridge of the Romans*, Groningen: Wolters (1956); de Souza P., 'Naval Battles and Sieges', in *The Cambridge History of Greek and Roman Warfare. Volume I: Greece, the Hellenistic World and the Rise of Rome*, ed. P. Sabin, H. van Wees and M. Whitby, Cambridge: Cambridge University Press (2007), pp. 434–60, especially pp. 437–9. Polybius specifically mentions its use at Mylae in 260 (1.22.3–9, 23.5–6) and Ecnomus in 256 (1.27.12, 28.11), but it was no doubt used in other battles as well. By the end of the war, the Romans had adopted a lighter, more maneuverable design for their 'fives' that would have been ill-suited for the heavy *korax*; cf. Polybius 1.46.4–47.10, 59.8. Indeed, the *korax* plays no role in the final battle of the First Punic War off the Aegates Islands in 241 (Polybius 1.60–61).

[19] See Lendle O., *Texte und Untersuchungen zum technischen Bereich der antiken Poliorketik*, Wiesbaden: Fritz Steiner, 'Palingenesia' (1983), pp. 156–60 ('Äffchen').

[20] Diodorus, *op. cit*., 20.86.1, 88.7.

[21] For the Rhodian fire pots, see Livy, History of Rome, 37.11.1–15, 30.3–5; Polybius, *Histories* 21.7.1–4; Appian, *Syrian Wars* 24; Walbank F., *A Historical Commentary on Polybius*, vol. 3, Oxford: Oxford University Press, pp. 97–99; Casson, *Ships and Seamanship in the Ancient World*, *op. cit*., p. 123 with n. 93; and de Souza, 'Naval Battles and Sieges', *op. cit*., p. 443.

[22] The Greek verb used to describe this action – *hupodendruazô* (slipping in underneath under cover) – was no doubt coined for land warfare, but was clearly used to describe underwater divers by Philo (*op. cit.*, D 53).

[23] Underwater attacks on anchor lines (Arrian, *op. cit.,* 2.21.6; Philo, *op. cit.,* D 53); attacks on hulls by drilling (Philo, *op. cit.,* D 54); use of men on rafts armed with tridents to defend against such attacks (Philo, *op. cit.,* D 54).

[24] Appian, *Civil Wars*, 5.12.119.

could be erected on one's deck and then broken down or even thrown overboard if flight became necessary.[25] When painted with different colors or some other distinguishing characteristic, these towers also served as a way to distinguish the ships of one fleet from another.[26]

The pace of technology

Before the end of the Peloponnesian War, there were only a few major advances in naval technology worth mentioning. The most important involved the introduction of the waterline ram, which some feel occurred in the third or fourth quarter of the sixth century.[27] This act revolutionized naval warfare by shifting the emphasis from deck fighting – the age-old method of conducting sea fights – to ram strikes delivered by maneuverable galleys that were themselves the primary weapons. Other innovations involved the construction of two and three level galleys, culminating in the introduction of the trireme on a large scale, within a generation after the introduction of the waterline ram.[28] By contrast, the fourth century witnessed the development of polyremes from 'fours' to (at least)

[25] Light deck towers are found on 'fours' and larger classes. We find them on Alexander's ships at Tyre in 332 (Diodorus, *op. cit*., 17.45.2); on Philip's ships at Chios in 201 (Polybius, *op. cit.*, 16.3.7); on a Rhodian ship off Side in 190 (Livy, *op. cit.*, 37.23.4–5); on Roman ships off Mylae (Appian, *Civil Wars*, 5.11.107) and off Naulochus in 36 (Appian, *Civil Wars*, 5.12.121), and at Actium in 31 (Plutarch, *Antonius*, 66.2; Cassius Dio, *Roman History*, 50.23.3, 33.4). We know they were light because at Actium, Antony's men jettisoned their towers into the sea in order to escape (Cassius Dio, *op. cit.*, 50.33.4).

[26] See Appian, *Civil Wars*, 5.12.121.

