WARSHIPS OF THE FIRST PUNIC WAR: AN ARCHAEOLOGICAL INVESTIGATION AND CONTRIBUTORY RECONSTRUCTION OF THE EGADI 10 WARSHIP FROM THE BATTLE OF THE EGADI ISLANDS (241 B.C.)

by

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April, 2016

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Oared warships dominated the Mediterranean from the Bronze Age down to the development of cannon. Purpose-built warships were specifically designed to withstand the stresses of ramming tactics and high intensity impacts. Propelled by the oars of skilled rowing crews, squadrons of these ships could work in unison to outmaneuver and attack enemy ships. In 241 B.C. off the northwestern coast of Sicily, a Roman fleet of fast ramming warships intercepted a Carthaginian warship convoy attempting to relieve Hamilcar Barca’s besieged troops atop Mount Eryx (modern day Erice). The ensuing naval battle led to the ultimate defeat of the Carthaginian forces and an end to the First Punic War (264–241 B.C.). Over the course of the past 12 years, the Egadi Islands Archaeological Site has been under investigation producing new insights into the warships that once patrolled the wine dark sea. The ongoing archaeological investigation has located Carthaginian helmets, hundreds of amphora, and 11 rams that sank during the course of the battle. This research uses the recovered Egadi 10 ram to attempt a conjectural reconstruction of a warship that took part in the battle. It analyzes historical accounts of naval engagements during the First Punic War in order to produce a narrative of warship innovation throughout the course of the war. It employs experimental three-dimensional

reconstructions in the Rhinoceros and Orca 3D software based on archaeological evidence in order to determine basic hull dimensions and fundamental characteristics of the Egadi 10 warship's design. Finally, it compares the resulting reconstruction to Polybius' accounts of the warships that sank at the site.

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Chapter 1: Introduction

Oared warships dominated the Mediterranean from the Bronze Age to the development of cannon. The construction of purpose–built warships meant that they were specifically designed to withstand the stresses of ramming tactics and high intensity impacts. Propelled by the oars of skilled rowing crews, squadrons of these ships could work in unison to outmaneuver and attack enemy ships. Oared warships stopped the advancing armies of Xerxes at the Battle of Salamis (480 B.C.), defeated the Carthaginians (in the Punic Wars), and allowed Octavian to transform Rome into an empire after the Battle of Actium (31 B.C.). While these ships played pivotal roles throughout the Mediterranean basin, their construction, development, and classification systems still remain shrouded in uncertainty.

Fortunately, recent archaeological work is helping to change this picture. The ongoing excavations at the Egadi Islands conducted through the combined efforts of the RPM Nautical Foundation, a U.S. based non-profit archaeological research organization, and *Soprintendenza del Mare* (Sicily, Italy), the cultural authority tasked with the management of Sicily's submerged cultural heritage, have located eleven rams from the Battle of the Egadi Islands (241 B.C.) to date. The mid-3rd century B.C. Egadi rams have revealed a wealth of new information about three-finned rams, which in turn have the potential to yield new insights into warship construction.

This thesis seeks to partially reconstruct the basic design of the Egadi 10 warship (Figure 1), in order to provide a new interpretation of the warships that sank during the Battle of the Egadi Islands. The Egadi 10 ram, nicknamed Hamilcar Barca, was excavated by the RPM Nautical Foundation during the 2014 summer field season of the Battle of the Egadi Islands Archaeological Site. Using Rhinoceros and Orca 3D software, this study will employ experimental three-dimensional reconstructions based on archaeological evidence in order to determine basic hull dimensions and fundamental characteristics of the Egadi 10 warship design during the First Punic War (264–241 B.C.). This study will also analyze various naval engagements during the First Punic War through historical accounts, in order to gain a better understanding of warship evolution during the First Punic War. It will conclude with a comparison of the resulting reconstruction and the accounts of Polybius of the warships that sank at the Egadi Islands site.

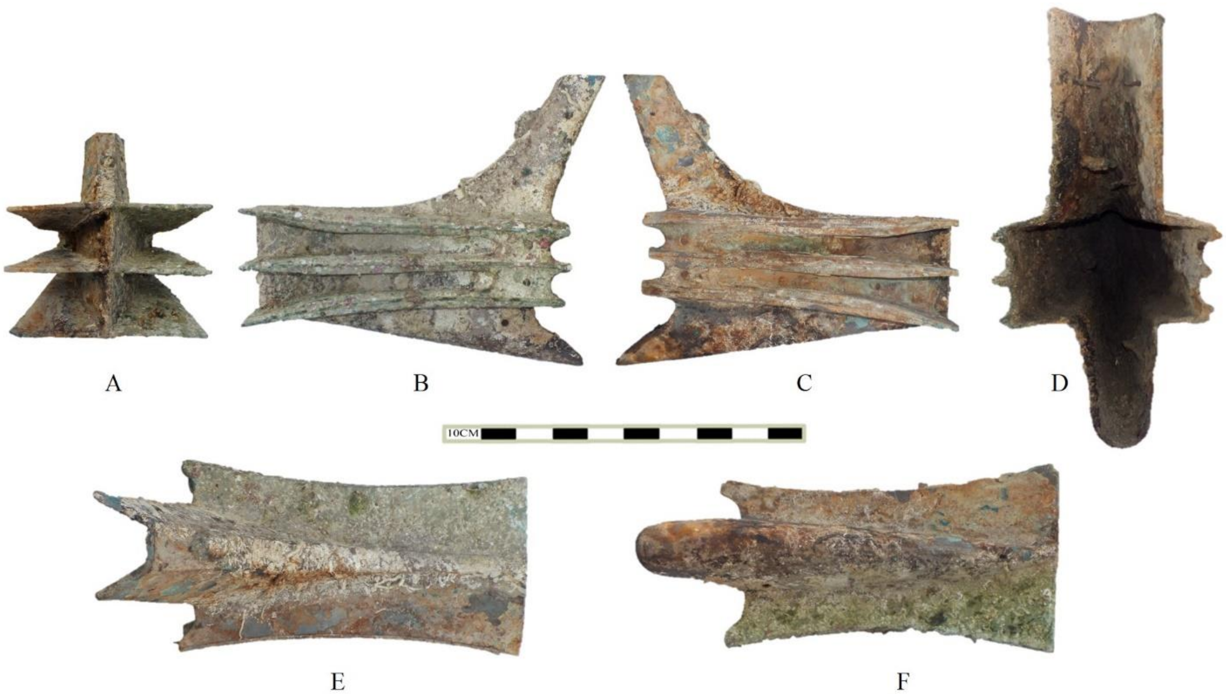

FIGURE 1. The Egadi 10 Ram (*a*) Front (*b* Port side (*c*) Starboard side (*d*) Interior looking aft (*e*) Top (*f*) Bottom (Image by author, 2016)

The original Egadi 10 warship represented the functional execution of the most advanced naval tactics employed in the western Mediterranean during the 3rd century B.C. It began as a cognitive process within the mind of the shipwright. It began to take shape as the shipwright and the shipyard crews fabricated raw materials into the various pieces of the ship. Once assembled, the ship was crewed by oarsmen and commanding officers, trained to utilize the ramming vessel to its full potential (Steffy 1994:5). A reconstruction is incomplete unless it produces a link to analyze the society that built, operated, and utilized the ship and must, therefore, be studied through a context of interrelated constraints that continuously influenced the construction and operation of this warship.

Research Questions

The intended goal of this thesis is to answer questions pertaining to the theoretical and physical reconstructions of a Roman warship sunk during the Battle of the Egadi Islands in 241 B.C. Specifically:

- How much of a warship structure can be reasonably reconstructed using the available archaeological evidence?
- What does this reconstruction reveal about the potential classification and capacity of the warships?
- How does the reconstruction relate to Polybius' statements about the ships that took part in the Battle of the Egadi Islands?

The three-dimensional structural design was created using data compiled from archaeological sources in order to produce a potential shape and size of a warship that took part in the Battle of the Egadi Islands. Combining various archaeological resources and the trials of the *Olympias* trireme replica (Morrison, Rankov, and Coates 2012) allowed for the extrapolation of average scantling dimensions. Dimensions of the keel, ramming timber, stem, and wales were generated from direct measurements of the Egadi 10 ram. The overall size of the vessel was constrained to the sizes of ancient Mediterranean shipsheds, especially those found at Carthage. Average scantling dimensions were projected based on ratios of ships with similar sizes. The analysis of historical evidence, provided by the accounts of ancient authors, will examine the evolution of warships over the course of the First Punic War. Texts relating to warship construction will also be analyzed for supplementary evidence to assist in the reconstruction effort.

Evidence of the Oared Warship

The warships that took part in the Battle of the Egadi Islands were oared vessels, built using shell-based construction techniques, and specifically designed for ramming. While these ships played pivotal rolls throughout the Mediterranean basin, their construction, development, and classification systems still remain shrouded in uncertainty. Although little direct archaeological evidence for hull structure is available, using contemporary evidence from merchant vessels, it is understood that these ships utilized shell-based construction. Planking was fastened directly to the keel and joined edge-to-edge along the entire hull with mortise-and-tenon joints. Floor timbers and futtocks alternating with pairs of half frames provided additional structural support. These warships were built with a specially designed bow, structurally including the keel, wales, stem, and a specifically designed ramming timber that allowed these vessels to actively engage in ramming warfare.

Historical accounts and iconography provide a multitude of vague descriptions and images that depict various warships from different eras. Warships are described in historical accounts ranging from Thucydides to Virgil. Warship iconography dating to the 3rd century B.C. decorates Carthaginian tombs, pottery, and Roman coinage (Figure 2) (Casson 1978; Morrison 1995). Shipsheds found around the Mediterranean provide insight on the lengths and breadths of the hulls they once housed. The most substantial archaeological evidence comes from the Athlit ram found off the coast of Israel (Casson and Steffy 1991), the Acqualadroni ram (Buccellato and Tusa 2013) found near the Straight of Messina, and the recent finds from the Egadi Islands (Tusa and Royal 2012).

FIGURE 2. Carthaginian tomb relief ca. 3rd century B.C. (Morrison 1995:68)

Currently there are no extensive surviving examples of warship hulls. The best evidence of warship construction remains the timbers found in the Athlit Ram (Steffy 1981). In recent years there have been many new studies published in regards to Mediterranean warships thanks to the context and identification of the Egadi rams. Studies of Octavian's Actium Monument (Murray 2012) and various shipsheds from around the Mediterranean (Blackmann 2010) are able to provide better interpretations thanks to the Egadi Island Battle Site. These sources represent the best archaeological evidence for ancient Mediterranean warships to date.

It is also difficult to determine the differences between warship classifications. This study presupposed that warship classification was directly linked to the amount of rowers per rowing station. Meaning a *trireme* (three) had three rowers per side per oar bank, a *quadreme* (four) had four, and a *quinquereme* (five) had five. Although this classification of ships is still highly debated, it is currently the best evidence of differentiating the classes of warships described in historical texts.

Ramming Warfare

The use of ramming signaled a shift in the tactics of naval warfare, from the ship as a form of transport and a fighting platform to the ship as a weapon. The goal of ramming a ship was to penetrate or spring the timbers of the enemy vessel, allowing water to seep in and swamp the hull (Morrison 1996:222). Rams placed at the waterline, delivered devastating damage by punching holes at or below the waterlines of enemy ships. Stricken vessels would become difficult to maneuver and rendered unusable as their hulls took on water.

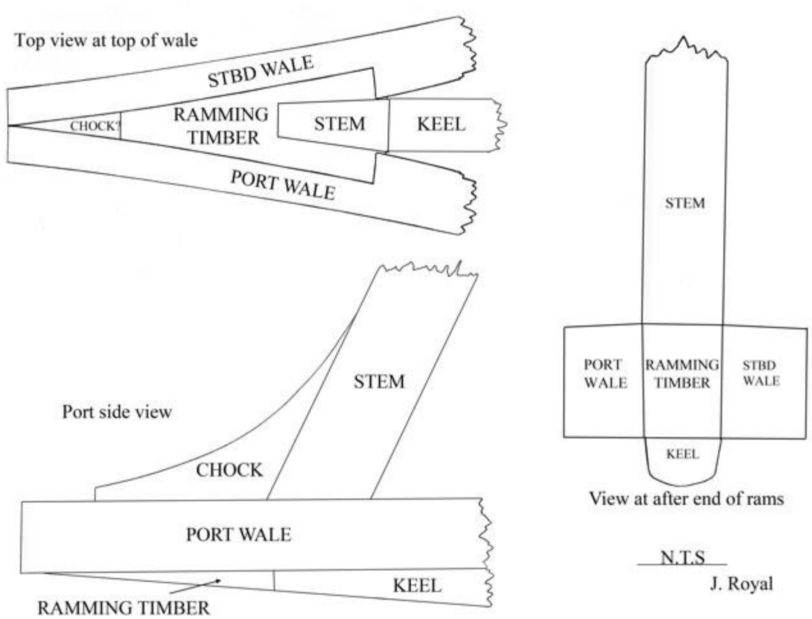

FIGURE 3. Interior bow timber arrangement (Courtesy of Dr. Jeffrey Royal, 2012)

A heavily constructed bow and large support timbers were essential to deflect the force of impact throughout the ship (Figure 3) (Morrison 1996:359). Without heavy timbers acting to longitudinally reinforce these warships, a ramming blow could shatter both the target and the attacking ship. The force of impact was dispersed by these heavy timbers as far back as possible to prevent damage to the attacking ship (Pitassi 2011:39). Large timbers were concentrated both within and surrounding the ram to aid in force dispersal (Casson and Steffy 1991:38).

The specific design of the ram was important for its success. The Egadi rams, were designed with horizontal blades on a vertical spine (Casson and Steffy 1991:68). The impacting piece was not pointed but rather flat-headed so that it did not become lodged in the enemy vessel (Figure 4). If the ram became stuck, it might cause the attacking ship to sink with the swamped enemy vessel (Morrison 1996:363–368). Enemies could also board the trapped ship or the ram could twist off and damage the attacking ship, as noted by Herodotus at the battle of Alalia in ca. 540 B.C. (Casson and Steffy 1991:78).

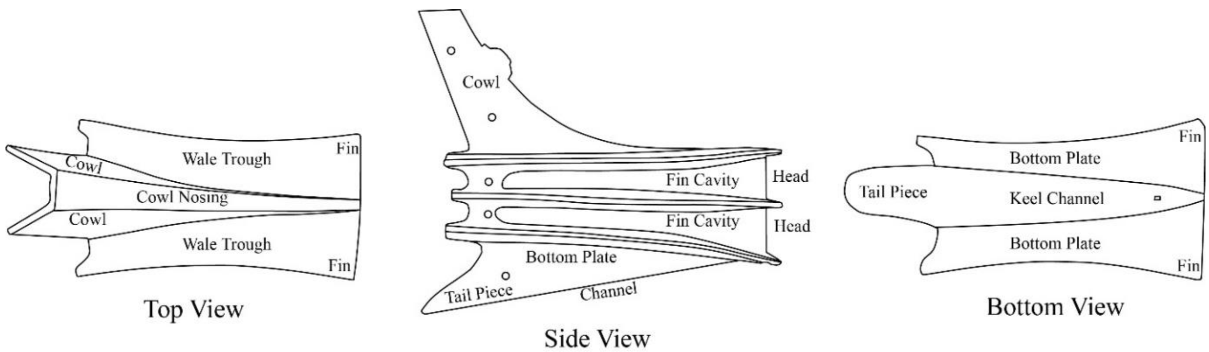

FIGURE 4. Schematic of Egadi 10 Ram terminology (Drawing by author, 2016)

Speed and maneuverability were critical assets of these warships. After ramming, the vessels needed to withdraw quickly to avoid endangering themselves (Morrison 1996:363–368). The ideal area to ram was the broadside or in the stern of the enemy ship (Casson and Steffy 1991:79). Although charging an opposing vessel head on is considered dangerous (Morrison 1996: 361) the Egadi rams show evidence of direct head on collisions (Figure 5). An attacking vessel in some instances would also bring their oars in and approach along the side of the enemy vessel to break off the oars and render the enemy vessel immobile.

Warships used their bulk, momentum, and weight as a weapon; the ship in its entirety became a guided missile, with the ram serving to concentrate the force of the impact. Much like a spear or a battering ram, the combination of a curved surface and sharp angles allowed the momentum of the ship to be concentrated into the small striking surface of the ram (Casson and Steffy 1991:37).

FIGURE 5. Egadi ram 3 and 4 showing evidence of head on collisions (Courtesy of Dr. Jeffrey Royal, 2012)

Ship Reconstruction Theory

For a reconstruction to be justified it must produce a finite series of interpretations judged by the standards of their prevailing contemporary shipbuilding techniques (Crumlin-Pederson and McGrail 2006:57). In order for the partial reconstruction of the Egadi 10 to provide worthwhile data and new insights into aspects of the ships that sank at the Egadi Islands, it was developed within a framework of explicit conceptual and technological ideas. A detailed framework of methodological considerations and theoretical constraints insured the greatest amount of accuracy possible. This section analyzes the theoretical concepts and provide the context which framed the partial reconstruction of the Egadi 10 warship.

Capital versus Contributory Reconstruction

Ship reconstruction is an experimental process requiring research and interpretation that attempts to understand the original shipbuilding process, the shape and construction of the hull, and the ways in which the ship was utilized. There are various forms and levels of ship reconstruction ranging from lines and construction drawings, three-dimensional models, all the way to full-scale replicas. Capital and contributory reconstruction were two general categories developed by J. Richard Steffy (1994:214–221) to define and distinguish reconstructions based on the amount of surviving archaeological evidence. Capital reconstructions include detailed lines drawings, construction plans, and models based on a substantial amount of archaeological remains. Contributory reconstructions supply new information and interpretation of hull remains that are too degraded or scarce to conclusively define the original construction of the hull (Steffy 1994:215). By this definition, the Egadi 10 reconstruction is a contributory reconstruction. A full reconstruction would require extensive portions of an intact hull. While the Egadi 10 ram in conjunction with additional archaeological evidence can provide an interpretation of the hull, it is not enough to convincingly present the hull as it once was. While there is not enough direct evidence to produce a complete reconstruction, the use of three-dimensional modeling software and the comparative evidence from the discovery of eleven rams since 2005 allowed for a basic hull design that was used to calculate hull properties such as weight, displacement, and crew capacities. There is no claim that the current reconstruction attempt represents the Egadi 10 warship with complete accuracy. Instead, this contributory reconstruction should be viewed as a vehicle for exploring questions regarding ancient warship size and shape, and as a hypothesis to be tested against future archaeological evidence.

The Egadi 10 Warship as Material Culture

The shipwrights (*faber navalis*) constructed the Egadi 10 within a framework of technological limitations and ideological expectations. Unfortunately, although the conceptual framework of shell-based mortise-and-tenon construction is known its direct application in warship construction is not. This major gap required the development of a framework by Adams (2001) that defined the limitations constraining the construction of a vessel by using supplementary data.