[27] Most scholars traditionally place the ram's introduction at a relatively early date. Morrison J. and Williams R., *Greek Oared Ships 900–322 B.C.*, Cambridge: Cambridge University Press (1968), p. 7 argue for its depiction on Mycenaean pottery (but see Morrison 1995 below); Van Doorninck F., 'Protogeometric Longships and the Introduction of the Ram', *International Journal of Nautical Archaeology* 11 (1982), 277–86 (esp. p. 283), and Casson, *Ships and Seamanship in the Ancient World*, *op. cit.*, p. 49 believe the ram was introduced during the ninth century; Wallinga H., 'The Ancestry of the Trireme', in *The Age of the Galley. Mediterranean Oared Vessels since pre-classical Times*. ed. J. Morrison, Annapolis: Naval Institute Press, 'Conway's History of the Ship' (1995), p. 36 feels that the ram is clearly seen in Greek vase painting around 750, and that a Bronze Age predecessor is not improbable; and Morrison J., 'The Trireme', in *The Age of the Galley. Mediterranean Oared Vessels since pre-classical Times*, ed. J. Morrison, *op. cit.*, pp. 54–55 argues for a late-eighth-century introduction of the ram at the same time as the first triremes appear. He bases this view on warships depicted on a relief from the palace of Sennacherib showing the evacuation of Tyre by King Luli (= Kuyunjik Relief) in 701. Despite the weight of these opinions, Mark S., 'The Earliest Naval Ram', *International Journal of Nautical Archaeology* 37 (2008), 253–72 argues convincingly for a mid-sixth-century introduction of the waterline ram based upon his definition of the ram as a purposeful offensive weapon. I have followed this view in my remarks.

[28] Wallinga, 'The Ancestry of the Trireme', in *The Age of the Galley*, ed. Morrison, *op. cit.*, p. 36 lists 'four' major innovations between the collapse at the end of the twelfth century and the creation of the Persian 'royal navy' of triremes c. 525: (1) multiple level galleys, (2) the 20-oared galley and 50-oared galley, (3) the introduction of the outrigger frame and rowing bench (*parexeiresia* and *thranos*), and (4) the introduction of the waterline ram.

'thirteens' and all the complex developments accompanying the creation of the naval siege unit[29]. This burst of technological innovation is remarkable and the factors responsible for it deserve some comment.

The most obvious enabling factor was the availability of liquid capital and the will to spend it at effective annual levels for multiple years. The main costs involved the recruitment, hiring and nurturing of skilled engineers. This meant providing them with sufficient resources to build workshops (i.e., laboratories), hire expert riggers (*technitai*), establish smithies and foundries, carry out experiments, make observations, posit new designs, and so forth. Failures had to be encouraged, not just tolerated, while the engineering teams conducted their work.[30] In most cases (but not all – the city of Rhodes offers an obvious exception), we find that the best teams were assembled by single rulers, like Dionysius I of Syracuse (ruled 406–367). Fathers succeeded by sons and even by grandsons – Philip II (359–336) and Alexander the Great (336–23), Antigonus 'One Eye' and Demetrius 'the City Besieger' (combined reigns 306–283), Ptolemy I, II and III (combined reigns 305–222) – produced the most impressive results. Regimes like these had the ability to follow long term policies better than did states run by numerous shifting alliances between elites.

Thus, the engineers of Dionysius I produced the first hand-held catapults and the first 'fives' while those of Philip II produced the first torsion catapults and the first *helepolis*.[31] This last device, a large mobile siege tower, was built by Philip's chief engineer Polyidos for his siege of Byzantium in 340. For a number of reasons, largely involving the king's inability to control the harbor, the siege was a failure and Polyidos must have worked with his colleagues in the years following 340 to analyze the main problems and theorize solutions. Their efforts, which have gone completely unrecorded, explain how Alexander was able to modify his fleet in the field to accept catapults, siege towers and other machinery when he besieged Tyre eight years later in 332.[32] As we have seen, in doing so, he created the first naval siege unit, or collection of ships devoted to siege warfare. Of all the technology monarchs, Demetrius 'the City Besieger' stands as the best example of one who consciously embraced his largest weapons and warships as manifestations of his own persona.[33] It can be no coincidence that his largest ships (his 'eleven,' 'thirteen,' 'fifteen,' and 'sixteen') were built in the years following

[29] By the turn of the century, the largest class for which we have evidence is a 'thirteen' retrieved by Demetrius from Athens shortly after the battle of Ipsus in 301; see Plutarch, *Demetrius*, 31.1–3. For the ancient evidence behind our knowledge of these classes and their capabilities, see Murray, *The Age of Titans.*, *op. cit.*, Appendices A–D, pp. 251–82.