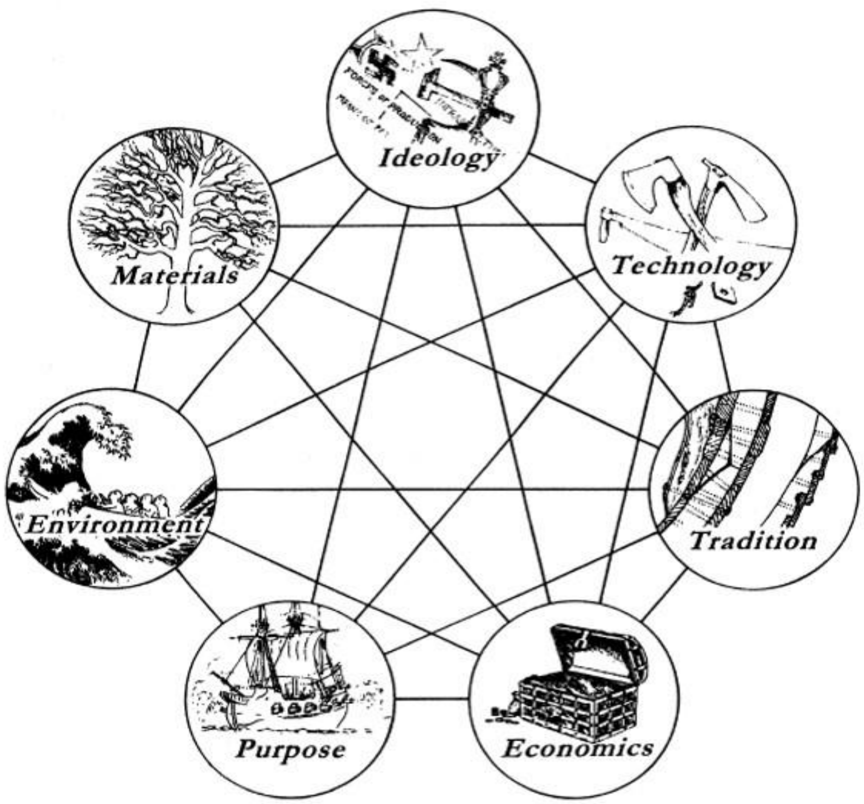

FIGURE 6. Interrelated constraints on the form, structural characteristics, appearance and use of watercraft. (Adams 2001:301)

The archaeological interpretation of the Egadi 10 ram needed to go beyond the physical reconstruction of an object in order to analyze the vessel as the product of a cultural ideal (Steffy 1994:5–6). Using this process, this thesis examined themes including ship classifications, tactics, rates of construction, and rower capacities. The ship that once held the Egadi 10 ram was a purpose-built warship constructed within a series of functional, technical, social, economic, and environmental constraints (Figure 6). The Egadi 10 ship was the manifestation of the specific need to build an effective and menacing warship within a series of physical and metaphysical constraints. While each aspect could be analyzed individually, these categories represent a dynamic network that served to shape the conditions from which the Egadi 10 vessel was produced (Adams 2001:300). The analysis of each of these broad components provided important insight that helped to define and guide the reconstruction process.

Purpose

While many ships served a variety of purposes, the Egadi warships were designed for the sole purpose of naval warfare (Steffy 1995; Morrison et al. 1995; Murray 2012). Ramming warfare necessitated a specialized construction producing a ship that was sleek, fast, and adequately reinforced to withstand the physical strains of ramming and carrying crews of oarsmen. Identifying this specialization, the reconstruction relied on a series of limitations that served as controls and checks for the vessel.

The Egadi 10 warship was a balance of speed, strength, and maneuverability. It was specifically designed to support a large crew of oarsmen that could effectively attack and defend against other vessels. Crews were trained to carry out specially designed tactics such as the *diekplous* and the *periplous* described by Thucydides (7.36.3–4). The *diekplous* maneuver seems to have involved the attacking ship breaking through a line of opposing ships in order to outflank them and allow for a ramming attack on the stern quarter of an enemy (Lazenby 1987:170). Similarly, the *periplous* involved a warship outflanking a pursuing ship in order to gain the advantage and attacking from the stern (Whitehead 1987:181). Although these tactics cannot be defined clearly, it seems that they involved squadrons of ships attempting to outmaneuver and outflank opposing ships.

The ultimate purpose of the Egadi 10 was effectively engaging in naval ramming attacks necessitating the ability to withstand the forces generated during those actions. This meant that the ship required sufficient structural reinforcement to disperse the stresses of ramming impacts. It also needed sufficient space in order to house rowers to provide an adequate means of propulsion. The tactics developed for this type of naval warfare further support vessel construction that efficiently balanced performance and hull integrity. The efficiency of the Egadi 10 warship was dictated by the technical choices made by its shipwrights.

Technology

Shipwrights rely on the technological knowledge they possess in order to construct a vessel to meet the specifications for an intended purpose. The technology available to those shipwrights is a corpus of artifacts, behaviors, and knowledge (Schiffer and Skibo 1987:595). This technological knowledge rests upon standards which underlie the entire construction process from the fabrication of raw materials to the final assembly of the ship. It also includes a series of practices and principals needed to produce the dimensions and shape of the intended vessel (Schiffer and Skibo:597–598).

Technological systems were a difficult subject to approach with the sparse archaeological remains from the Egadi 10 warship. Previous work on the Athlit ram provided important ideas and understanding of the function of the bow timbers (Steffy 1991:6–39). Without detailed evidence of the hull, the best solution was to use supplementary evidence collected from merchant vessels to provide evidence of construction and assembly sequences.

The construction of merchant vessels utilized common construction standards employed by Mediterranean shipwrights. Hulls were built using a shell-based construction that derived the strength and integrity of the ship from its planking. Planking was joined edge-to-edge using mortise-and-tenon joints, reinforced by an internal support structure of floor timbers and futtocks alternating with pairs of half frames (Figure 7). In order to shape and construct their vessels, shipwrights had a specific set of tools available to them, allowing them to utilize their practical knowledge and skills. The assortment of tools available affected the design and assembling of timbers, planks, and fastenings (Crumlin-Pedersen and McGrail 2006:54–55).

FIGURE 7. Kyrenia Ship showing common construction features of a mortise-and-tenon hull (Courtesy of Robin C.M. Piercy)

Evidence from studies of Roman woodworking helped illuminate the tools and processes that would have been used to build the Egadi 10 warship. Roman woodworking was a highly specialized trade with many different sub-specialties (Ulrich 2007:272–274). Archaeological examples of Roman carpentry tools exist throughout the Mediterranean. The House of the Craftsmen (*Casa del Fabbro*) located at Pompeii has yielded a larger number of hand tools used in woodworking (Ulrich 2007:7–10). The most common tools represented within the archaeological record include adzes, augers, chisels, planes, axes, saws, and hammers. The cutting edges of these tools were fashioned from iron with wooden or bone handles. Measuring tools also existed, and were usually fashioned from bronze (Ulrich 2007:13–58). These tools were the necessary implements that allowed Roman shipwrights to construct naval vessels. They represent the technical abilities of contemporary woodworking.

Tradition

While there is currently no direct archaeological evidence for the construction process utilized in creating these warships, supplementary evidence of boat building tradition is manifest in merchant vessels and iconography. The craft tradition of 3rd century B.C. Mediterranean ships incorporates a system of ideas and established norms that impose certain design parameters and aspects of construction (Adams 2001:301). While standards and modes of naval construction remain elusive, it seems likely that generally accepted standards did exist.

Iconographic traditions depicting warships provided artistic interpretations of warships that assisted in defining basic hull shapes and characteristics. Artistic representations should not be interpreted as detailed blueprints of structural details. Galleys depicted on Roman coins minted during the First Punic War, for instance, served as propaganda (Morrison 1995:67). Wall reliefs and statues like the 3rd century B.C. Carthaginian tomb relief (Figure 2) and the 1st century B.C. Tiber Island Ship (Krauss 1944) displayed in public places serve similar purposes (Figure 8). These images provide a glimpse into the representations deliberately created to demonstrate to the public the prominence and importance of the expenditures incurred in raising and maintaining navies. The study and interpretation of wall reliefs, statues, and coinage serve as glimpses into the cognitive traditions of ships through the lens of artists and the general public.

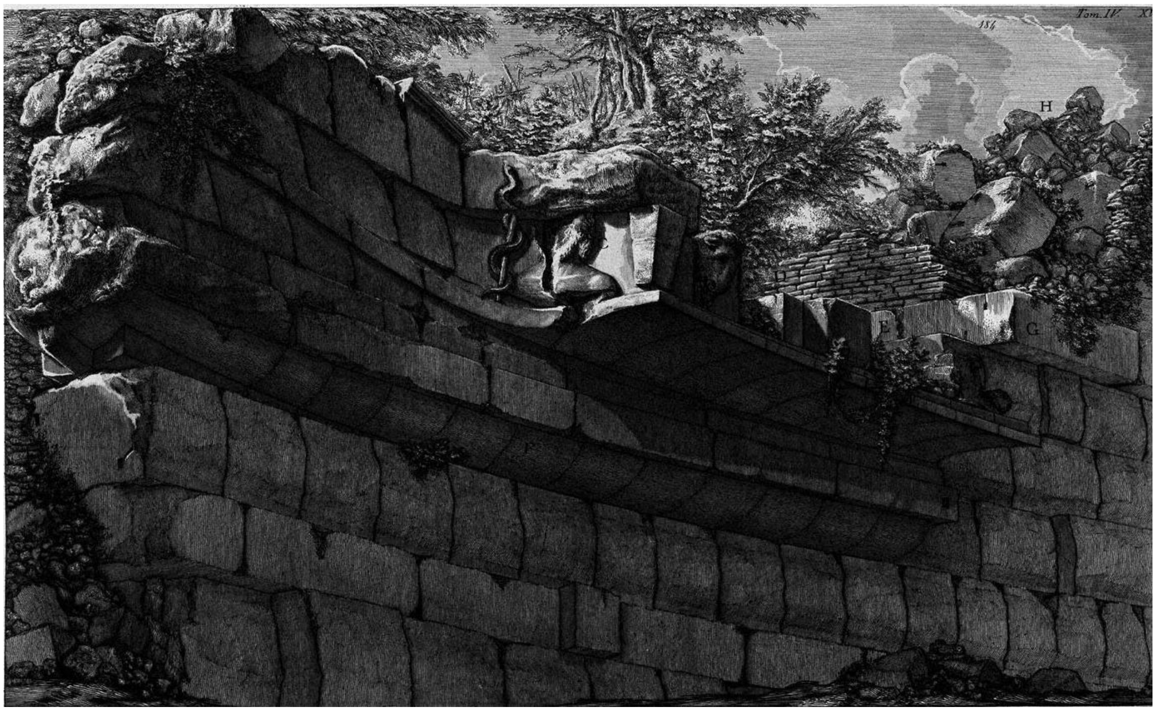

FIGURE 8. 16th century illustration of the Tiber Island Ship by Italian Artist Giovanni Battista Piranesi

Economy

The building programs that produced ships like the Egadi 10 warship were an economic force requiring a concerted and regulated effort on a political and military scale. They necessitated the collection and movement of raw materials, employment of skilled and unskilled labor forces, and mass training programs for rowing crews. Shipbuilding programs would constitute a large infrastructure that supported various satellite industries (Adams 2001:303). Naval expenditures were an economic force that were an integral part of the Roman and Carthaginian economies.

There were multiple financial responsibilities concerning the construction and maintenance of an oared warship (Adams 2001:303). Both Rome and Carthage needed shipyards that could cut and shape timber, forges that could produce fasteners and the rams, and the skilled and unskilled workers to fulfil those functions. Once the ships were completed the state needed sufficient funding for the raising and maintaining of crews as well as regular upkeep of the ships themselves.

Oared galleys were logistically reliant on their bases, whether it be a naval harbor or a friendly port, or even a friendly stretch of coastline (Casson 1994:119). Rowed galleys, like the Egadi 10 ship, required regular supply lines to restock their food and water stores. The men rowing the vessels needed time to rest and to sleep. Fleets needed to be regularly resupplied and required expenditures for general maintenance including repairs and refitting, especially after battles or wrecking events.

Diodorus (23.15.4) addresses the great cost to Rome and Carthage of resources and wealth that were spent on maintaining a war both on land and at sea. The economy of building, arming, and maintaining naval fleets was a major factor that dictated rates of construction and the optimal operation of those fleets. The Egadi 10 ship was built during the last years of the war and would have been part of a larger naval program that built and maintained the ships that took part in the battle of the Egadi Islands.

Materials and Environment

The materials and environment served as constraints which shaped the traditional and technological capacities of ancient Mediterranean shipwrights. Broadly, the Mediterranean basin is characterized by mild wet winters and long dry summers. Trees in the coastal areas most commonly grow on hilly and mountainous terrain. The geological formations of these regions rest on soft limestone foundations, which form soils that are conducive to tree growth (Meiggs

1982:39–42).The materials available to the shipbuilders influenced the construction parameters of the ship (Adams 2001:303).

The Egadi 10 warship represents an ideological culmination of shipbuilding knowledge and technological expertise. The framework presented created a cultural foundation of the various factors and constraints that affected the development and construction of these warships. It was utilized to provide meaningful insight into ancient naval cognition, construction, and warfare the reconstruction.

Thesis Outline

This chapter introduced the topic of the thesis and research questions that guided the reconstruction and analysis process. It discussed the significance of oared warships, previous work surrounding naval rams, and the theoretical framework supporting this reconstruction. Chapters two analyzes the historical accounts of the First Punic War and the evidence they provide relating to naval actions and warships. Chapter three presents the fieldwork and raw data collected to support the reconstruction. Chapter four presents and discusses the archaeological and historical sources on warship reconstruction while the final two chapters discuss the process of reconstruction and the results of this research.

Chapter 2: Historical Analysis of the First Punic War

Introduction

The events of the First Punic War are documented by the ancient author Polybius (1.5–1.65). However, this one account is neither complete nor is it contemporary. Polybius' accounts of the causes, events, and effects of the First Punic War were written almost a century after they occurred. Polybius states that he is using the accounts of two other historians (Quintus Fabius Pictor and Philinus of Agrigentum), neither of which survive. For this reason, other ancient texts were consulted in order to gain the best possible understanding of the historical events.

In addition to Polybius' *Histories*, research was conducted on Diodorus' *Bibliotheca Historica* to study the historical events during the mid-3rd century B.C. These sources, along with Theophrastus' (5.7) discussion on ship timbers provided clues in regards to the construction of warships. Although this experimental work primarily relied on archaeological evidence to support reconstruction hypotheses, it utilized these historical informants in areas where little to no archaeological evidence was available. The cultural contexts of these texts and their authors were critically analyzed, using current scholarly interpretations, in order to ascertain the intentions of these texts. This helped in determining whether or not these authors could be used as reliable sources to support or contradict reconstruction hypotheses.

Throughout the course of the First Punic War, Rome developed its naval power utilizing a series of innovative technological adaptations and strategic decisions. Polybius' historical accounts provided valuable information in regards to the construction and operation of Rome's naval forces. In order to better interpret the details concerning the technical aspects of warships during the First Punic war, it was first necessary to understand and analyze the greater historical context of the naval actions that took place over the course of this lengthy war. By tracing the evolution of Roman naval expertise throughout the course of the war, it was possible to investigate the technical and tactical aspects that could be drawn from historical accounts, in order to understand the interactions of Roman culture with naval warfare.

Roman Naval Experience Prior to the War

Prior to the outbreak of the First Punic War, Rome was primarily a land-based power. We should not assume, however, that the Romans had no experience with the sea. The earliest treaty signed between Rome and Carthage in 508 B.C. stated that Roman vessels were prohibited from sailing beyond the Fair Promontory (Hermaeum, just north of Carthage) (Polybius 3.22). This indicates that as early as the late 6th century, Rome was involved in maritime activity that could be seen as potentially threatening to Carthaginian interests.

Sometime in the late 4th century B.C. the treaty between Rome and Carthage was renewed (Polybius 3.24). The terms of the treaty seem to allude to the potential of Roman naval actions. The treaty stated that Roman ships were restricted from trading, plundering, or settling west of Hermaeum (including Spain and Sardinia). Although the restriction served to protect Carthaginian interests against any potential naval threats, it does seem to indicate that Rome possessed the naval capacity to threaten Carthaginian naval interests in some way. The third and final treaty before the outbreak of war was signed in 279 B.C. It extended the terms of the previous treaty and included a new clause that stated Carthage would supply transport or warships if either power were in need of assistance (Polybius 3.25).

Although the treaties do not provide direct evidence of Roman naval capabilities, they do suggest that there was a serious potential for Roman naval units to intercede in Carthaginian interests. Throughout the course of the 4th century, there are many examples that verify Roman involvement in various maritime aspects. In 394 B.C. a Roman warship was sent with votive gifts to the Temple of Apollo at Delphi. By 386 B.C., the port at Ostia was established, enabling larger shipments of goods to transport through Rome (Pitassi 2009:18–20). The first proper Roman naval engagement is reported in 338 B.C. during the end of the Latin War (340–338 B.C.). A Roman fleet under the command of Consul Caius Maenius defeated a Latin and Volscian fleet near Antium (Pitassi 2009:20).

Though these individual events identify an active naval element in Rome during the preceding 130 years, the best evidence for a naval infrastructure comes in 311 B.C. At this time, a naval board (*Duoviri Navales*) was established in order to equip and maintain a fleet during the Second Samnite War (326–304 B.C.) (Scullard 1980:135). The creation of this board implies that the naval capacities of Rome grew to such a proportion that they needed to be facilitated by a specific council, distinct from terrestrial forces.

The existence of this naval board is proof that the Romans had an established naval tradition well before the outbreak of the First Punic War. It also supports the implications present in the treaties between Rome and Carthage. The restrictions placed upon Roman trading, raiding, and colonizing can be viewed as acknowledgement of an organized Roman naval force that posed a potential threat to Carthaginian interests. Although all of Rome's territorial holdings were based on one land mass it should not be assumed that Rome lacked the experience to challenge Carthage at sea.

Naval Actions During the First Punic War

Prior to the war, treaties with Carthage established Roman terrestrial dominance of the Italian peninsula and promoted Carthaginian naval supremacy. In the early 3rd century B.C., Rome was the center of a confederacy, compromised of complex alliances, controlled through military strength and treaties. Carthage had a major naval presence, controlling extensive trade routes throughout the western Mediterranean (Lazenby 1996:11). The major point of contestation between the two powers centered around the occupation of Sicily. In 264 B.C., the First Punic

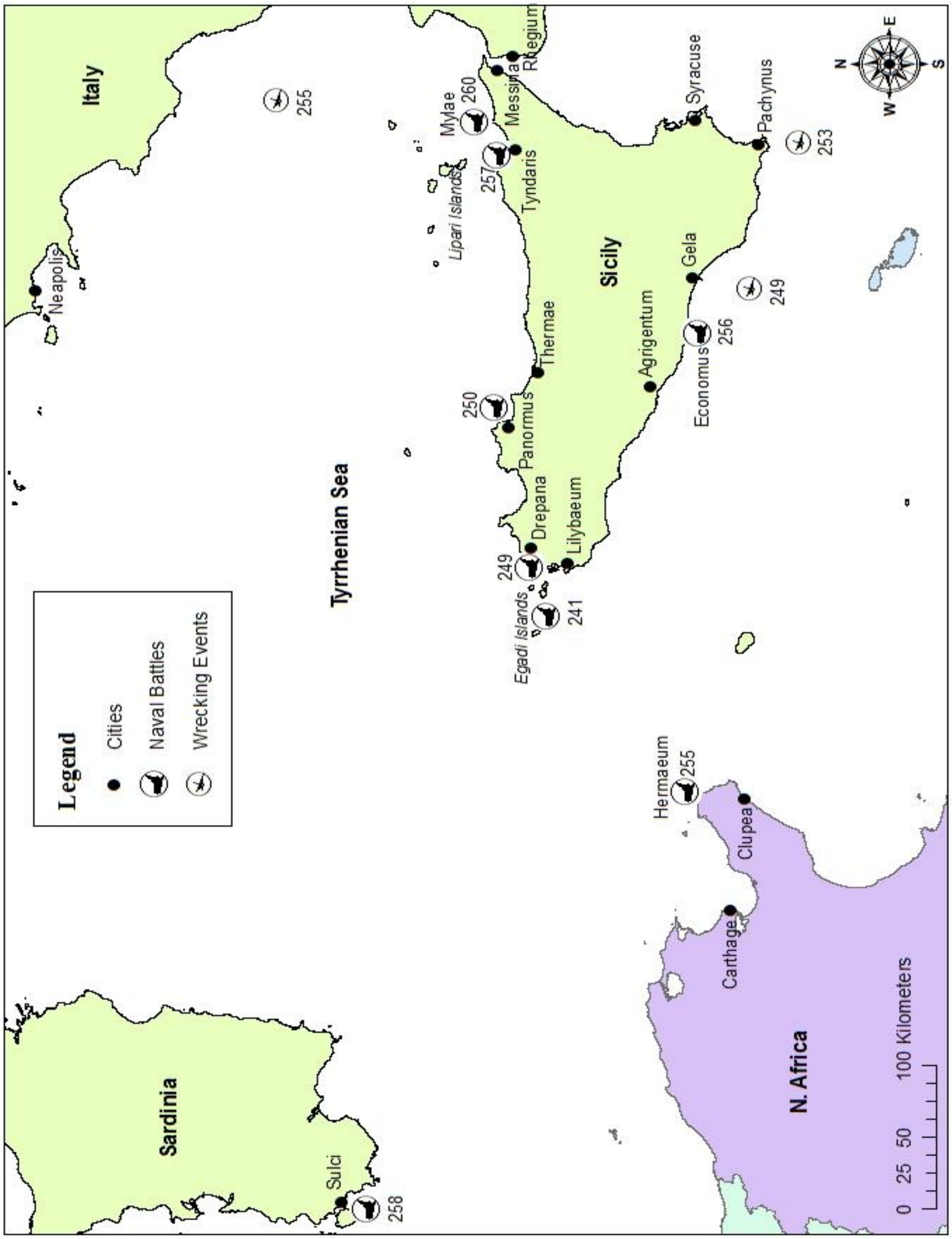

FIGURE 9. Naval engagements of the First Punic War

War (Figure 9) broke out after tensions between Carthage and Rome reached critical mass.

The Battle of Mylea (260 B.C.)

The first major naval engagement took place off the coast of Sicily near the town of Mylea, in 260 B.C. A Roman fleet numbering 120 ships, under the command of Gaius Duilius, was sailing to prevent the Carthaginians from raiding the Sicilian coast when it came upon a Carthaginian fleet. The Carthaginian forces numbered 130 ships, under the command of Hannibal (Polybius 1.20). The Carthaginians, expecting an easy victory over their inexperienced adversary, hastily charged the Roman fleet. In order to counter the speed and maneuverability of the Carthaginian ships, the Romans employed their uniquely designed boarding bridge, the *corvus*.

The *corvus* was a gang plank at the bow of the ship that could be dropped onto the nearest enemy to allow a boarding party to cross and capture their ship. The device consisted of a 7.30m long pole that was 0.23m–0.25m in diameter with a pulley at the top. Around the pole was a slotted gangplank that measured 1.21m in width and 11.00m in length, with a railing at about knee height. At the upper underside of the plank was an iron spike that would embed itself into the deck of the opposing ship (Polybius 1.22).

The Carthaginians lost approximately 50 ships in the engagement. Thirty ships were captured while the other 20 were destroyed (Polybius 1.23). By utilizing technical innovation, the Romans were able to gain their first naval victory over the Carthaginians.

Sulci (258 B.C.)

Following this initial naval victory, the Roman fleet remained deployed along the Sicilian coast. Shortly afterwards, the fleet was successful in raising the siege of Segesta as well as assaulting the town of Macella. In 259 B.C. Hannibal returned from Carthage to Sardinia with reinforcements for troops stationed in Sicily. The Roman fleet was able to successfully blockade the Carthaginian fleet near Sulci along the Sardinian coast, resulting in the loss of a large number of Carthaginian ships (Polybius 1.24). Following this action, the Carthaginian general was crucified by his troops and the island of Sardinia came under Roman control.

Tyndaris (257 B.C.)

In 257 B.C., a small skirmish occurred when a Carthaginian fleet sailed passed a Roman fleet anchored off of Tyndaris, under the command of Gaius Atilius. Although the skirmish seems to have had no serious consequences, it did establish that the two fleets were now evenly matched in terms of naval capabilities (Polybius 1.25).

The Battle of Economus (256 B.C.)

The next major naval engagement occurred in 256 B .C. at Economus. The Romans prepared an invasion force at Messina intended for the African coast in order to directly attack Carthage. The Carthaginians, having learned of the invasion plans, sent their fleet from Lilybaeum to intercept the Romans. The Carthaginians ships numbered 350, under the command of Hamilcar and Hanno. The Roman fleet numbered 330, under the command of the Consuls Marcus Atilius Regulus and Lucius Manlius. The Roman squadrons were organized into a wedge shape. The first and second squadrons sailed in line ahead formation. Two *hextereis* formed the center with each successive ship sailing *en echelon* to the leading ship. The third squadron sailed in line abeam, with horse transports in tow. The fourth squadron brought up the rear, thus creating a closed formation. The Carthaginians formed in standard line abeam formation, with their left flank at a slight angle to the shore (Polybius 1.26).

The Carthaginian plan was to draw out the Roman center, thus allowing the Carthaginians to outflank the Roman formation. This strategy was favorable to the Carthaginian tactic of ramming, while avoiding the Roman *corvi* and boarding parties. The Roman wedge formation prevented the Carthaginians from outflanking their center. Instead, the Roman center (first and second squadrons) engaged the Carthaginian center. While the Carthaginian left was forced to engage the third squadron, the Carthaginian right engaged the fourth squadron (Polybius 1.27–1.28). Thus instead of outflanking the Romans with a pincer movement, the Carthaginians were forced to fight the Roman fleet in three separate battles. The battle resulted in 24 Roman ships sunk with none captured while Carthaginians losses amounted to 30 ships sunk and 64 ships captured. The wedge formation seems to have been specifically engineered in order to combat Carthaginian tactics. The combination of tactical and technological innovation by the Romans allowed them to gain the upper hand. As a result, the Roman fleet was able to sail across to Africa in an attempt to attack Carthage directly.

The Battle of Hermaeum (255 B.C.)

After a year of seemingly indecisive campaigning, Roman forces under the command of Marcus Atilius Regulus found themselves in a crisis after suffering defeat (Polybius 1.29–1.35). A Roman fleet of 200 ships was dispatched in order to extract the remaining troops from Africa. When the fleet reached the Libyan coast, it engaged and defeated a Carthaginian squadron at Hermaeum, capturing 114 ships. The Roman fleet then evacuated the Roman troops and set sail back to Sicily (Polybius 1.36).

Wrecking Events and Raiding the Libyan Coast (255–253 B.C.)

As the fleet reached the coast of Sicily, it was caught in a storm and suffered heavy losses. Of the 364 ships that were in the fleet, only 80 survived, resulting in the greatest loss of Roman ships during the course of the entire war (Polybius 1. 37). However, undaunted by this major loss, the Romans set about replacing the ships lost in the storm and, by 254 B.C., had a fleet of 300 ships besieging the town of Panormus (Polybius 1.38).

In 253 B.C., the Roman fleet under the command of Consuls Gnaeus Servilius and Gaius Sempronius sailed back to Africa intending to raid the Libyan coast, but was unsuccessful in gaining any major ground aside from running aground on the island of Menix. On the return trip, the fleet was again caught in a storm near Camarina/Pachynus off the coast of Sicily and lost more than 150 ships. Following these consecutive storm wreckings, the Romans abandoned their shipbuilding program for two years (252–250 B.C.) (Polybius 1.38).

The Siege of Lilybaeum (250 B.C.)

In 250 B.C., the shipbuilding program resumed with an order to construct 50 new ships (Polybius 1.39). The addition of the newly constructed ships bolstered the Roman fleet by up to 200 ships, which were sent once again to blockade the town of Lilybaeum (Polybius 1.41). The siege lasted until 249 B.C. and, while it was mostly unsuccessful, it did result in the capture of a Carthaginian *quadreme* as well as the *quinquereme* of Hannibal the Rhodian (Polybius 1.45–1.47).

The Battle of Drepana (249 B.C.)

In 249 B.C. Rome sent another fleet to Sicily under the command of the Consul Publius Claudius Pulcher to attack the unsuspecting forces under the Carthaginian commander Adherbal, stationed in the harbor at Drepana. The Carthaginians caught wind of the incoming attack and were able to organize their crews in time and mobilize the fleet. Publius then, famously disregarding augury signs, attempted to attack the harbor. Forming the fleet in line ahead formation, the Romans attempted to attack the harbor with the coast off their starboard side. The Carthaginians were able to use the coastline to their advantage; in conjunction with their faster ships and more experienced rowers, they were able to defeat the Roman fleet by pinning it against the shore (Polybius 1.49–1.51).

In response to this defeat, the Romans sent a relief force under convoy with 60 warships to Lilybaeum. However, a larger Carthaginian fleet of 100 warships, under the command of Carthalo, was able to intercept the Romans. After a series of unfavorable skirmishes, the Roman fleet was caught in a storm that nearly wrecked the entire fleet (Polybius 1.52–1.54). This series of events effectively left Rome without a navy. After this disaster, there was a substantial lull in naval activities for the next few years, as the Romans seemed to abandon their naval ambitions for a time.

Hamilcar Barca Raids the Italian Coast (247–242 B.C.)

In 247 B.C., Hamilcar Barca was appointed general of the Carthaginian forces. He conducted a series of minor raids on the Italian coast but Polybius makes no mention of any naval engagements. The two sides found themselves evenly matched for the duration of the next seven years (Polybius 1.56–1.58). It was not until 242 B.C. that the Romans were once again able to raise a fleet. At this point, Rome undertook to construct a fleet of 200 *quinqueremes* based on the *quinquereme* that was captured during the siege of Lilybaeum (Polybius 1.59).

The Battle of the Egadi Islands (241 B.C.)

The final naval battle of the First Punic War took place north of the Egadi Islands (*Aegates*, *Aegusae*) in 241 B.C. This battle saw a stark reversal of Roman tactics. By this point in the war, the Roman navy was an experienced fighting machine and no longer relied on the *corvus* as its main weapon. By 241 B.C., the Romans adapted their warship construction methods to produce ships capable of effective ramming. Roman shipwrights were building light, fast ramming warships. This indicates that the Romans adopted new tactics and strategies that relied on ramming.

In 241 B.C., the Carthaginians dispatched a relief convoy, under the command of Hanno, to their units in Sicily. This time the Romans, under the command of Gaius Lutatius, set out to intercept the Carthaginian fleet (Polybius 1.61). The Carthaginian ships were at a major disadvantage because they were heavily laden with relief supplies. Unable to properly maneuver or reach optimal speed, the Carthaginians were defeated. As a result, the Carthaginians suffered losses amounting to: 50 ships sunk and 70 taken as prizes.

The actions of the Roman fleets over the course of the First Punic War provide some information about the development of Roman ship technology and battlefield tactics. As they grew more adept at naval warfare, their shipbuilding techniques changed, and they adapted their tactics to conform to their sailing abilities. Tracing the Roman navy's development encapsulates the ingenuity of Roman engineering and tactical brilliance.

Polybius, The Historian

Polybius wrote about the events of the First Punic War almost a century after they occurred. He wrote during a time at which Roman power and domination was reaching a level not yet experienced in the Mediterranean. In order to understand the context of the events of the First Punic War, it is important to understand the context of the written record.

Polybius was a Greek taken hostage by Rome after the battle of Pydna in 167 B.C. He came from the privileged elite of the Achaean League, and his experience in both war and politics was extensive. During his time as a Greek soldier and politician, Polybius served as Hipparch, cavalry general, and second in command to the Greek confederacy forces (McGing

2010:13). His extensive background meant he was well versed in previous historical writings, like those of Herodotus, Thucydides, and Xenophon.

Throughout the course of his account, the influence of these writers becomes apparent. Polybius, like Herodotus, makes sure to set aside passages that deal specifically with the geography of the regions he discusses, in order to orient the reader to the series of events (McGing 2010:54). For example, during his account of the siege of Lilybaeum, he devotes an entire section to the description of the topography of the surrounding area (1.42). The analysis of battles reflects that of typical accounts provided by Thucydides of the Peloponnesian War (McGing 2010:58). The aspect of analytical narration most closely resembles the writing of Xenophon, who, like Polybius, was a soldier-politician turned historian (McGing 64).

At the beginning of the first book (1.3–1.4), Polybius stated his intention of writing a pragmatic history focused on the progression of events, in order to be utilized as an education source. The first book served to introduce the reader to the two main protagonists of the history (McGing 2010:45). Polybius' target audiences were the rich and powerful aspiring to leadership positions. It was specifically intended to introduce Greeks to the history of Rome (McGing 2010:67).

Understanding Polybius' background and the intention of his writing addresses certain biases that may affect the interpretations of his work. Even though Polybius stated that his intentions were to provide a comprehensive history that could be utilized as an educational tool in order to explain Rome's rise to power, it must be remembered that he was nonetheless writing a history with certain intentions aimed at a target audience. Polybius began writing his histories while still a captive of Rome. During his captivity, he moved through the upper circles of the Roman elite. Aside from his own opinionated views, it seems very likely that the narrative would have been tailored to suit the needs and wants of those same elites for whom the history was being written. It is not unreasonable to assume that certain unfavorable events were omitted in order to avoid aggravating his captors.

Polybius wrote his history a century after the events of the First Punic War, during the Third Punic War and the final destruction of Carthage. This brings about the issue of the accounts of Philinus of Agrigentum and Quintus Fabius Pictor that Polybius explicitly addresses in order to write his own account of the war (1.14). In his critical analysis of these writers, Polybius addresses the biased views of the two authors (1.15). Polybius then explains that these two accounts were not truthful because the two writers were too strongly affected by their biases. In this way, Polybius, like a modern historian, critically analyzed multiple sources in order to gain the most comprehensive view of historical events.

Although the accounts of Philinus and Fabius Pictor do not survive, a brief analysis of the two historians is possible. It is possible that Philinus served as a mercenary to Carthage during the First Punic War (Hoyos 1985:103; Walbank 1945:11). It is from Philinus that Polybius draws his description of the third treaty between Rome and Carthage (Polybius 3.24). On the other hand, Fabius Pictor was a Roman Senator focused on publicizing the Senate's political program to the Greeks (Walbank 1945:1). Diodorus also names Philinus as one of his sources for the events of the First Punic War (23.81).

It must, however, be remembered that Polybius was affected by bias as were his predecessors. He was a Greek writing a Roman history under the auspices of Roman patrons. In addition, although it is not immediately apparent once the history addresses the period contemporary to Polybius' life; the author did not hesitate to write himself into his own accounts. This means that the comprehensive and pragmatic account of history succumbed to similar biases that Polybius initially sets out to avoid. This must be kept in mind when analyzing his descriptions of naval ships and tactics.

The most pertinent issue of Polybius' writing for this thesis is his description and classification of naval units. Throughout the entire account of the First Punic War, Polybius identified *quinqueremes* (πεντήρεις) as the only ships used during the various naval engagements. He did, however, differentiate between the early Roman *quinqueremes* that were built heavily in order to support a larger contingent of marines and the sleeker, faster *quinqueremes* crewed by 300 men, built just before the Battle of the Egadi Islands. This simple generalization of warships needed to be expanded in order to provide an interpretation for the Egadi 10 warship reconstruction.

Throughout the course of the war, the fleets of Rome were in a state of constant flux. Ships were lost in battle and wrecked in storms, while new ships were built and captured ships were refitted and reintroduced into the fleets. Even if Polybius' accounts were factual, the *quinqueremes* would vary in their construction depending on their origins. Consideration of the state of the Roman navy before the war provided more evidence supporting Roman fleets that were made up of different types of vessels. Prior to the war, the Roman navy was supplied by ships through alliances with coastal cities. The ships would, therefore, represent the personal qualities of shipwrights from various regions of the Italian peninsula.

The logistical considerations of these fleets also need to be addressed. The sheer size of the fleets operating during the First Punic War necessitated a massive infrastructure of not only shipyards but also support vessels that could supply the fleets and augment actions during naval engagements. Contemporary fleets of the eastern Mediterranean had already developed into highly specialized units analogous to the modern-day aircraft carrier groups. The naval siege unit, consisting of larger ships supported by smaller, faster ships, was the standard fleet during this time (Murray 2012:132–133). Although the nature of naval battles in the east were focused on harbor protection and harbor assaults, this model is the only contemporary example of how such large fleets were able to operate.

The fleets of *quinqueremes* were almost certainly augmented by smaller, faster, and more maneuverable ships serving as support craft. It is for this reason that Polybius' omission of other types of vessels is called into question. It is possible that Polybius found it unnecessary to go into logistical detailing of the fleets in order to focus on the larger scope of his history. It may also be possible that he decided to focus only on the larger ships in order to emphasize the more prominent ships of the fleets.

It is possible that Polybius emphasized the use of *quinqueremes* because they were more expensive to build. In writing a history that would enhance the Roman image, he may have attempted to play up the importance of the larger and more expensive ships. The way in which Polybius uses the word *quinquereme* may also be intended as a general term for warship rather than a specific type. The large fleets at the Battle of the Egadi Islands would have probably consisted of variously sized ships. Therefore, the use of the word *quinquereme* was meant as a generalization to include all the ships without having to go into a detailed explanation (Tarn 1907:59). By the time Polybius recorded his histories, the exact numbers and identifications of the fleets from the First Punic War may have been lost or obscured.

Diodorus, The Sicilian

Diodorus Siculus was born in Agyrium (Agira) Sicily (1.4.4). He was a Greek historian who wrote his *Bibliotheca Historica* between 60 and 30 B.C. In stating the scope of his work, Diodorus (1.4.2–7) explains that much of his research took place in Rome and Alexandria.

However, Rome receives relatively little attention throughout the course of his histories (Sacks 1990:117–121). Analysis of Diodorus' work indicates, that as a Sicilian under Roman control, he held passive resentment towards the imperial domination of Sicily by Rome (Sacks:125–127).

Diodorus also chronicled the events of the First Punic War. Unfortunately, only fragments of his account remain. The fragments that do survive provide important insights that help to cross-examine Polybius' accounts. Diodorus includes many anecdotes that personify the Romans and the Carthaginians in many ways that Polybius omits. Analysis of Diodorus' work indicated that his main source for the First Punic War was Philinus (Walbank 1945:11–15; Hoyos 1985:102–103; Sacks 1990:128). The fragments of Book 23 that do survive provided an interesting comparison to Polybius' accounts.

Diodorus' (23.1–22) description of the First Punic War characterizes Roman and Carthaginian commanders through anecdotes that reflect on some of the historian's personal sentiments. Diodorus provided these anecdotes concerning Roman ingenuity:

> For example, in ancient times, when they were using rectangular shields, the Etruscans, who fought with round shields of bronze and in phalanx formation, impelled them to adopt similar arms and were in consequence defeated. Then again, when other peoples were using shields such as the Romans now use, and were fighting by maniples, they had imitated both and had overcome those who introduced the excellent models. From the Greeks they had learned siege craft and the use of engines of war for demolishing walls, and had then forced the cities of their teachers to do their bidding. So now, should the Carthaginians compel them to learn naval warfare, they would soon see that the pupils had become superior to their teachers. (23.2.1–2)

Diodorus reinforced the technical skills of the Romans through examples that illustrated Roman ability to overcome different challenges. The passage epitomizes the Roman's ability to adapt their weapons and strategies to overcome the Etruscans. This example emphasized their ability to adapt to the maritime threat posed by Carthage.

While Diodorus admits that the Romans were adept at defeating their enemies, he does not shy away from criticizing them. Another anecdote describes the commander Atilius, refusing Hamilcar's request to cease fighting in order to bury the dead. This demonstrates the Roman commander's disregard to honor the customs of war and the gods (23.12.1). Although it seems likely that Polybius had access to this information his omission of this passage may serve as an example of his pro-Roman agenda. On the other hand, Diodorus' critical approach to Rome may reflect his sharing of Philinus' pro-Carthaginian sentiment (Walbank 1945:7).

The surviving fragments of Diodorus' history of the First Punic War differ from the accounts provided by Polybius. Although it seems that these two authors drew from similar sources, their respective histories demonstrate differences and conscious omissions on the part of the authors. Although Diodorus is at times critical of the Romans, he makes it a point to highlight the Roman's ability to overcome new threats by adopting tactics and technology. This parallels the Roman's ability to reverse engineer captured Carthaginian ships like the *quadreme* captured during the siege of Lilybaeum (250 B.C.). It further supports the implementation of specialized tactics that led to the naval victory at Economus (256 B.C.). These anecdotes provide valuable context that help to frame Polybius' history of the First Punic War.