[30] On the time required to perfect new technologies see, for example, Rihll, *The Catapult*, *op. cit.*, p. 80.

[31] Although we possess no direct evidence that Philip II produced the first torsion catapults, this statement represents a reasonable guess based on available evidence. See now Rihll, *The Catapult*, *op. cit.*, pp. 76–90.

[32] See Murray W., 'The Development of a Naval Siege Unit Under Philip II and Alexander III', in *Macedonian Legacies. Studies in Ancient Macedonian History and Culture in Honor of Eugene N. Borza*, ed. T. Howe and J. Reames, Claremont, CA: Regina (2008), pp. 31–55.

[33] Plutarch, *Demetrius*, 20.1–5 and 43.3–4; see Murray, *The Age of Titans*, *op cit.*, pp. 106–107 for the *helepolis*, and 125–28 for Demetrius' 'fifteen' and 'sixteen.'

his failure to take the harbor at Rhodes in 305, which must have produced the same soul-searching as had Philip's failure at Byzantium 35 years earlier.[34]

I have already observed that advanced technology was not acquired or realized quickly. It took years to gather the experts, to refine the weapons, and to train men to use them. This was even true once the technology was generally known. As described above, Alexander's genius at Tyre required eight years of background work and training. By contrast, Antigonus 'One Eye's' siege of the same city in 314 took 15 months because he had no fleet and because he had not maintained a suitable team of engineers.[35] Not until his son Demetrius oversaw the creation of a proper corps of engineers do we find the regime efficiently gaining cities through siege warfare, as they did when Demetrius besieged Cyprian Salamis in 306. The decisive sea battle fought off this city in that year was, in fact, a failed attempt by Ptolemy to break Demetrius' siege.[36]

Although it took years for a ruler or state to gain results from their military engineers, the pace of development increased once an engineering team reached a certain level of accomplishment. And this level was reached more quickly when a state of war or hostility persisted for a long period of time. Such conditions allowed for the employer (and his engineers) to gauge the results of new weapons in the field and to make adjustments when they failed to produce the desired outcome. Not surprisingly, a key factor in driving the pace of technology in the late fifth and fourth centuries was the growing importance of siege and counter-siege warfare. Repeated attacks by Carthaginian siege armies between 409 and 405 left the Sicilian cities of Selinus, Himera, Akragas and others in ruins. This, in turn, led to the first Sicilian hand-held artillery and larger-than-normal warships in the hope of countering the enemy's siegecraft expertise.[37] In the eastern Mediterranean, both Philip II and his son Alexander III relied on sieges of coastal cities to increase the lands they controlled: Olynthus (346); Perinthus, Selymbria, and Byzantium (340); Miletus and Halicarnassus (334); and Tyre and Gaza (332).[38]

As we have seen, naval technology developed at an astonishing pace in the generation following Alexander. There were good reasons for this. The wars waged between Alexander's successors (*Diadochoi*) and their offspring (*Epigonoi*) focused on controlling coastal cities through conquest and defense. Warships accordingly grew in size and complexity well beyond 'fives.' A similar trend can be seen in the refinement of mobile siege towers, landing bridges, covered battering

[34] For the dates of Demetrius' various ship classes, see Murray, *The Age of Titans*, *op cit.*, pp. 126–27.

[35] Diodorus, *op. cit.*, 19.61.5: the siege of Tyre lasted 'a year and three months.'

[36] See Murray, *The Age of Titans*, *op cit.*, pp. 105–111.