Discussion of Historical Evidence

There has been some speculation as to the design and construction of the early Roman *quinquereme*. In order to construct their first proper fleet, the Romans used a captured Punic ship that ran aground in the Straits of Messina in 264 B.C. (Polybius 1.20). While Polybius states that the ships were copied from a captured Punic vessel, there is the possibility that aspects of the Roman design was borrowed from other maritime traditions as well (Thiel 1954:174–177). An analysis of the design and use of the *corvus* may provide a potential alternative to the origin of the Roman design.

The *corvus* was essentially a gangplank that could be dropped onto the nearest enemy to allow a boarding party to cross and capture the opposing ship. It was, in essence, a device that attempted to recreate the conditions of a land battle upon the sea. The invention of the *corvus* was a crucial aspect of Roman naval tactics. Polybius states that knowing their ships were poorly built and manned by inexperienced crews, the introduction of the boarding bridge allowed the Romans a tactical advantage (1.22). The *corvus* deterred from ramming attacks because if a Carthaginian ship engaged a Roman ship within striking range of the corvus, it became vulnerable to Roman boarding attacks.

The question remains, as to the origin and design of the *corvus*. Polybius himself admits not knowing who invented or suggested its application. The *corvus*, along with the extra marines on board, would have necessitated heavier construction of the entire vessel. If the Romans used the design of the captured Carthaginian *quinquereme*, they must have heavily modified it. However, if the Romans used a hybrid design, their ships would be purpose built for boarding tactics. The Roman *quinqueremes* would therefore be heavier, resulting in slower speeds but of more heavy construction. The possibility therefore exists that the first Roman *quinqueremes* were of a new design but Polybius did not specify the differences to the Carthaginian *quinqueremes*.

The Battle of Mylea provides the first example of the successful deployment of the *corvus* against the Carthaginians. The Carthaginians, having underestimated Roman capabilities, were unprepared to deal with boarding tactics. Once the *corvus* was securely attached, the overwhelming number of Roman marines would have easily been able to overcome the standard contingent of forty marines on board a Punic vessel. If the Romans captured only 30 Punic ships during this first battle, they would have gained about 9000 experienced rowers, and 30 fast and maneuverable warships.

The reason for the use of the *corvus* may have been an attempt by the Romans to capture as many Carthaginian rowers as possible. This would provide the Romans with a supply of experienced rowers who could be used to man Roman warships or train other rowers. If this was their intention, then it should not be assumed that the early Roman warships were poorly built copies of a captured Carthaginian warship. Instead, the design of early Roman *quinqueremes* would have been built for a specific purpose.

If captured Carthaginian rowers were used aboard Roman ships, they are absent from Polybius' record. A possible explanation for this situation lies within Polybius' intent to present the differences between Rome and Carthage. One of the major differences of the opposing forces was the way in which they supplied their armies with men. The Romans relied on armies conscripted from their extensive citizenry within the confederacy. On the other hand, the Carthaginians relied on paid mercenaries (Scullard 1980:162).

By the Battle of Economus in 256 B.C., the Romans fully understood the strengths and weaknesses of their ships. They anticipated the Carthaginian tactics and planned their formations accordingly. The Carthaginian formation aimed to avoid the boarding tactics by flanking and ramming the Roman ships. In anticipation of such a naval attack, the Romans divided their forces specifically to contend with a long distance sailing voyage as well as the possibility of a naval engagement (Polybius 1.26).

The wedge formation allowed the Roman ships to sail in relative close proximity to one another, providing better communication and protection. For the Carthaginians, this formation proved difficult to distinguish and obscured the size of the fleet, thus giving the Romans an advantage (Lazenby 1996:91). Therefore, it is likely that the Carthaginian strategy presupposed a standard line abeam formation. The Carthaginians planned to avoid the *corvi* by drawing out the Roman center and attacking the Roman ships from behind. This strategy would have worked if the Romans had not already anticipated such an attack. Instead of flanking the leading Roman squadrons, the Carthaginian wings were forced to engage the third and fourth squadrons directly. The combined effect of the wedge formation and *corvus* was a specifically engineered tactical decision by the Romans, resulting in a tactic that could overcome technical superiority.

The *corvus* was an important weapon that allowed the Romans to compensate for their naval inexperience. If the *corvus* was not properly stowed or if it was not possible to stow the *corvus* appropriately, it would affect the performance of a vessel along with making it dangerously top heavy. Therefore the *corvus* was well suited in calmer waters on the northern Sicilian coast, but in the turbulent waters of the southern Sicilian coast, the top-heavy vessels seem to have performed poorly. The subsequent wrecking of the Roman fleet in 249 B.C. again proved that the Roman ships were poorly equipped to deal with rough seas. The loss of almost the entire fleet left Rome without a navy for the next seven years.

In 242 B.C., the Romans once again constructed a fleet. However, this time the ships were of sleeker design and were based on the 'Rhodian' model captured during the siege of Lilybaeum (Polybius 1.59). This raises the subject of shipyard capabilities. It seems unreasonable to assume that Rome was able to build a fleet of 200 ships, of completely new design, in just under a year. Instead, the relative absence in naval activities of the preceding seven years provides the time frame during which the Romans were able to build and train this new fleet.

In 241 B.C., the final naval battle of the First Punic War took place to the north of the Egadi Islands. In a major reversal of roles, it was now the Roman fleet that was fast and maneuverable while the Carthaginians were encumbered by heavier ships laden with supplies. Although Polybius does not provide details of the actual engagement, it is clear that the Romans now employed ramming tactics to overcome the Punic ships.

Conclusion

Understanding the context which frames the history of the First Punic War aided in the interpretation of the technical aspects of the warships. Polybius' accounts of the early Roman ships stated that they were badly outfitted and difficult to manage (1.22). Inexperienced crews may have resulted in slower speeds, but it seems that the quality of the ships was much better than is credited to them. As previously stated, the Romans relied on their coastal alliances to patrol the waters of the Tyrrhenian Sea. Even if Roman shipwrights had little experience in building warships, their allies would have provided skilled shipwrights with the knowledge necessary to build warships. It may also be the case that the first Roman warships built during the war were not based on a captured Carthaginian ship. Instead of building ships they knew they would be unable to operate effectively, the Romans built ships that would play into their strengths.

The developments of the Roman Navy in the First Punic War are a testament to the skill of Roman engineering and tactical innovation. It seems highly unlikely that the Romans were unfamiliar with the sea prior to the First Punic War. Aside from the battle of Drepana and the two wreckings of the fleets due to storms, the Romans were consistently able to claim naval victories over the Carthaginians. If nothing else, Rome's continuous ability to overcome the Carthaginians at sea should indicate their prowess as seafarers. The historical accounts of

Polybius and Diodorus aided in understanding the social and economic aspects that framed the processes of shipbuilding. Attempts to identify the Roman naval infrastructure help to provide a context for the various logistical processes needed to construct and maintain fleets of such magnitude. Only archaeological sources can reveal construction guidelines and the approaches taken by shipwrights.

Chapter 3: Fieldwork and Raw Data

Introduction

This chapter will discuss the methodological approach to data collection utilized in the reconstruction process of the Egadi 10 warship. It will present all information gathered during the 2014 field season. This includes details concerning the environment of the Egadi Island site as well as the equipment and methods used.

Historical Research

Prior to the commencement of fieldwork and reconstruction, historical research was conducted in order to gather information concerning the written accounts which led to the identification of the site as the last major naval battle of the First Punic War (264–241 B.C.). The objective of providing a context of naval actions was to analyze Roman naval capabilities in order to develop the historical background framing the Egadi 10 warship reconstruction.

Overview of the Egadi Islands Archaeological Project

Since 2005, studies and excavations at the Egadi Islands site have been conducted by the *Sopritendenza del Mare*, the cultural authority tasked with the management of Sicily's submerged cultural heritage. The site, now confirmed as the location of the Battle of the Egadi Islands, was brought to the attention of Italian authorities in 2004 after the seizure of a bronze ram (designated Egadi 1) from a private collection in Trapani, reportedly recovered by a fisherman around Levanzo Island (Tusa and Royal 2012:11).

The landscape of the Battle of the Egadi Islands currently extends from the Carthaginian anchorage site on Marittimo Island to the Roman anchorage site on Favignana Island, running along the western coast of Sicily from Marsala to Bonagia Bay. The main concentration of artifacts is located within sector PW–A (Map 1). PW–A begins at an open sandy sector in the

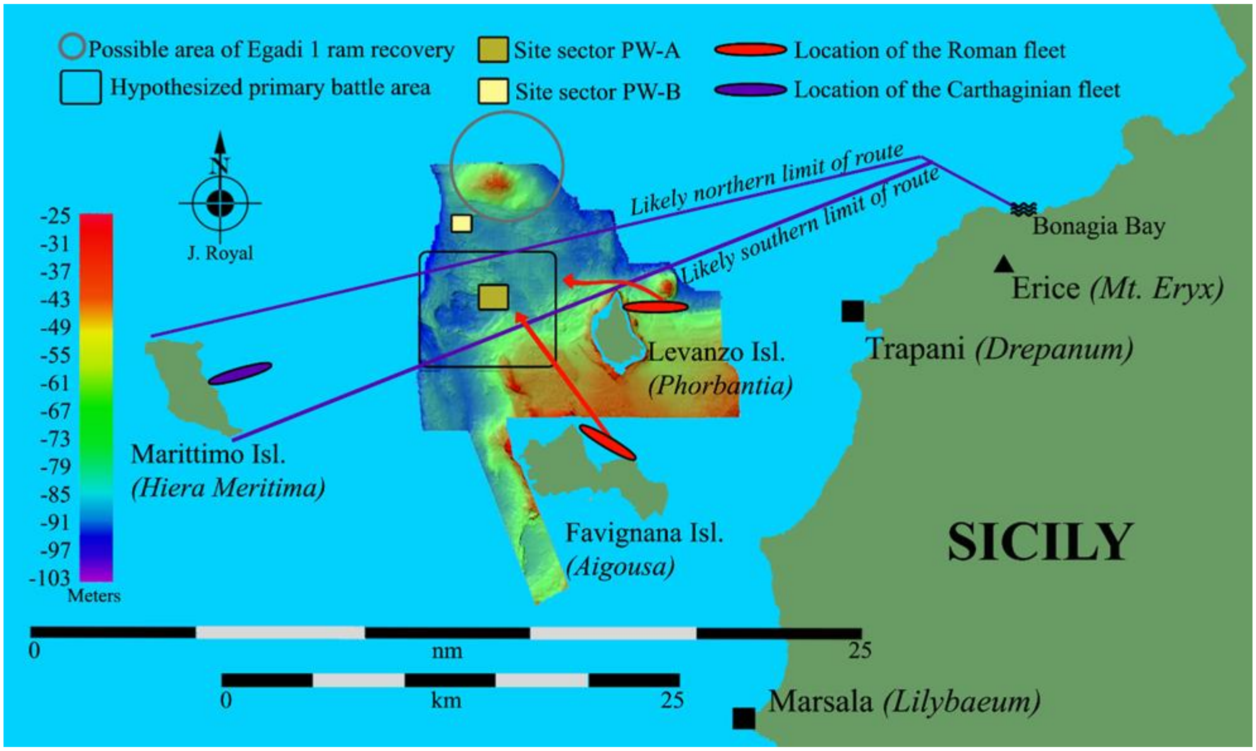

FIGURE 10. Main Site Map (Courtesy of Dr. Jeffrey Royal, 2014)

east and extends into a rocky area farther west (Royal and Tusa 2012:12). The eastern portion of the site features a relatively flat sandy bottom, ranging 79–80 m in depth. Rock outcrops rise in the western portion, ranging 75–79 m, providing a protective zone against currents and fishing nets. Weather is relatively calm during the summer; however, higher winds tend to occur in June causing waves of up to 4–5 m, which can impede field operations. Prevailing current ranges from 1.0–2.5 knots from the north. The area is protected by a 3–kilometer square exclusion zone, prohibiting commercial traffic and fishing, indicated by the black box (Figure 10).

Fieldwork conducted during the 2005–2007 seasons defined the seafloor and produced bathymetric data represented by the colored areas on the main site map (Tusa and Royal 2012:11). Consecutive seasons of fieldwork have yielded a series of rams, amphoras, tableware, anchors, and helmets. In 2010, a 1 km^2 area was designated PW—A after the location of a large concentration of artifacts in an area due west of Levanzo Island. This sector yielded 4 bronze rams, 8 bronze helmets, and 175 Greco/Italic V/VI and Punic amphoras. In 2013, the Egadi 10 and 11 rams were located just north of the previous finds along this rocky outcrop.

Equipment

FIGURE 11. Research Vessel *Hercules* leaving Trapani Harbor (Photo by author, 2014)

Although the Battle of the Egadi Islands site is located between three islands, it is a short ride from the Port of Trapani to the site. Due to the location, a research vessel is needed in order to access the site. Fieldwork utilized RPM's research vessel *Hercules*. The *R/V Hercules* is a 37.3 m long, 6.55 m wide, 2.22 m maximum draft, powered by two 900–horsepower Caterpillar diesel engines monohull vessel (Figure 11). In addition, it is equipped with two Thrust Master Azimuth engines, one located at the bow and one located about midships. These thrusters are stowed during transport and are lowered during field operations. In conjunction with a Kongsberg Dynamic Positioning system, the Azimuth thrusters are used to move and stabilize the Hercules on specific GPS locations, allowing for precise locations during operations.

FIGURE 12. ROV being launched from the aft deck of the R/V Hercules (Courtesy of Johnny Dryden and RPM Nautical Foundation, 2014)

The ship's Remote Operated Vehicle (ROV) is stored on the aft deck of the *Hercules* and is launched and retrieved using a 5–ton capacity A–frame. The Seaeye Panther XT ROV is equipped with a 360-degree sonar navigation system, a depth sensor, a Kongsberg HiPAP 350 tracking and positioning system, along with two forward mounted multi–function manipulator arms (Figure 12). Deploying and retrieving the ROV requires a three-person team. A crewmember must operate the tether winch while two personnel manually stabilize the ROV during deployment and retrieval. The Hercules is also equipped with a 5–ton capacity crane for general use as well as heavier artifact recovery.

Survey and Discovery of the Egadi 10 Ram

The Egadi Islands Archaeological Project relies on a four-dimensional geospatial analysis program called *Fledermaus*. Using this system, the project has been able to log and map every phase of survey and excavation (Figure 13). This has produced an interactive site plan that combines bathymetric data, side scan data, and artifact placement within an interactive three–

dimensional map. At the end of each season, survey data is uploaded into separate layers that overlay the base site plan.

Clusters of black circles represent the tracts covered by the ROV; each circle measures thirty meters in diameter which represents the functional usage of the forward mounted sonar. Artifacts are investigated and identified through a combination of sonar and visual inspection by the ROV team led by Dr. Jeffrey Royal. After discovery, each artifact is investigated, assigned a catalogue number, and marked using GPS tracking. Red points indicate Roman amphoras, white points identify Carthaginian amphoras, purple points represent helmets, and yellow squares delineate ram locations.

The Egadi 10 ram was located and identified during the 2013 field season. Its location was marked by GPS on the ship's maps so that it could be found again the following season. Ram 10 rested on its starboard side at a depth of 79.2 m. A majority of the ram was buried in the

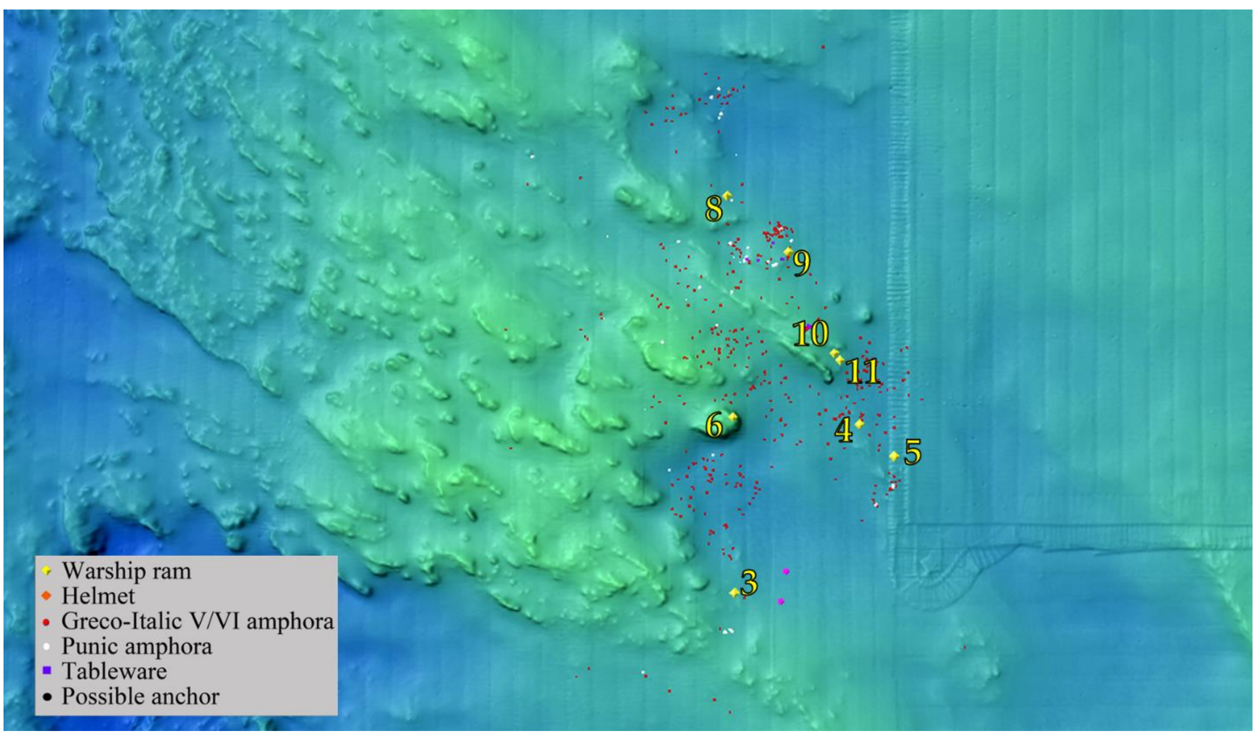

FIGURE 13. Bathymetric map showing locations of Egadi rams along with Roman and Punic amphora (Courtesy of Dr. Jeffrey Royal and *Sopritendenza del Mare*, 2014)

FIGURE 14. Egadi 10 Ram lying on the sea bottom (Courtesy of the *Sopritendenza del Mare* and RPM Nautical Foundation, 2014)

bottom with the upper port wale and a portion of the cowling protruding up from the sandy seabed (Figure 14).

Excavation of the Ram

The process of raising the ram began on 22 June 2014. Sand was cleared away from the exterior in order to determine its outer dimensions. A small two-inch induction dredge, attached to the ROV's left manipulator arm, was used to clear the sand and collect small fragments scattered around the ram for later examination. Dredging operations were halted periodically in order to document and photograph exposed layers. Continuous video streams recorded onto the ship's DVR received views from the ROV via fiber-optic transmitters from a high definition look down camera and a low resolution camera mounted onto the right manipulator arm.

Due to survey commitments in other areas and inclement weather, the *R/V Hercules* did not return to the site for five consecutive days. On 27 June 2014, excavation operations resumed, and the ROV was equipped with a 0.5 m x 1 m x 0.2 m container for the recovery of objects from inside the ram. In order to minimize the risk of jettisoning artifacts during ram recovery,

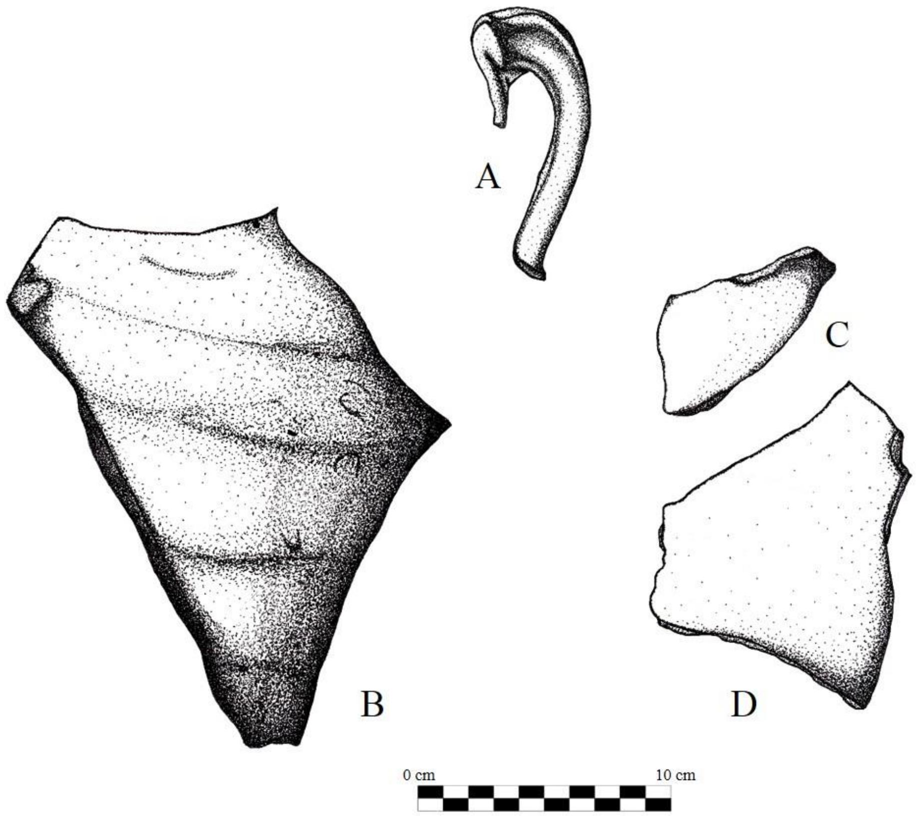

FIGURE 15. Illustrated ceramics (*a*) Punic amphora handle (*b*,*c*,*d*) Punic amphora sherds (Drawing by author, 2014)

dredging focused on the interior of the ram. An amphora handle and three sherds from a single Punic amphora along with one large concretion were recovered from the interior surface layer of the ram. Each object was labeled, measured, photographed, and illustrated (Figure 15).

The following day, 28 June 2014, dredging operations recommenced on the exterior of the ram, aiming to uncover the edges of the underside. Two thin aluminum rods were slide underneath the cowl, serving as guides for the strap used to haul the ram to the surface. It was first necessary to pull the ram upright in order to secure it for raising to the surface. An industrial grade strap was then winched around the driving center towards the tapering side of the cowl. Once the strap was secured, operations were halted for the day to allow for adequate time to return to port.

Due to inclement weather, the ship was confined to port for the next four days. It was not until 2 July 2014 that operations could resume onsite. Upon returning to the site, the ship's engineers prepared to lift the ram using the crane (Figure 16). The crane cable was lowered to depth and connected to the strap around the ram by the ROV. In order to prevent loss of material located in the interior, the ram was quickly lifted off the bottom. As the ram was lifted, the strap cinched around the cowl, providing a good hold on the ram while tipping the heavier forward end of the ram towards the bottom. This provided a safe means of recovery while preventing any spillage of the ram's contents. Once at the surface, the ram was set on a wooden pallet and secured for transport back to port.

FIGURE 16. Deck crew preparing crane for retrieval of Egadi 10 ram (Courtesy of RPM Nautical Foundation, 2014)

Measuring and Recording the Ram

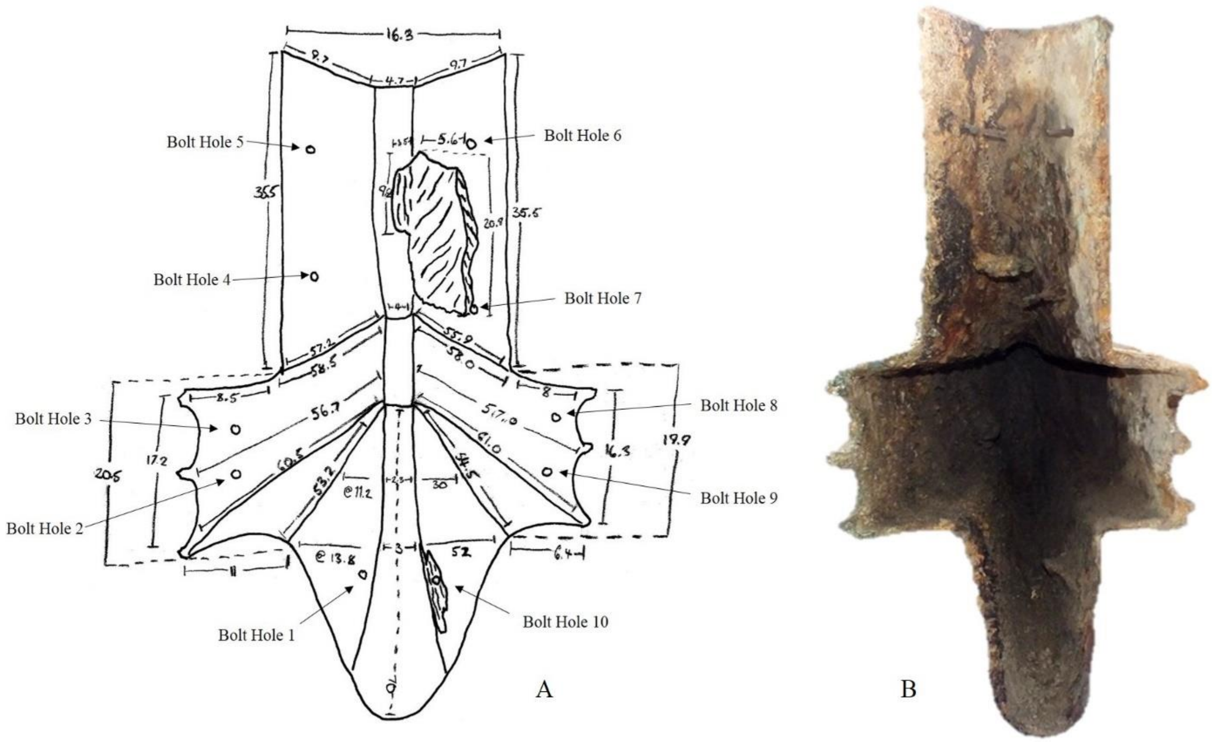

FIGURE 17. (*a*) Drawing of ram interior with measurements (*b*) Photograph showing ram interior (not to scale) (Image by author, 2014)

Once in port, analysis of the ram and its contents began. Due to a lack of on shore facilities, examination of the interior ram contents was conducted on the aft deck of the *R/V Hercules*. Documentation and removal of artifacts and mud layers was conducted while the exterior of the ram was periodically wet with salt water to prevent any excess damage due from drying. As each new mud layer was excavated, soil samples and photographs were taken along with schematic drawings for measurements (Figure 17).

With the ram onboard, analysis and documentation of the Egadi 10 ram continued for five days before it was handed over to the Sopritendenza del Mare for conservation, storage, and display. Measurement data was collected using templates developed by Dr. Jeffrey Royal. Detailed measurements were taken of all exterior and interior features as well as thicknesses of the bronze. With all measurements recorded, it was determined to sketch and re-measure the interior of the ram in order become closely familiar with the interior structure.

The cowl nosing (Figure 1) was decorated with an incised Roman inscription naming the quaestor, who was likely to be the patron funding the casting of the ram or the ship itself. Due to the obstruction of the exterior concretions, it was not possible to determine the exact lettering, but preliminary inspection produced the spelling: *L QVINCTIO F QVNISTOR POB(D)AVET*.

FIGURE 18. Incised graffito found along interior of the cowling (Courtesy of the *Sopritendenza del Mare*, 2014)

The top of the nose cowl was decorated with a Roman helmet. Of special interest was graffito incised into the inner surface of the ram along the starboard side of the cowl (Figure 18).

With the outer layers of clay and mud removed, the research team discovered that a section of remaining mud was actually the decomposed remains of the ramming timber (Figure

FIGURE 20. Documentation of interior of ram (a) Initial contents (b) Ramming timber visible (c) Fully processed interior (Courtesy of the *Sopritendenza del Mare*, 2014)

19). A concretion located midway up the timber on the top side was interpreted as a probable fastener that connected the chock or nosing to the ramming timber. A copper fastener measuring 13.8 cm in length and 0.8 cm thick was found towards the outer part of the ram and timber

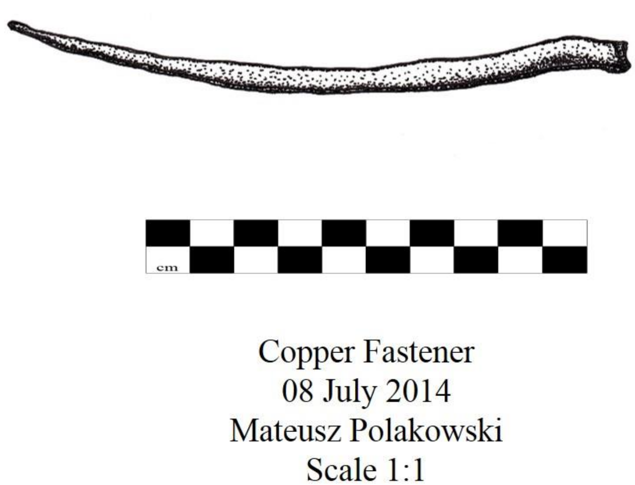

FIGURE 19. Copper fastener found in the interior of Egadi 10 (Drawing by author, 2016)

remains most likely attached the stem to the ramming timber (Figure 20). In total, nine individual artifacts were labeled and three sediment samples were taken.

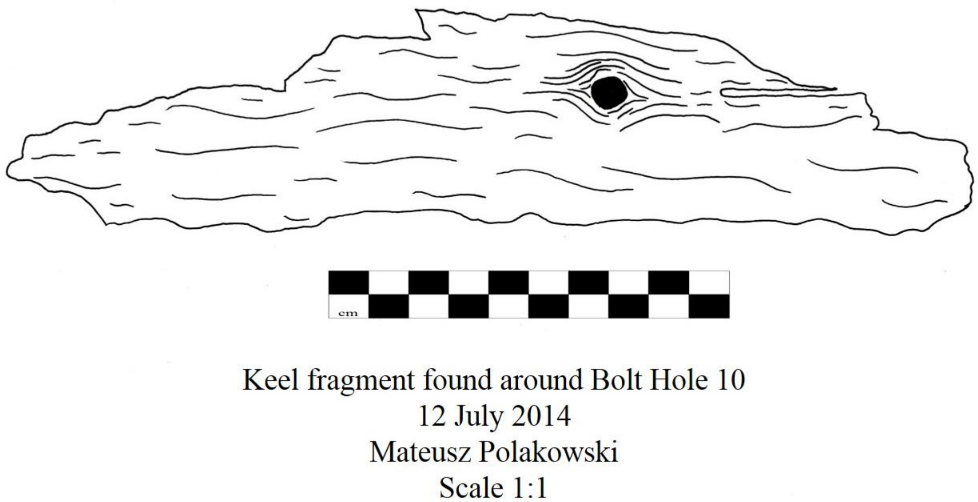

FIGURE 22. Oak keel fragment (Drawing by author, 2014)

In addition to loose artifacts found in the interior, two small intact samples of timber were recovered from the ram. A small fragment of the keel was found attached around Fastener Hole 10 (Figure 21) and a small fragment of the stem remained attached to the outermost starboard

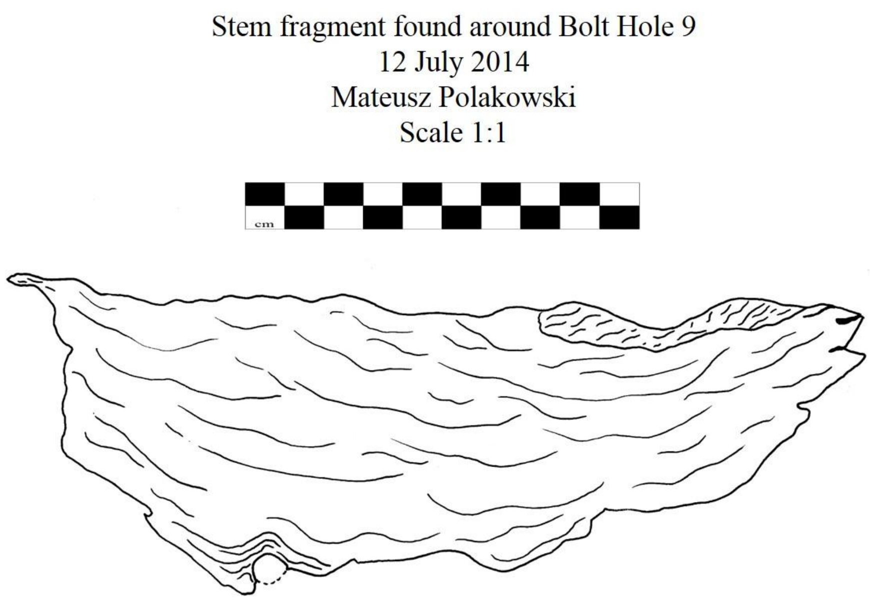

FIGURE 21. Elm stem fragment (Drawing by author, 2014)

Fastener Hole 9 (Figure 22). These pieces were carefully removed and placed in storage containers in order to be tested at a later date. The results indicated that the keel fragment was oak and the stem piece was elm (Dr. Jeffrey Royal 2014, pers. comm.). Once all the interior contents were removed and catalogued, measurements and photographs were once again taken of the entire ram.

Once detailed drawings and photographs were complete, a three-dimensional image of the ram was recorded using a *Sense 3D Scanner*. The scanning device is a handheld scanner that connects directly to a laptop computer via a USB cable and produces a three-dimensional image with an error margin of 2 mm. Drawings, measurement forms, and three-dimensional scans were then used to cross check measurements.

The Egadi 10 measures 80.9 cm maximum length, 39.7 cm maximum width, 70.5 cm maximum height, and weighs 162.5 kg. The ram head measures 25.8 cm in height, 38.5 cm at the top fin, 39.7 cm at the middle fin, and 37.5 cm at the bottom fin. Thickness of the bronze casting ranges from 2.70 cm to 3.20 cm except for the fins, which are solid for the forwardmost 13.7 cm. A decorative Roman helmet adorns the top of the cowl, measuring 9.87 cm in height, 5.98 cm in width, and 3.9 cm in depth.

A total of ten bolt holes were located towards the aft end of the ram, five each on starboard and port sides. Hole diameters ranged between 1.14 and 1.9 cm. Bolt hole 7 still retained part of a bronze bolt, measuring 1.14 cm in diameter and 3.5cm in length. A piece of oak keel was found at hole 10, measuring 28.5 cm in length, 6.5 cm in width, and between 0.8 and 1.9 cm in thickness. A remaining piece of the elm stem was found between holes 6 and 7; it measured 22.8 cm in preserved length, 7.9 cm in width, and had an average thickness of 0.9 cm.

A copper nail, found in the interior of the ram, measuring 13.7 cm in preserved length and between 0.2 and 0.8 cm thick probably fastened the chock to the ramming timber.

Conclusion

Once the Egadi 10 ram was fully recorded, it was turned over to the *Sopritendenza del Mare* for cleaning and conservation. Although the Romans claimed a decisive victory at the Battle of the Egadi Islands, it seems their fleet did suffer casualties. The Roman helmet and the inscription decorating the outer surface of the ram strongly suggest that the Egadi 10 ram belonged to a Roman warship that sank during the battle. Since this is the only direct evidence for the Egadi 10 ram's origins, the following reconstruction will identify the Egadi 10 warship as a Roman warship. The data collected could now be used to begin the partial reconstruction of the ship that sank during the battle. However, before the reconstruction could begin, a database of supporting evidence was compiled in order to provide supplementary data relating to warship construction. The following chapter details this evidence.

Chapter 4: Evidence Relating to Warship Construction

Introduction

This chapter will discuss archaeological evidence and data collected to assist the subsequent reconstruction of the Egadi 10 ram and warship. Data compiled from twelve sites on keels, planking, wales, stems, sternposts, frames, and fasteners served as the archaeological evidence that supported the reconstruction efforts. This database consisted of direct archaeological evidence including the Egadi rams, contemporary merchant shipwrecks, large merchant ships from later periods with heavier construction, and the contemporary shipsheds at Carthage.

Archaeological Evidence Relating to Warship Construction

As a ramming warship, the Egadi 10 needed to not only withstand the general stresses exerted upon the hull, such as hogging and sagging, it also required the structural integrity to deliver and withstand the shock generated during ramming battles. Shell-based construction, the main shipbuilding tradition of the Mediterranean during the 3rd century B.C., relied on tightly fitting mortise-and-tenon joints to disperse shear forces along the length of the hull. This principal made the mortise-and-tenon craft an optimal hull type for ramming warfare. The longitudinal forces generated during impact would disperse along the length of the wales while the mortis-and-tenons would act effectively as a chain mail coat absorbing shock and dispersing the load across the entire hull (Morrison 1995:131). Careful planning, detailed design, and skilled craftsmen converged to produce a fleet of ships that could fulfill their purpose as sea going vessels of war. Every structural aspect of the ship needed to work in unison in order to achieve the vessel’s full potential.

Other than the bow timbers of the Athlit ram (Steffy 1991:6–39) and the Acqualadroni ram (Buccellato and Tusa 2012), there remains an unfortunate dearth of information regarding structural components of warship construction. Iconography (Figure 2) assisted in the research process by providing basic ideas of appearance and construction. However, iconographic interpretation is not an accurate means to analyze specific construction details such as assembly processes and component timbers (Zeev, Kahanov, Tresman, and Artzy 2009:5). The use of iconography in this research was limited to areas such as the curvature of the keel and the discussion of the upper structural components, including the outrigger and rowing system. Archaeological, historical, and iconographic examples were chosen on the basis of building tradition and proximity to the 3rd century B.C (Crumlin-Pedersen and McGrail 2006:55).

The *Olympias* Trials

Before discussing the historical and archaeological evidence, the sea trials of the *Olympias* need to be recognized for their importance in understanding the oared galleys that once patrolled the wine dark Mediterranean. In 1981, the Trireme Trust began a collaborative effort involving historians, archaeologists, and shipwrights culminating in the reconstruction of the Greek trireme named *Olympias* (Morrison, Coates, and Rankov 2000). The reconstruction provided valuable insight into the construction and operation of a Greek oared warship. However, this was an attempted reconstruction of a Greek *trieres*, a three-banked warship from the 5th century B.C., like the ones used to defeat the Persians at the Battle of Salamis (480 B.C.). The warships found at the Battle of the Egadi Islands (241 B.C.) sank over 200 years later and were likely to differ from the construction of 5th century warships. Despite this issue, the *Olympias* (Morrison, Coates, and Rankov 2000) reconstruction was a valuable resource to this project, supplying important information regarding oar power and the human element necessary to propel these warships. The physical calculations, trials, and structural design of the interior proved essential in providing possible rower arrangements, tactics, and capabilities.

The Ram

The Egadi 10 ram is a bronze three-fin waterline ram, cast around the bow, protecting the integrity of the ship and increasing its damage potential. Terminology developed by J. Richard Steffy (1995:10–12) for the Athlit ram was revised by Dr. Jeffrey Royal and applied to the features of the Egadi rams, in order to remain consistent with previous studies (Figure 23).