[37] Diodorus, *op. cit.*, describes in some detail the fighting at Selinus (13.55–57), Himera (13.59.4–61.6), Akragas (13.85–90), Gela (13.109–111.2), and the hurried evacuation of Camarina (13.111.3–6). For the chronology of these events and their effects on Dionysius' new weapon systems, see Murray, *The Age of Titans*, *op cit.*, pp. 24–25, 80–84.

[38] For these sieges and the sources informing us about them, see Murray, *The Age of Titans*, *op cit.*, pp. 85–100. Although not technically a coastal city with a harbor open to attack, Gaza's position on the coast allowed it to be attacked indirectly by Alexander's naval siege unit, which brought in the siege machinery.

rams, protective coverings, floating harbor barriers, and the designs of city walls and harbor entrances. There was plenty of money, as each side dedicated tax revenues and treasure, secured by Alexander's conquests, to pay the hefty price tags associated with such offensive and defensive hardware.[39]

We should also not underestimate the impact on technological advancement caused by the prolonged period of conflict among Alexander's successors. The endless wars between the families of Antigonus, Ptolemy and Seleucus provided jobs for generations of engineers (*mēchanikoi*) and weapons manufacturers (*architektones* and *technitai*), who designed, built and maintained the new siege machinery and high-end warships. For example, Philip's engineer Polyidos had at least two pupils, Diades and Charias, both of whom continued their service with Alexander. Engineers like these, or like Philo 'the Byzantine' worked for various employers, conducting experiments and overseeing teams of skilled craftsmen (*technitai*), who in turn passed their knowledge to their own apprentices.[40] Like the engineers and master craftsmen (*architektones*) who headed the workshops, these craftsmen could also have reputations for excellence if we may judge from an event during Demetrius' year-long siege of Rhodes in 305. A Rhodian commander named Amyntas captured some freighters bound for Demetrius' camp, on board which were 11 *technitai* 'worthy of note' who were coming to join the besieger's engineering team.[41]

Working together, these skilled teams designed and built many new fortifications in the years just before and after Demetrius' famous siege at Rhodes. They carefully positioned artillery towers to provide overlapping fire along both landward and seaward approaches to city gates and weak sectors of the walls. They strung floating barriers called *kleithra* across harbor entrances which they flanked with towers armed with 20 and 30 mina catapults to hinder the attacks of an enemy's naval siege unit.[42] Other engineers and specialized craftsmen designed, built and maintained the heavy warships that carried out such attacks. These galleys reached sizes we can barely imagine, and were fitted with heavy bronze rams that weighed multiple tons and were cast to exacting standards.[43]

[39] When he besieged Tyre in 314, Antigonus 'One Eye' had at his disposal some 35,000 talents he had collected from various royal treasuries (Diodorus, *op. cit.*, 19.48.7), plus 11,000 talents in annual revenues (Diodorus, *op. cit.*, 19.56.4–5).

[40] On Philo, see Murray, *The Age of Titans, op cit.*, pp. 129–31, with references.

[41] Diodorus, *op. cit.*, 20.93.5.

[42] For the placement of *kleithra* and 20 and 30 mina artillery towers at harbor entrances, see Philo, *op. cit.,* C 52, 56–57. A 30 mina catapult projected a stone ball that weighed 30 minai (roughly 17.1kg). Surviving stone catapult shot with their weight values inscribed on them demonstrate that a mina roughly equals a pound; see Marsden, *Greek and Roman Artillery. Historical Development*, *op. cit.*, p. xix, who follows the calculations of Hultsch F., *Griechische und Römische Metrologie*, 2nd edn, Berlin: Weidmannschen Buchhandlung (1882), p. 138 that an Attic 'Solonian' mina = 436.6 grams, which equals 0.96 pound (US/British).