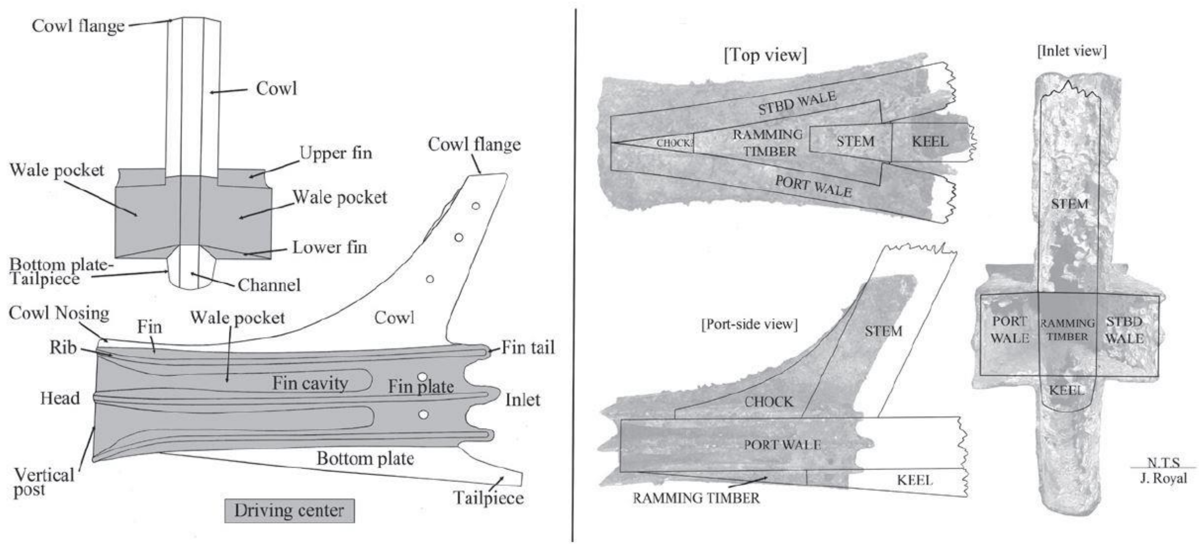

FIGURE 23. Ram terminology and timber placement (Tusa and Royal 2012:13)

The Egadi rams, the Athlit ram, and the Acqualadroni ram share the five basic structural elements: a ramming head, driving center, wales pocket, a cowl for the stem, and a bottom plate for the keel. Each component worked in unison to protect the integrity of the ship while dispersing sheer forces of ramming along reinforced longitudinal timbers such as the ramming timber, keel, and wales. The addition of the ramming timber to the bow timbers provided the necessary reinforcement to withstand frontal ramming attacks. The basic dimensions of the ram and its interior contents provided the only direct archaeological evidence of the Egadi 10 warship. With no corresponding hull structure found, research relied on corresponding data from secondary and tertiary archaeological evidence.

The Egadi 10 ram is consistent with the sizes of the other rams recovered from the Egadi Islands Archaeological site (Table 1). All the rams fall within a range of a little under a meter in length and height. Although variations in casting thickness and timber slots are apparent, it seems to indicate that all of the recovered Egadi rams belong to the same class of ship.

TABLE 1

Basic Measurements of the Egadi Rams (1-11), the Egadi 9 was excluded due to lack of available measurements (Tusa and Royal 2012: 18-19)

Weight (kg)	Max Height of Ram Head	Upper Fin Width	Middle Fin Width	Lower Fin Width
167.8	24.7	41.5	40.5	39.5
75.8	22.6	x	30.4	31.8
184.5	24.9	37.0	38.4	36.8
130.5	24.4	37.0	35.7	34.0
57.4	26.5	33.4	33.2	30.0
154.0	26.0	39.8	40.6	41.5
164.0	26.0	38.0	39.0	38.0
141.4	27.5	40.0	39.5	39.3
162.5	25.8	38.5	39.7	37.5
x	23.5	40.0	39.4	40.8

Artifact Name	Max. Length of Ram (cm)	Max. Height (cm)
Egadi 1	84.0	81.5
Egadi 2	75.6	x
Egadi 3	85.0	73.0
Egadi 4	93.5	65.6
Egadi 5	64.0	x
Egadi 6	100.9	67.1
Egadi 7	74.0	x
Egadi 8	86.1	64.2
Egadi 10	80.9	70.5
Egadi 11	83.8	63.3

The Athlit and Acqualadroni Ram

The best data relating to the construction of ram bow timbers remains the Athlit ram (Casson and Steffy 1995). The Athlit ram is considerably larger in size in comparison to the Egadi 10 ram, with a 2.26 m maximum length, 76 cm maximum width, 96 cm maximum height. With a weight of 465 kg, it is over twice as large (Steffy 1995:10). Its bow timbers, consisting of twelve different timbers and fastener arrangements, form a complex interlocking system meant to withstand forces generated during ramming. The discovery of the Acqualadroni ram, in 2008 near the straights of Messina, provided archaeological evidence of a simpler bow timber arrangement that consists of only five separate timbers (Buccellato and Tusa 2013:79–81). The Acqualadroni ram is smaller than the Athlit, weighing about 300 kg and measuring 135 cm in maximum length, 90 cm maximum height, and 62 cm in maximum width (Buccellato and Tusa 2013:77).

Although the interior timber arrangements of the Athlit and the Acqualadroni rams are similar, having two separate sources of information provided greater context for the projection of the Egadi 10 bow timbers. While the Egadi rams are similar in size and share the same structural design, only the Egadi 10 has yielded any significant samples of timbers. The Acqualadroni ram is much closer in size to the Egadi 10 and might provide a more accurate but not definite example of bow timber arrangements for smaller rams.

Shipwrecks

A series of roughly contemporary shipwrecks provided archaeological examples of ship building traditions in order to extrapolate and justify the basic construction features of the Egadi 10 hull. The wrecks used in this research are representative of shell-based pegged mortise-and-tenon shipbuilding traditions of the ancient Mediterranean. Selection of specific wrecks relied on chronological and geographical proximity to Rome and Carthage during the mid-3rd century B.C. Wrecks from later dates were selected to supply correlative data between larger vessels and their scantling dimensions.

The Ma'agan Michael wreck (Linder 1989; 1992; Kahanov 1991) and the Kyrenia Ship (Steffy 1985) were chosen based on their hull preservation and subsequent reconstructions (Zeev at al. 2009; Steffy 1985; 1994:42–59). Although the Ma'agan Michael dates between the 5th and 4th centuries B.C., its inclusion is justified because it represents building tradition of edge joined planking with pegged mortise-and-tenons, along with a framing system consisting of alternating half frames and floor timbers.

The Kyrenia Ship remains the best contemporary example of merchant shipbuilding during the 3rd century B.C. Its extensive hull remains and reconstructions provide a comprehensive example of merchant vessel construction from the ancient Mediterranean world. Although the scantling dimensions of the Egadi 10 warship cannot be directly determined, the Kyrenia Ship provided the best example of contemporary ship size to scantling ratios. These ratios are important because while the Kyrenia Ship's dimensions are too small to support the structure of a larger vessel, the ratio of ship size to scantling dimensions could be applied accordingly to a larger vessel.

Although the remains of the Marsala ship date to the 3rd century B.C. and were located less than 40 km from the Egadi Islands site, its use for this research remained limited. The excavation and subsequent studies conducted (Frost 1971; 1974) alleged that the finds constituted the remains of an oared warship. In recent years, those conclusions have come under scrutiny (Casson 1985; Dr. Jeffrey Royal 2015, pers. comm.), with potential to reclassify the vessel. Due to the limited evidence regarding the original context of the site and finds, only scantling data was used for the projection of possible timber dimensions. Further discussion and interpretation of the Marsala hull dimensions was omitted due to its complexity, which surpassed the intended scope of the present study.

The Capestillo site (Frey, Hentschel, and Keith 1978) was located off the coast of the Aeolian Islands near Lipari along the northeastern Sicilian coast. Dating between the 3rd and 2nd centuries B.C., its proximity to the Egadi Islands and its heavier construction features provided an example of a ship similar to the Kyrenia Ship but with larger scantlings. Although excavation of the wreck was limited to a 6 m square area, the survey was able to document between eight and ten contiguous strakes, eight frames, mortise-and-tenon joints, a large longitudinal timber measuring 30 cm in width by 6 cm thick, and a round wooden pole 7 cm in diameter. The heavier construction of the Capestillo ship was useful for this study because it provided a direct example of a vessel with larger scantlings from the 3rd century B.C.

Wreck sites selected from the 1st centuries B.C. and A.D. provided archaeological evidence of larger ship construction and the continuation of the Mediterranean shell-based ship building tradition. Their inclusion in this study relied on substantial intact portions of hull, detailed research and archaeological reports, and possible structural similarities to warship construction. The Madrague de Giens ship (Tchernia et al. 1978; Gianfotta and Pomey 1981), the Mahdia ship, and the Caesarea wreck were merchant vessels over twice as big as the Kyrenia and Capestillo ships. Dating from the 1st Centuries B.C. and A.D., the evidence from these wrecks provided detailed examples of larger scantling dimensions purposefully constructed to withstand higher stresses from greater cargos. These three hulls featured construction with two layers of pegged mortise-and-tenon planking combined with heavier frames. The incorporation of these wrecks into the research provided comparisons of different planking and thicker framing arrangements.

The Nemi Barges (Ucelli 1950) were large pleasure galleys built for the Emperor Caligula in the 1st century A.D. The large hull size of these two vessels (71 m and 73 m) goes well beyond the projected size of the Egadi 10 warship. Although these barges were not sea-going vessels, they did supply evidence of larger ship construction as well as the ability of Roman shipwrights to engineer unique structures for specific requirements (Steffy 1994:71). The scantlings from the Nemi Barges provided an example of the potential lengths and structural components of floating vessels that were specifically designed to carry heavy loads.

The Anse des Laurons 2 ship (Gassend, Liou, and Ximenes 1985) dates to the 2nd century A.D. and was incorporated into this study for the archaeological evidence it provided for upperworks and deck construction on Mediterranean vessels. The well-preserved wreck also provided evidence of a ship with a strong framing system, parts of rigging, and removable bulwarks (Steffy 1994:72). The Laurons 2 ship is also important because it reinforces the continuity of the shell-based ship construction tradition in the western Mediterranean into the early first millennium A.D.

All of the shipwrecks selected were merchant vessels with the exception of the Nemi Barges. Resulting from their need to carry loads of cargo under sail, these vessels were constructed to the specific requirements of the tasks they were commissioned for. Therefore, the dimensions and measurements provided by contemporary merchant vessels could not be directly applied to warship construction. Instead, scantling dimensions needed to be combined from larger ships of later periods in order to account for the greater stresses and weights exerted on warship hulls.

Shipsheds

Shipsheds are found all across the Mediterranean and, while exact dating of the shipsheds has been difficult, the ones at Carthage provided the best evidence of naval installations built for building, maintaining, and storing oared galleys in the western Mediterranean (Morrison and Williams 1968:181–186; Casson 1971:82). Using the Carthaginian shipsheds does not imply that the Egadi rams came from Carthaginian ships. Since there is historical evidence that indicates the Romans commandeered their warship designs from captured Carthaginian ships, it seems likely that their warships closely resembled each other during this period.

Studies conducted on sedimentation, backfill, and construction aspects along with historical accounts provided by Appian and Strabo placed the final stone harbor installation at Carthage in a mid-3rd century to mid-2nd century B.C. range (Hurst and Stager 1978:342–344; Blackman 2013:157). A description by Appian (*Libyca*, 14.96) dating to 146 B.C. remains the most detailed account of the Carthaginian harbor:

> The harbor had communication with each other, and a common entrance from the sea seventy feet wide, which could be closed with iron chains. The first port was for merchant vessels, and here were collected all kinds of ships' tackle. Within the second port was an island, and great quays were set at intervals round both the harbor and the island. These embankments were full of shipyards

> which had capacity for 220 vessels. In addition to them were magazines for their tackle and furniture. Two Ionic columns stood in front of each dock, giving the appearance of a continuous portico to both the harbor and the island. On the island was built the admiral's house, from which the trumpeter gave signals, the herald delivered orders, and the admiral himself overlooked everything. The island lay near the entrance to the harbor, and rose to considerable height, so that the admiral could observe what was going on at sea, while those who were approaching by water could not get any clear view of what took place within. Not even incoming merchants could see the docks at once, for a double wall enclosed them, and there were gates by which merchant ships could pass from the first port to the city without traversing the dockyards. Such was the appearance of Carthage at the time. (14.96)

The earliest phases of potential harbor structures and human-made navigational channels at Carthage date between the 5th and 4th centuries B.C. (Hurst and Stager 1978:337–341). Archaeological excavations at the site determined various stages of harbor construction, with a final stone harbor dating between the 3rd and 2nd centuries B.C. (Hurst 1978; Hurst and Stager 1978:341–342). Timber harbor structures were excavated below the final stone layer providing evidence of earlier harbor installations dating between the 4th and 3rd centuries B.C. (Hurst 1979:23–28). Although construction dates are disputed, the shipsheds at Carthage were the most accurate evidence of harbor structures used to build, house, and maintain the warships that took part in the Battle of the Egadi Islands (Figure 24).

The breadth of the perimeter shipsheds measured 5.2 m at the bottom and 6.6 – 6.7 m at the interaxial width (halfway along the long axis of the sheds) (Blackman 2013:310). The shipsheds on the central island had twenty two sheds with lengths ranging from 27 to 35 m and two larger sheds measuring 44 m and 47 m in length (Blackman 2013:311). These sheds had an average width of 5.30 m, while two larger sheds had widths of 7.30 m (Blackman 2013:311).

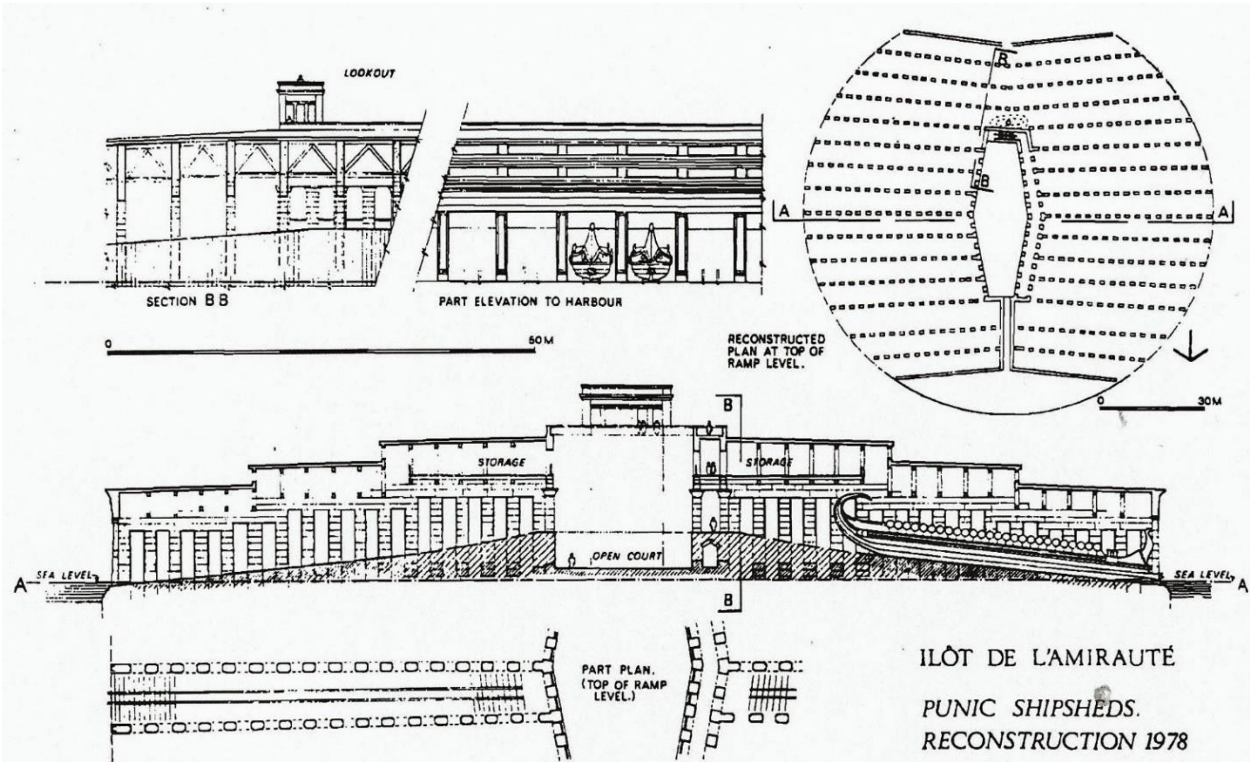

FIGURE 24. Reconstruction of the Punic shipsheds at Carthage (Hurst 1979:30)

The lengths and beams of the most common shipsheds provided the best possible dimensions for warships during the mid-3rd century B.C. Polybius' (1.47) remark that the later Roman warships were produced based on Carthaginian designs provided a connection with the harbor installation that built and launched Carthage's fleets. These shipsheds are also the closest geographically and chronologically to the Battle of the Egadi Islands, which allowed for their use in determining an average length and beam based on the most common slips.

Historical Sources Regarding Warship Construction

For the purpose of this study, Theophrastus and Vegetius provided valuable historical information pertaining to shipbuilding and naval operations. These sources were not included in the comparative studies because they did not directly provide information on events concerning the First Punic War. However, inclusion of these sources provided a historical context that aided in the reconstruction and analysis of the Egadi 10 warship.

Theophrastus (371–287 B.C.) was a Greek naturalist, philosopher, and successor to Aristotle at the Lyceum. In his *Enquiry into Plants*, Theophrastus (*HP* 5.7.1–3, 5.7.5) attempted to create the first classification of trees, shrubs, and other plants through the examination of their appearance and properties. In Book 5, Theophrastus wrote that fir, pine, and cedar were the preferred timbers used for shipbuilding. Silver fir was especially sought after for warship construction (5.7.1–3).

Vegetius served in the imperial bureaucracy during the late 3rd or early 4th century A.D. (Milner 1993:xxv–xxix). Although he wrote his technical treatises much later, they aided in discerning certain Roman naval traditions. Book 4 of *The Epitome of Military Science* (4.32–46) provided information on various aspects of naval warfare including the hierarchy of officers, shipbuilding, navigation, and tactics.

According to Vegetius (4.32), each warship had a single captain (*navarchus*) described as a merchant ship owner (*navicularius*) in charge of training the oarsmen and marines. He listed cypress, pine, larch, and fir as the common timbers used in construction with bronze fasteners due to their resistance to corrosion (4.34). His discussion of naval tactics described warships as fighting platforms for marines (4.44–46). However, he does mention warships relying on well-trained oarsmen's ability to carry out maneuvers that could result in ramming (4.43).

These accounts provided valuable supplementary evidence of the construction and organization of the warships that took part in the Battle of the Egadi Islands. Recommendations for types of timbers allowed the reconstruction to compare potential construction materials. The organization of crews to their captains provided information relating to naval organization.

Conclusion

Shipwrights tasked with building fleets of warships must have worked with a set of traditional scantlings, rules, and key measurements (Morrison, Coates, and Rankov 2000:207). The similarity of the sizes, forms, and interior dimensions of the Egadi rams supports this claim. However, without further evidence of hull construction, a partial or contributory reconstruction is limited to the extrapolation of general dimensions and assembly processes from archaeological evidence present in the traditions of shipbuilding found in merchant vessels and hinted at by shipsheds.

The projection of scantling dimensions necessitated consultation of shipwrecks with greater hull preservation. Dimensions needed to be larger than contemporary wrecks in order to support the structural dimensions of a warship. Larger vessels from later periods provided correlative data between ship size and timber dimensions. The projections of hull timbers was intended to guide research and present possible displacement and weighting properties. Until direct archaeological evidence of a warship hull is discovered, there will be no way to determine complete details of hull construction.