[43] For the exacting standards exhibited by the casting of the 465 kilogram Athlit ram, see Murray, *The Age of Titans*, *op cit.*, pp. 35–38; and Oron A., 'The Athlit Ram Bronze Casting Reconsidered: Scientific and Technical Re-examination', in *Journal of Archaeological Science* 33 (2006), 63–76. The largest rams displayed on Augustus' Victory Monument at Nikopolis (the rams were taken from Antony's and Cleopatra's largest warships, i.e., 'tens') were many times more massive than the half-ton Athlit ram; see *ibid.*, pp. 38–47.

The largest ships had double or perhaps twin hulls, were rowed by thousands of oarsmen and sported wide decks for carrying siege towers, batteries of catapults, landing bridges, battering rams, troops of marines, javelineers, slingers and archers.[44]

The high cost of naval technology

The expenses involved in building and maintaining such high-tech forces were astronomical because they included not only the large polyremes, but also the smaller craft that protected and supported the core of the siege unit. Ptolemy II's fleet during the mid-third century was the largest ever built, including 224 ships larger than 'threes,' with many multiples of the larger polyremes. Uncounted among this total were more than 4,000 vessels of smaller sizes used for various purposes throughout the Ptolemaic empire.[45] This number is so huge that it is difficult to interpret satisfactorily. Precisely how many men were required to run such a fleet we will never know, but the totals must have been staggering.[46] And when the costs finally became unsustainable during the latter half of the third century, this elaborate fleet disappeared from sight.

By comparison, the naval siege units brought by Mithridates VI to Rhodes in 88 and to Cyzicus in 74 were meager. By this time, a credible siege force consisted of a few 'fives' (one served as his flagship), a large number of 'threes,' merchant ships and smaller craft like *hēmioliai*.[47] At Rhodes, Mithridates attempted to scale the harbor walls by means of a large *sambukē* or scaling ladder mounted on a pair of warships, but it collapsed before achieving its purpose. When he attacked Cyzicus fourteen years later, he brought a large siege tower with a retractable landing bridge up to the wall on a pair of yoked 'fives,' but the defenders poured burning pitch on the ships and forced them to withdraw.[48] Long gone were the days of Demetrius, when he advanced four pairs of yoked freighters against the harbor defenses of Rhodes (305) and, when these efforts failed, took a week-long break to repair these machines and

[44] A double hull involves two separate hulls connected by a deck, like a modern catamaran. A twin hull involves a single hull with two parallel keels. Many questions regarding the oar system and hull configuration of these largest polyremes remain unresolved; see Murray, *The Age of Titans*, *op cit.*, pp. 171–207; Sleeswyk A. and Meijer F., 'Launching Philopator's "Forty"', *International Journal of Nautical Archaeology* 23 (1994), 115–18; and Sleeswyk A. and Meijer F., 'Quantitative Analysis of the Oarage of Philopator's "Forty"', *Mnemosyne* 50 (1996), 185–98.

[45] Athenaeus, *op. cit.*, 5.203D; the total of 'fives' in Ptolemy's fleet was only 17, which seems too low for a class that served as the standard warship at this time. Perhaps 'fives' were among the 4,000 'other ships' mentioned by Athenaeus in this quotation; see Grainger's observation in Murray, *The Age of Titans*, *op cit.*, p. 188 n. 51.

[46] See Murray, *The Age of Titans*, *op cit.*, pp. 189–90.

[47] Appian, *Mithridatic Wars*, 4.25 (Mithridates' 'five'); 4.25–26 ('threes' and merchantmen); a *hēmiolia* appears in Mithridates' fleet in 87 (Appian, *Mithridatic Wars*, 5.29).

[48] See Appian, *Mithridatic Wars*, 4.24–27 (siege of Rhodes) and 11.73–75 (siege of Cyzicus).

build another floating siege tower 'three times the size of the former in height and breadth'.[49] And this was before the big ship mania reached its peak under Ptolemy II Philadelphus (reigned 283–246).