Chapter 5: A Conjectural Three-Dimensional Reconstruction of the Egadi 10 Warship

Introduction

The theoretical divisions of design, assembly sequence, and structural philosophy (Hocker 1998:6) provided a framework for organizing and orienting the reconstruction process, allowing for detailed analysis of various aspects of the hull and its cultural context. The Egadi 10 vessel was part of a greater shipbuilding ideology, producing ships that could effectively employ ramming attacks to sink or incapacitate enemy vessels. Initial inspection of the Egadi 10 ram during the 2014 field season strongly suggests that the Egadi 10 ram belonged to a Roman warship. Now that all the evidence has been presented, this chapter will present the reconstruction and hydrostatic testing results of the hypothesized hull of the Roman Egadi 10 warship.

This research relied on three-dimensional computer modeling to examine, through digital reconstruction, construction aspects and seaworthiness of the Egadi 10 warship. Rhinoceros and Orca3D provided software platforms that allowed for experimentation with interactive models that could be quickly modified and retested. The great advantage of using this software over hand-based drawing was the ability to quickly change and alter hull shapes while producing highly accurate hydrostatic tests.

Before three-dimensional modeling began, a preliminary lines drawing of the Egadi 10 was drafted by hand in order to become familiar with the characteristics and construction features of contemporary hulls (Figure 25). This initial drawing indicated areas of the hull that required specific supplementary evidence and determined the critical measurements that needed to be gathered for the best possible data set. The lines drawing was completed before fieldwork began. This drawing used the Egadi 4 ram to estimate hull parameters, specifically focusing on

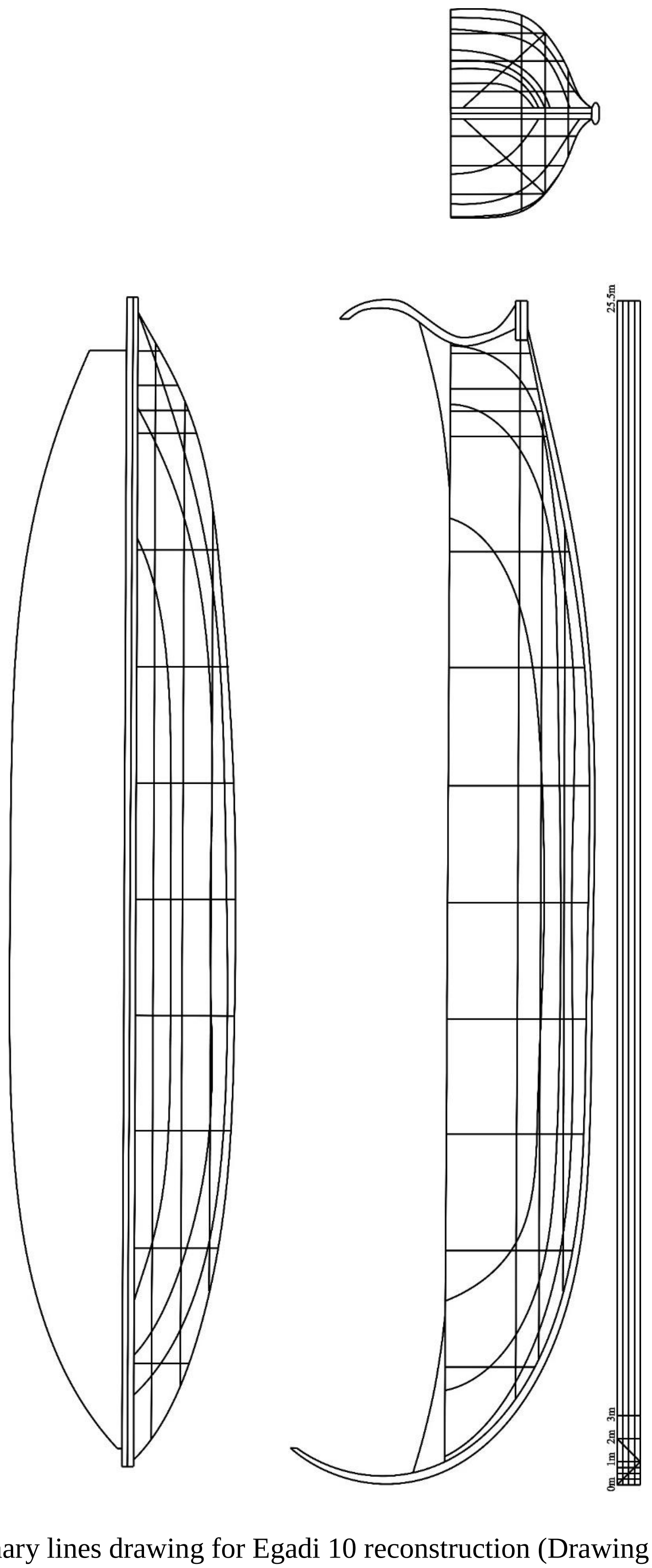

FIGURE 25. Preliminary lines drawing for Egadi 10 reconstruction (Drawing by author, 2014)

stem, keel, and wale dimensions. It highlighted areas of importance, specifically in the collection of measurements from the ram, in order to produce the best possible data for timber extrapolation.

Reconstructing the Bow Structure

The process of reconstruction began with the direct evidence of the Egadi 10 warship: the data provided by the ram itself. The most complete structural evidence of the Egadi 10 warship

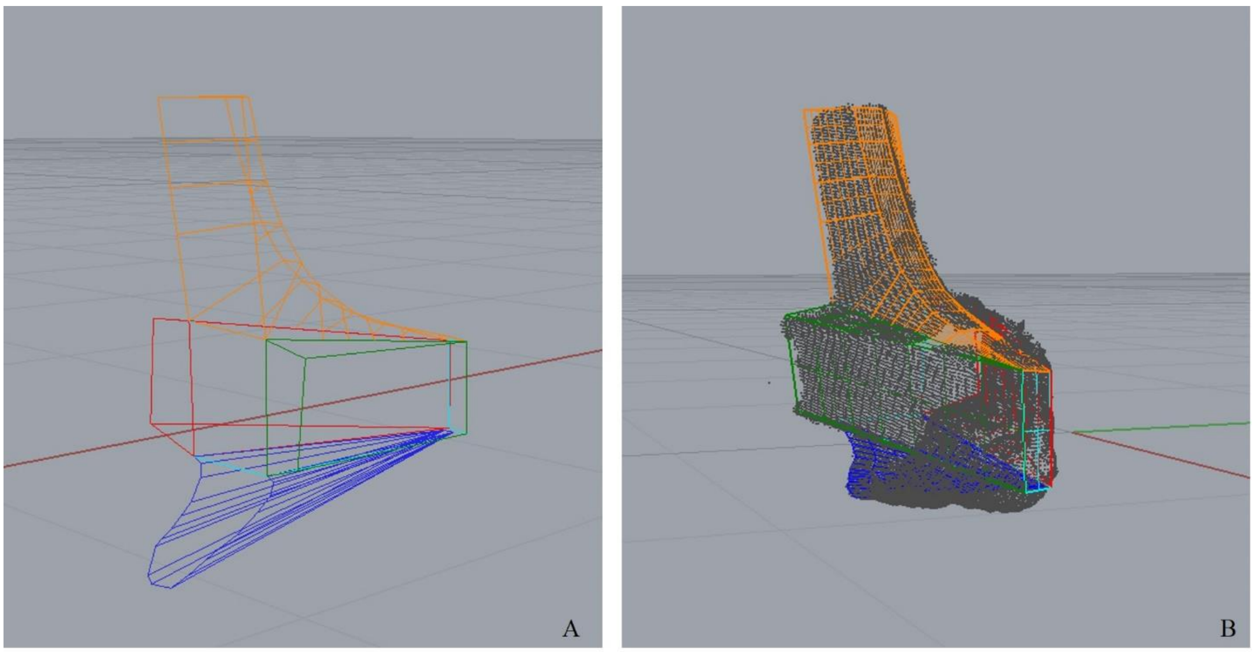

FIGURE 26. Modeling ram and bow timber in Rhinoceros (*a*) Initial lines and measurements taken by hand (*b*) Combining measurements with scan of Egadi 10 interior (Created by author, 2015)

were the interior dimensions of the ram. The first step was the extrapolation of bow timbers. Three-dimensional modeling began by importing the scan of the Egadi 10 ram into Rhinoceros and converting the file from a mesh into a point cloud (Figure 26). The measurements taken by hand were compared with the point cloud generated by the three-dimensional scan in order to adjust the model within 1 mm of variance. Since only small fragments of wood remained inside the ram, the reconstruction of the interior relied upon the shapes of the sockets. Since the ram

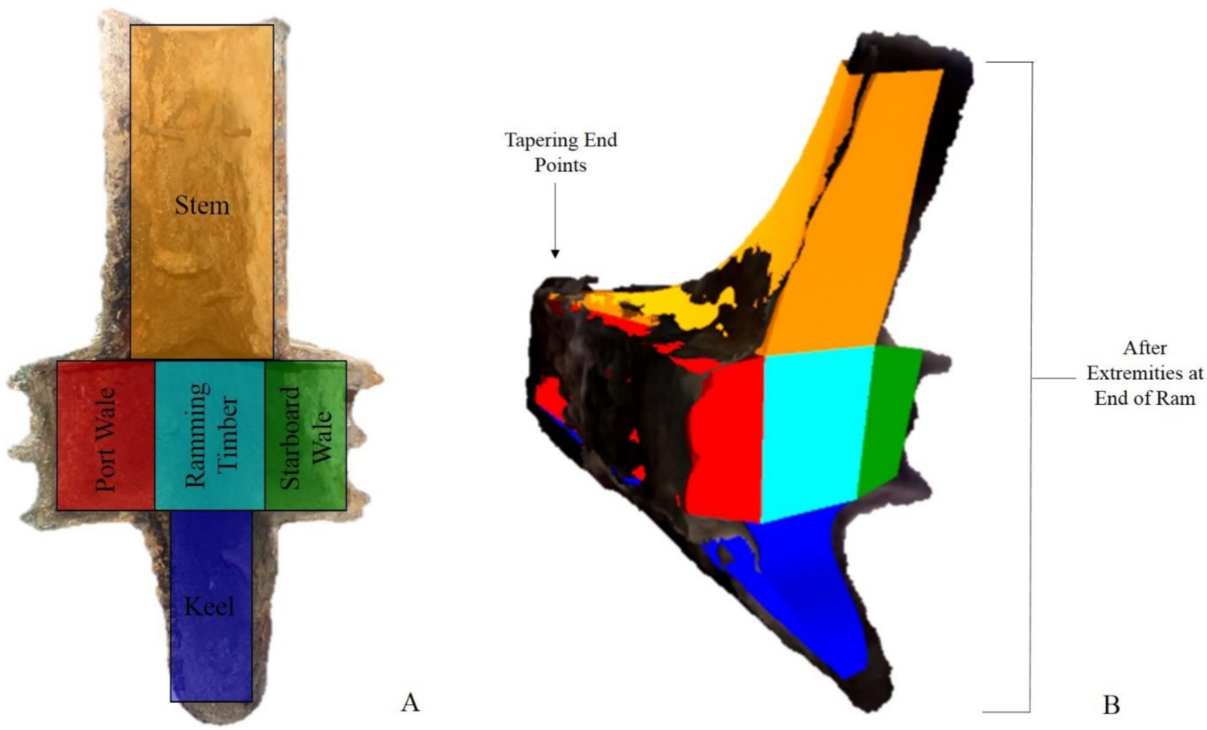

FIGURE 27. Bow timbers as they are reconstructed within the Egadi 10 Ram (a) Arrangement of bow timber at the exit of the ram (b) Isometric view of the interior ram scan and reconstructed timbers (not to scale) (Created by author, 2015)

was cast onto the bow timbers directly in order to provide the best possible fit, the interior contours provided enough substantial evidence to accurately determine the basic timber structures, as per the evidence of the Athlit casting analysis (Eisenberg 1991: 40–50). Using Rhinoceros' polyline function, the timber sections were individually constructed and assigned their own colors for easier distinction: Stem-Orange, Starboard Wale-Green, Ramming Timber-Teal, Port Wale-Red, Ram-Blue (Figure 27). The dimensions of the timbers inside the ram are given at their after extremities at the exit of the ram and at their tapering end points inside the ram (Table 2).

TABLE 2

Bow Timber Dimensions Reconstructed from the Egadi 10 ram Interior

	Maximum Length within Ram (cm)	Molded Dimension at Exit of Ram (cm)	Molded Dimension at Forward End (cm)	Sided Dimension at Exit of Ram (cm)	Sided Dimension at Forward End (cm)
Keel	70.0	14.5	4.0	13.7	10.0
Ramming Timber	54.5	20.5	16.0	52.0	4.0
Starboard Wale	61.0	19.9	16.0	8.0	2.0
Port Wale	60.5	20.5	16.0	11.0	2.0
Stem and Chock	57.2	35.5	4.0	16.3	4.7

The structure of an ancient ramming warship was one of its most important components. The ability of the bow to deliver and withstand ramming attacks was paramount to its ability as a lethal warship. The Egadi 10 ram is very similar in size to the other rams recovered at the site (Table 1), meaning that the warships that sank at the battle belonged to a certain class of vessel. About half the size of the Athlit and the Acqualadroni rams, the Egadi 10 belonged to a much smaller class of ship that would have been dwarfed by the warships that held the Athlit or Acqualadroni rams.

Hull Forms

Since the bow timbers provided the only direct archaeological evidence, it was then necessary to introduce secondary evidence in order to define a hull shape that conformed to the dimensions established through archaeological research. The hull form of the Egadi 10 warship was confined by constraints that would allow it to attain its intended performance characteristics. The maximum extent of the hull was limited by the sizes of the 218 Carthaginian shipsheds which measured between lengths of 27 m to 35 m and beams of 6.6 m to 6.7 m. However, it is important to keep in mind that the ships needed to be smaller than the maximum extents of the shipsheds and there needed to be enough room for crews to repair the hulls. As a result a maximum of length of 31 m and beam of 5.5 m was determined to guide the initial design of the hull. The two larger shipsheds at Carthage were omitted because they were likely used for larger capital ships.

Although the Egadi 10 is most likely a Roman vessel that sank during the battle, Polybius' (1.59) account of the Romans using a captured Carthaginian *quadreme* as a model for their ships allows for the use of the Carthaginian shipsheds for basic dimensions. The vessel's draft was limited by its need for speed and maneuverability and by the placement of the ram, which roughly needed to sit at the waterline. The hull design required it to be able to function during battle as a lightweight war galley, but it also needed to carry supplies, troops, and make short overseas voyages. The Egadi 10 warship needed to be versatile without sacrificing its functionality.

Length to Beam Ratios

A rowed galley needed to be long, slender, and of shallow draft relative to its displacement in order to reach optimum performance (Coates 1995:128). Hulls with long displacement and low drafts reduced the resistance created as the ship traveled through the water while optimizing oar system propulsion. On the other hand, lateral stability for sailing and accommodation of oarsmen required a sufficient breadth. The design of the Egadi 10 reconstruction needed to provide a practical balance of combat capability and performance under oar and sail while maintaining hull integrity and seaworthiness.

The reconstruction relied on length to beam ratios between 6:1 and 7:1, based on the necessary hull coefficients determined by Coates (1995:128–129) and Steffy (1991:29–39) and the sizes of the shipsheds at Carthage. The most effective oared warships minimized the wetted area of the hull while maximizing the number of effective rowing spaces, translating into long hulls with minimal waterline depths. These ratios are vital factors in keeping a ship's effectiveness in the water. Since warships relied on speed and maneuverability, these factors would have been a priority to the ancient shipwright. They are found on the 1st century A.D. Oberstimm vessel (Hockmann 1990; 1991) and the Mainz vessels (Hockmann 1993), which were oared river galleys built by the Romans for their northern imperial conquests. These ratios are also present cross-culturally on oared galleys like the later medieval galleys of the Mediterranean (Alertz 1991: 144–148) and the Norse Skuldelev ships (Olsen and Crumlin-Pedersen 1978).These ratios needed to be maintained through the course of the hull design in order to produce a viable rowed warship.

Combining the dimensions of the Carthaginian shipsheds and the necessary length to beam ratios the final hull design was reconstructed with a 28.71 m length and a 4.42 m beam. This resulted in a 6.5:1 length to beam ratio and would allow the vessel to be safely berthed and repaired within the confines of the shipsheds.

The Lines Drawing

With the general hull constraints determined, the stem was extrapolated in order to provide an end point to create a loft of the surface of the hull to the interior of the planking. The stem was extended from the dimensions taken from the interior of the cowl of the Egadi 10 ram. Since no archaeological evidence was available to determine the shape of the stem, the extension of the stem past the ram was conjectural and was based on estimates taken from the Athlit ram and given the curving shape seen in numerous depictions of contemporary warships including the Carthaginian tomb relief, the Tiber Island ship, and Roman coins depicting the bows of warships (Morrison 1995: 67; Casson 1978: figure 107, 120–123).

After several control point adjustments an initial surface, representing the interior of the planking, was generated using the Orca3D naval architecture plugin for Rhinoceros. The *Define*

Sections function was used to generate a series of station lines along the length of the lofted surface. For the purpose of this reconstruction, sections were projected every meter along the length of the keel rabbet, resulting in a total of 28 stations. The length and beam of the vessel was maintained by factoring in the necessity of allowing the maximum number of rowers within the dimensions provided by the Carthaginian shipsheds. For this reason while the bow of the vessel was sleeker and more finely shaped, the stern was designed with a rounder shape. This allowed for a greater number of rowers in the aft section while preserving the length to beam ratio of the hull.

The displacement of a vessel is the weight of the volume of water displaced by the underwater portion of the hull and equals the weight of the ship at a given waterline. In order to produce more comprehensive hydrostatic results and a better understanding of the vessel's displacement, two waterlines were set at the middle fin of the ram (1.25 m) and at the top fin of the ram (1.35 m). Both waterlines allowed the ram to act as a cutwater while remaining in an optimal striking area against another hull. Testing two different waterlines provided comparative data of two possible displacements resulting in a better hypothesis of crew capacities. Additional waterlines were generated every 0.25 m below the 1.25 load waterline, but only the two hypothetical load water lines were analyzed for displacement purposes. Four buttock lines were generated every 0.5 m, between 0.5 m and 2 m along the hull.

Each surface was individually projected between a select set of lines using the loose loft function or the various surface creation options offered in Rhinoceros. The process of editing control points and creating lofts between curves was repeated multiple times in order to create a fair hull shape. Once the keel, rabbet lines, and main wales were determined, section lines were constructed using shapes determined from the hull plans of contemporary Mediterranean

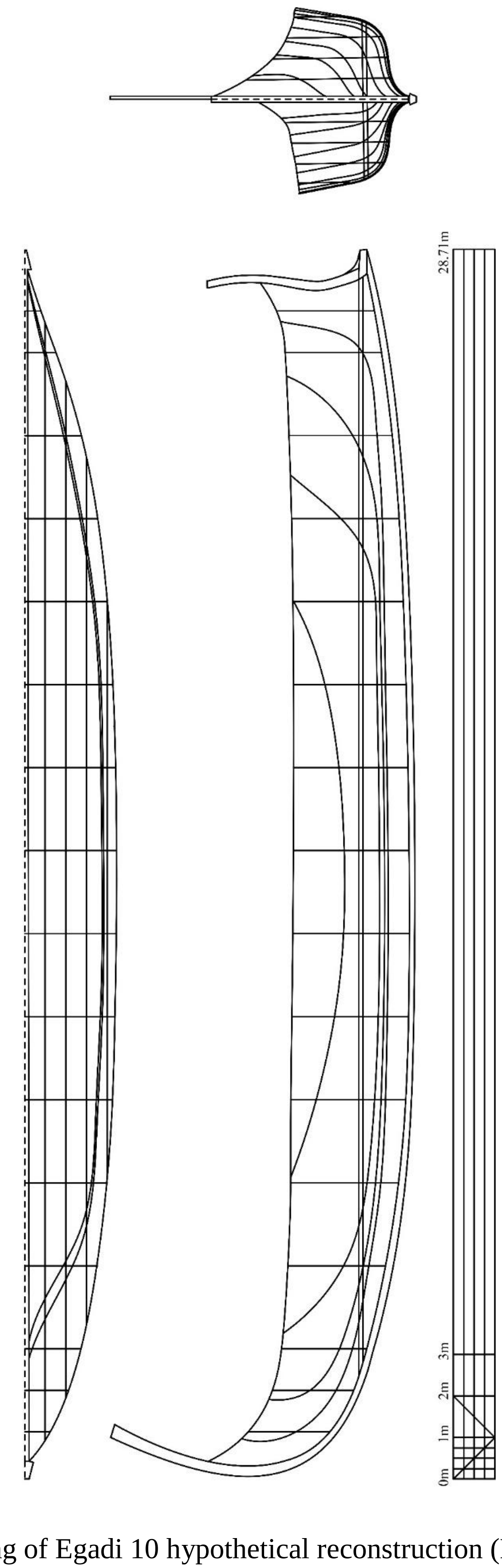

FIGURE 28. Lines drawing of Egadi 10 hypothetical reconstruction (Drawing by author, 2016)

construction. The wine glass shape, as it is commonly referred to, is the most common hull type found in the ancient Mediterranean. This shape is found on hulls as early as the Ma'agan Michael shipwreck (Steffy 1991: figure 3–21), to the Kyrenia Ship (Steffy 1991: figure 3–32), and the larger ships of later periods like the Madrague de Giens (Pomey 1978: plate 36).