In the western Mediterranean, Romans and Carthaginians generally avoided ships larger than 'sixes.'[50] This is not to say they scrimped, if we are to believe the numbers of 'fives' they built during the First Punic War. According to Polybius, the Romans and Carthaginians lost over 1,200 'fives' during twenty-three years of the First Punic War (264–241) alone, which is a considerable number by any reckoning.[51] Toward the end of the war, however, both sides struggled to build and man their fleets, as is made clear by the war's concluding battle off the Aegates Islands in 241. Two years earlier, their treasury bare, the Romans had financed their fleet of 200 warships by relying on loans from private citizens.[52] The sudden appearance in Sicily of a new Roman fleet surprised the Carthaginians who, never expecting the Romans to fight for control of the seas, had neglected their naval forces. After the fleet's arrival in the summer of 242, it took the Carthaginians nine months to respond with a fleet of their own.[53] The force they sent out in spring 241 contained Roman ships captured at Drepanum in 249, and was manned by hastily gathered, untrained crews.[54] Obviously, there were limits to the budgets of both sides.

As just stated, the Romans resisted the lure of polyremes bigger than 'sixes,' and built only a few of these, which served as flagships. They preferred instead to rely mainly on 'threes,' 'fours' and 'fives,' and when engaged in naval siege warfare, pressed their 'fives' into service, lashing them together to serve as suitable bases for catapults and siege ladders (*sambukai*).[55] And then, once the need for a navy had passed, the Romans laid up their fleet, only to find, when the

[49] Diodorus, *op. cit.*, 20.88.7.

[50] The Carthaginians apparently used at least one 'seven,' which they had captured from Pyrrhus (perhaps in 276 when Pyrrhus left Sicily), and then lost to the Romans at Mylae in 260. See Polybius, *op. cit.*, 1.23.1–10 and Plutarch, *Pyrrhus*, 24.1.

[51] Polybius, *op. cit.*, 1.63.4–9. The Romans lost 700 ships, the Carthaginians 500.

[52] Polybius, *op. cit.*, 1.59.1, 6–8.

[53] Polybius, *op. cit.*,1.59.8 says the Romans dispatched their fleet in 242 'at the beginning of summer,' perhaps June; Eutropius, *Short History of Rome*, 2.27 gives the date of the battle as March 10, 241.

[54] Polybius, *op. cit.*,1.61.5. For the Roman ships captured at Drepanum in 249 and then sent back to Carthage, see *ibid.*, 1.51.12 and 53.1. At least 7 Roman ship rams (out of a total of 11 found so far) were found among a scatter of amphoras in a debris field marking the battle zone off Levanzo Island (in the modern Egadi group). Lying together, the rams and amphoras came from the same ships, which must have belonged to the heavily laden Carthaginian fleet. For the discoveries by the Egadi Islands Survey up through 2012, see Tusa S. and Royal J., 'The landscape of the naval battle at the Egadi Islands (241 B.C.)', *Journal of Roman Archaeology* 25 (2012), 7–48.

[55] One can see this clearly in Rome's sieges of Syracuse in 213, New Carthage in 210, and Utica in 204; see Murray, *The Age of Titans*, *op cit.*, pp. 228–232.

next crisis called for naval action, that many of their ships were unserviceable.[56] Their lack of concern for a standing navy contrasts sharply with fourth-century Athens, who chose to maintain hundreds of warships along with their gear when she could barely afford to send them out.[57]

Many years later, during the Actian War between Antony and Octavian, we encounter the last fleet with a credible naval siege unit of mid-sized polyremes. It occurred in 32, when Antony and Cleopatra VII brought to Greece a large invasion force to wrest control of Italy from Octavian and his supporters. With his fleet of 500 'fighting ships' , Antony brought multiple numbers of 'sevens,' 'eights,' 'nines,' and 'tens,' to secure access to heavily fortified ports like Tarentum and Brundisium.[58] Octavian's admiral Agrippa saw to it that Antony's force never made it out of Greece, so we will never know if his strategy would have worked. What happened instead was the defeat of Antony's armada and the death of the polyreme siege unit. Never again would collections of polyremes be built to attack coastal cities, as Augustus now controlled the Mediterranean and had no need for such expensive weapon systems. Consequently, he decommissioned Antony's largest ships and cut the size of his fleet to the bone.

Conclusions

Naval warfare of all periods involves a degree of technology because of the warships themselves, which are carefully engineered machines. So long as the vessels were simply floating platforms for infantry contests, technological advances were small. Such a condition prevailed for thousands of years from the Bronze Age to the sixth century. At this time, the introduction of the waterline ram transformed warships into primary weapons and, thereafter, technological innovation began to affect the outcomes of battles much more than before. Now a vessel's speed, responsiveness, maneuverability and ramming performance determined the outcomes of battles, as did the skill of its oarcrew in executing coordinated maneuvers. A well-built warship in the hands of a skilled crew was

[56] It seems that no ships were added to the Roman fleet between the end of the First Punic War (241) and the beginning of the Second (218), when the Romans had roughly 220 'fives' and 20 light craft (Livy, *op. cit.*, 21.17.2 calls them *celoces*); see Thiel J., *Studies on the History of Roman Sea-Power in Republican Times,* Amsterdam: New Holland Publishing Company (1946), p. 35 n. 11. See also Casson L., *The Ancient Mariners. Seafarers and Sea Fighters of the Mediterranean in Ancient Times,* 2nd edn, Princeton: Princeton University Press (1991), p. 151: 'In 201 B.C., the nation that sixty years earlier had no fleet of its own was the greatest sea power in the Mediterranean. There were two hundred galleys in its slips.... A century later it was still the greatest power in the Mediterranean – but it had hardly a ship to its name.'

[57] Is it a coincidence that remains of numerous shipsheds still survive in the overbuilt modern harbors of Athens, while at Rome, we have yet to securely identify their *navalia* (shipshed complex) along the Tiber? See Rankov B., 'Roman Shipsheds', in Blackman D. and Rankov B., *Shipsheds of the Ancient Mediterranean*, Cambridge: Cambridge University Press (2013), especially pp. 47–50.

[58] Plutarch, *Antonius*, 61.1; Murray, *The Age of Titans*, *op cit.*, pp. 242–244.

a formidable weapon, particularly when it operated in coordination with other well-handled warships of similar design and performance. During the fourth century, when warships larger than 'threes' were designed to achieve new strategic objectives, the pace of technological innovation quickened, and then reached a crescendo during the centuries following Alexander's conquests.

What makes the Hellenistic period different from preceding ages is the degree to which warships became more and more elaborate, with complex rowing systems, and corresponding increases in hull dimensions, weight, ship structure and crew sizes. These increases in scale and complexity cost more money, required more maintenance, and demanded additional specialist training for those who worked the catapults, erected the fighting towers, or deployed the landing bridges. Fleets were now comprised of a large mix of galleys, some optimized for maneuver-and-ram warfare, others for frontal ramming, and others to serve as floating siege platforms. The early Hellenistic fleets of Demetrius and Ptolemy II Philadelphus were more complex, more versatile, more difficult to maintain, and much more expensive than the trireme fleets that fought off Salamis in 480.

Changes in the nature of naval warfare during the late fourth and early third centuries were driven by a new set of strategic objectives that all the major naval powers pursued: the capture and defense of coastal cities. What was once thought beyond the capability of a fleet, was now made possible by large sums of money, by the intensity of royal rivalries, by the long period over which these rivalries continued, and by the expert engineers and riggers who designed, built and maintained the weapon systems that were used. Although not everyone participated in the move toward increased complexity and gigantism, these trends affected all serious naval powers until the second century.

In the centuries that followed, less expensive forms of naval power were pursued, although they emerged again during the last phase of the Roman Civil wars when Agrippa built 'larger' and 'heavier' ships to defeat Sextus Pompey in 37, and when Antony brought a naval siege unit with him for his attack on Italy in 32. After the defeat of Antony and Cleopatra the following year at Actium, and their deaths a year later, Augustus found himself in control of the Mediterranean Sea. Thereafter, he seriously downsized his fleet, decommissioned the larger polyremes captured from Antony, and ushered in a new age of Mediterranean naval history with smaller fleets, smaller ships and much less costly weapon systems. The Hellenistic love affair with naval technology had run its course.