All lines are shown to the interior of the hull planking. A total of 16 sections line were spaced two meters apart, apart from two sections lines at the bow and three at the stern which were spaced a meter apart, and fit between the keel rabbet and the projected wales. The turn of the bilge was constructed in order to align as closely to the main wales as possible to provide the greatest amount of support to the area of the hull experiencing the greatest amount of longitudinal stress represented by the submerged area of the sections of the hull (Figure 28). Table 3 summarizes the principal dimensions of the reconstructed Egadi 10 hull, while Table 4 presents the results of hydrostatic analyses of this hull shape.

TABLE 3

Principal Hull Dimensions

	Lower Load Waterline	Higher Load Waterline
Length Overall (m)	28.71	28.71
Maximum Beam (m)	4.42	4.42
Length on Waterline (m)	25.83	26.14
Beam at Waterline (m)	3.72	3.8
Draft (m)	1.25	1.35
Freeboard (m)	3.49	3.59

TABLE 4

Hydrostatic Calculations

	Lower Load Waterline	Higher Load Waterline
Displacement in Salt Water (Metric Tons)	32.3	39.8
Waterplane Area (m^2)	71.17	74.75
Prismatic Coefficient	0.62	0.62
Block Coefficient	0.32	0.34

Midship Coefficient	0.52	0.55
Length to Beam Ratio	6.95	6.5
Beam to Draft Ratio	3.64	3.4

Structural Design

This section presents an interpretation of the Egadi 10 warship's construction, based on the Egadi 10 ram, contemporary vessel construction, texts, and iconography. While hypothetical in nature, the purpose of this interpretation is to serve as a means to generate hull weights that can then be tested to determine the most likely size of the Egadi 10 ship's crew. This, in turn, will help to answer the research question concerning the most likely type of vessel represented by the Egadi 10 ram.

The Egadi 10 warship would have been constructed in one of the shipyards operated by Rome during the First Punic War. These warships were part of a massive building program the Romans established to combat the Carthaginians. The Roman fleet at the Battle of the Egadi Islands was a purpose built fleet of fast ramming warship funded by taxation and the private citizenry of Rome (Polybius 1.59). This section will provide the structural components and their corresponding dimensions and weights from evidence collected from selected shipwrecks and additional archaeological sources.

A detailed construction plan was determined to be unnecessary for the purposes of this study because it would not be able to generate any definitive information that could not be modeled through the calculations of the Orca 3D program. Instead of spending time attempting to reconstruct the interior features of rower stations and upper structures, the reconstruction focused on the general dimensions of the ship and their comparison to the accounts provided by Polybius (Figure 29). The *Olympias* trials provided excellent information of possible rowing arrangements and physical analyses of rower potential as well as the human engine that powered the Egadi 10 vessel.

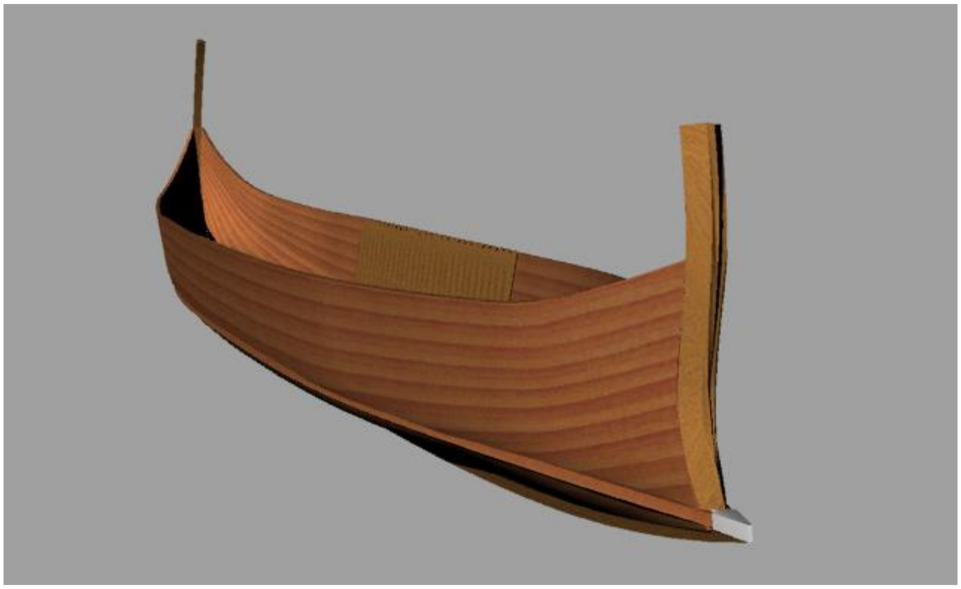

FIGURE 29. Egadi 10 with projected construction features (texture does not represent actual planking) (Created by author, 2016)

Materials

The materials needed to construct the Egadi 10 warship influenced the construction parameters of the vessel. Theophrastus (*HP* 5.7.1–3) provides the most direct information concerning the types of preferred shipbuilding timbers:

> Fir (*elate*), mountain pine (*peuke*), and cedar (*kedros*) are the standard ship-timbers. Triremes and long ships are made of fir because it is light, while round ships are made of pine because it does not decay. Some people, however, make their triremes of pine also, because they have no adequate supply of fir, while in Syria and Phoenicia they use cedar, because they are short of pine as well as fir. In Cyprus they use coastal pine (*pitys*) which grows in the island and seems to be of better quality than mountain pine (*peuke*). These woods are used for the main timbers, but for the trireme’s keel oak is used because it has to stand up to the hauling… They make the cutwater and catheads, which require special strength, of ash, mulberry, or elm. (5.7.1–3)

Fir was the most abundant timber found in the higher altitudes of Greece and Italy. The common European fir, or silver fir (*Abies alba*), was the dominant species found in the Apennine Mountains (Meiggs 1982:43). The silver fir is rarely found growing below 800 m and is desirable because it is light and less prone to knots, allowing for longer lengths of timbers (Meiggs 1982:119). In order for Rome to obtain the necessary timbers for ship construction, it needed to control or trade with as well as protect the areas that could produce those species.

Luckily, due to Rome's recent conquest of the Italian peninsula, fir and pine were abundant in the regions of Etruria and Umbria. On the other hand, the North African coast supplied Carthage with an abundance of oak, Aleppo pine, and cedar (Meiggs 1982:14–142). Combining the wood fragments recovered from the Egadi 10 ram and historical accounts, it was possible to interpret the vessel's component timbers with a high degree of confidence. The selected timber for components are discussed individually with each structural component. In addition to timbers, the shipbuilders also needed metal ores in order to produce the ram as well as the fasteners that held some components of the ship together.

Joinery and Fastening

The integrity of a long shell-based ship depended on tightly fitting pegged mortise-and-tenon joints, preventing planks from sliding against each other by carrying the shear forces exerted along the plane of the hull (Morrison 1995:131; Ulrich 2007:60). Similarly, joint and fastener placement required practical knowledge of the stress and forces exerted upon the hull. The construction of a large warship demanded intimate knowledge of the smallest components that held the ship together.

Mortise-and-tenon joints acted as a cohesive network providing strength and protection to the warship. Tenons held in place by oak pegs distributed lateral and longitudinal stresses, acting like thousands of internal frames throughout the hull (Steffy 1985:90). Therefore, their placement required careful calculation and marking. In order for the mortise-and-tenon structure to work, tenons needed to be fashioned from hard oak, spaced regularly, and tightly fitted in order to resist the crushing stresses exerted upon them. Treenails and pegs made of hardwoods expanded when impregnated with water, providing better grip and watertightness.

TABLE 5

Mortise-and-Tenon Dimensions of Selected Vessels

Shipwreck	Wood Type	Width x Thickness (cm)	Depth of Mortise (cm)	Average Spacing (cm)
Ma'agan Michael	Oak	3.5 x 0.6	6.75	12.5
Kyrenia	Oak	4.3 x 0.6	9.0	12.0
Marsala	Oak/Maple	– x 0.9	-	-
Capestillo	Oak	5.0 x –	6.0	17.25
Athlit Ram	Oak	7.5 x 1.1	10.25	11.7
Madrague de Giens	Oak	5.6 x 0.7 / 8.3 x 1.4	9.4	15.0
Mahdia	Olive/Acacia	12.0 x 1.2	-	7.0
Caesarea	Oak	8.5 x 1.1	10.9	13.5
Anse des Laurons 2	-	7.5 x 1.0	12.7	11

As shown in Table 5, mortise-and-tenon joinery was fairly uniform in ships from the ancient Mediterranean. Tenons were constructed of oak or other hard woods and are similar in width, thickness, length, and spacing relative to the ship's size. While contemporary tenons averaged 4.2 cm wide, 0.6 cm thick, and were spaced approximately every 12.0 cm center to center, tenons from the Athlit ram were wider, thicker, and more closely spaced. Tenon sizes from the Marsala ship were tested during the construction of the *Olympias* and could not hold up to the stresses anticipated by the design team (Morrison, Coates, and Rankov 2000:201). Based on these figures, a reasonable interpretation of the Egadi 10 tenon dimensions is about 5.0 to 5.5 cm wide, 1.0 cm thick, spaced 10.0 cm apart (Table 6).

TABLE 6

Tenon Dimensions of Egadi 10 Reconstruction

Wood Type	Width (cm)	Thickness (cm)	Spacing (cm)
Oak	5.0-5.5	1.0	10.0

In addition to pegged mortise-and-tenon joints, the planking of ancient Mediterranean vessels was joined into strakes by diagonal scarfs. Scarfs were well suited to resist the tension exerted on horizontal connections (Ulrich 2007:60).

The frames and the ram were held in place by metal fasteners and treenails. Bronze and copper nails were favored because they were known to last longer than iron fasteners in the water (Vegetius 34). This is corroborated by archaeological evidence from the selected shipwrecks (Table 7).

TABLE 7

Fastener Types Found in Selected Vessels

Shipwreck	Fastener Metal Type	Treenails Wood Types	Clenched Nails Driven Through Treenails
Ma'agan Michael	Iron	-	Iron
Kyrenia	Copper	Pine	Copper
Marsala	Bronze	Oak	Iron/Bronze
Capestillo	Copper/Iron	-	-
Athlit Ram	Bronze	-	Bronze
Acqualadroni Ram	Lead/Copper	-	-
Madrague de Giens	-	-	-
Mahdia	Copper	-	-
Caesarea	Copper Bronze	Oak	Bronze
Nemi Barges	Copper	Pine/Fir	Copper
Anse des Laurons 2	Copper/Bronze	-	-

A copper fastener measuring 13.7 cm in length and 7.0 cm thick found inside the Egadi 10 ram and the remains of bolts 9 and 10 (Figure 14) support the use of bronze and copper fasteners. The pattern of fasteners used to hold the ram at the bow is available due to the bolt holes in the bronze ram itself. The bolt holes in the Egadi 10 ram demonstrate that the ram was attached to the stem, wales, and keel with five bolts per side. The fastening pattern of the Egadi 10 ram provide the best direct evidence of assembly and spacing of fasteners of the bow timbers. However, without greater hull preservation of any ancient warship, it was not possible to determine the exact fastening pattern of the Egadi 10 hull.

The Keel

The keel of a Roman warship was the first and most important element of the ship's construction. In order for the ship to achieve its intended performance ability, the keel needed to be designed and hewn correctly to receive and support planking, wales, and frames. A warship keel served as the equivalent of the backbone of a floating missile, propelled by rows of oarsmen over open seas, delivering direct ramming attacks.

A keel over 15 m long would be hewn from three to four timbers due to limitations of tree sizes. The main length of the keel was cut from a single long timber between 15 to 17 m in length, to which the rising forward and aft sections of the keel were joined to by *trait de Jupiter* (bolt of lightning) scarfs. This type of scarf provided a strong self-locking joint in which the two timbers were joined with a diagonal hook scarf reinforced by a peg driven vertically through the middle. It would be ideal for a warship which would be subject to compression during ramming attacks (Morrison, Coates, and Rankov 2000:207).

TABLE 8

Keel Dimensions of Selected Vessels

Shipwreck	**Date (century)**	**Wood Type**	**Length (m)**	**Sided (cm)**	**Molded (cm)**	**Cross Sectional Area (cm^2)**
Ma'agan Michael	5th/4th B.C.	Pine	8.25	11.0	16.0	176
Kyrenia	4th/3rd B.C.	Pine	9.33	13.0	20.3	263.9
Marsala	3rd B.C.	Oak	-	-	-	-

Capestillo	3rd/2nd B.C.	-	-	-	-	-
Athlit Ram	2nd B.C.	Pine	-	20.0	32.0	640.0
Acqualadroni	2nd B.C.	-		18.0	24.0	432.0
Madrague de Giens	1st B.C.	Elm	40.0	35.0	40.0	1400.0
Mahdia	1st B.C.	Elm	-	-	-	-
Caesarea	1st A.D.	-	-	-	-	-
Nemi Barges	1st A.D.	-	-	20.0	30.0	600.0
Laurons 2	2nd A.D.	-	-	16.0	20.0	320.0

With maximum length determined using the 27 to 35 m lengths of the Carthaginian shipsheds, the forward dimensions of the keel were determined from the shape of the keel trough and the 164-degree downward angle of the Egadi 10 ram. Extrapolating the basic dimensions of the keel's size, shape, and rabbet relied on the traditional construction of keels evident in ancient Mediterranean shipwrecks (Table 8). The molded and sided dimensions, including the rabbet, were projected using measurements taken from the keel channel. As the keel extended aft, it tapered out slightly to a final sided dimension of 16.5 cm and 14.0 cm molded. This provided additional strength and is reflected in the surviving keels of merchant vessels such as the Kyrenia Ship (Steffy 1994:43).

During the trials of the *Olympias*, the builders noted that, in long ships, a rocker was only necessary towards the fore and aft sections of the keel (Morrison, Coates, and Rankov 2000:207). A slightly rockered keel would provide greater longitudinal support by reducing the sloping angle of the keel at either end and was better equipped to withstand and disperse the force of shock resulting from ramming (Dr. Jeffrey Royal 2014, pers. comm.). Tests conducted with the *Olympias* determined that a flat rise in the after portion of the keel was necessary to provide a surface upon which to haul the ship out of the water into shipsheds or along the shore. Therefore, the aft portion of the keel and sternpost were projected with a sharper and flatter rise.

Based on the keel fragment found, the keel of the Egadi 10 was hewn from oak. Oak was fitting for a warship keel because it provided greater longitudinal stiffness and greater tensile strength during ramming attacks. The rabbet of the keel was projected out to 6.5 cm in order to fit the thicker garboards and its angle was based on the 78-degree angles of the Kyrenia Ship (Steffy 1994: figure 3–25) and the Madrague de Giens wreck (Tchernia et al. 1978: figure 11). It is very likely that the keel was originally constructed from two to three sections, but the reconstruction utilized a single timber, as the number of segments did not matter for the purposes of hydrostatic calculations and weight analyses (Table 9).

TABLE 9

Keel Dimensions of Egadi 10 Reconstruction

Length (m)	**Wood Type**	**Sided (cm)**	**Molded (cm)**	**Angle at Exit of Ram**	**Cross Sect. Area (cm^2)**
17.0	Oak	16.5	14.0	164	231.0

Stem and Sternpost

The stem was extrapolated using the dimensions and angle of the cowling taken from the Egadi 10 ram (Table 10). At the point where the stem fit into the cowling it had a trapezoidal shape with a rabbet to receive the upper planking, secondary wales, and upper wales. The stem's thickness was reconstructed to 17.0 cm based on the projections of the stem in the ram cowling with an extra centimeter of additional support for shocks sustained during ramming attacks.

TABLE 10

Stem and Sternpost Dimensions of Egadi 10 Reconstruction

Timber	**Wood Type**	**Length (m)**	**Max. Width (m)**	**Max. Thickness (cm)**
Stem	Elm	3.5	33.0	17.0
Sternpost	Elm	12.85	21.0	31.0

The sternpost was briefly discussed in connection with the design of the keel. Although the Marsala wreck is claimed to be a warship (Frost 1973), even the architects of the *Olympias* admittedly decided that the straight sternpost from the wreck was not an acceptable shape for the warship. Thus, a longer, gentler slope was needed to reduce the effects of sagging at launch and to improve the flow of water across the length of the hull (Morrison, Coates, and Rankov 2000:197). The sternpost followed the gentle upward curve of the keel in order to provide the needed surface area for hauling and launching the vessel. The basic shapes of both the stem and sternpost also relies on iconographic evidence that shows fairly standard shapes of the prows and sterns of ancient galleys (Casson 1971: figures 119–133).

Planking and Wales

While Theophrastus' (5.7.1–3) account of timber types sought in warship construction favored the use of pine or fir, the best evidence of warship planking and pine wale construction remains the interior timbers of the Athlit ram (Steffy 1995:10–28). The effectiveness of a warship depended on its hull to withstand the stresses of hogging and sagging as well as ramming. In larger ships, maximum shell strength would be essential considering the greater effects of hogging and sagging. Closely spaced tightly fitting mortise-and-tenon joints would ensure that the stresses exerted along the lengths of the hull were distributed and supported accordingly.

Thicker garboards and lower strakes provided necessary support and in warships would have served as defense against penetration by an enemy ram. Six planks were recovered from the Athlit ram, averaging 4 cm thick except for the bottom two planks which were 7.5 cm thick (Steffy 1983:236). The main wales provided longitudinal support by taking the brunt of ramming impacts and dispersing them across a specifically designed network of planks and mortise-and-tenon joints. Secondary wales and upper wales were necessary for additional longitudinal support.

Using the collected information from hull remains, correlations between estimated original lengths, planking thickness, and timber types produced potential structural dimensions (Table 11). The Ma'agan Michael, Kyrenia, and Capestillo wrecks are fairly uniform in their length and softwood planking thickness. Both the double planked Madrague de Giens and the Mahdia hulls were constructed with hard deciduous woods with plank thicknesses of about 4 cm. The single planked Caesarea and the Nemi Barges employed soft woods with plank thickness of about 9.5 cm.

Table 11

Planking Thicknesses and Vessel Lengths of Selected Shipwrecks

Shipwreck	Date (century)	Planking Timber	Avg. Planking Thickness (cm)	Vessel Length (m)
Ma'agan Michael	5th/4th B.C.	Pine	4.0	14.4
Kyrenia	4th/3rd B.C.	Pine	3.7	14.0
Capestillo	3rd/2nd B.C.	-	4.5	20.0
Madrague de Giens	1st B.C.	Elm/Fir	4.0	38.0
Mahdia	1st B.C.	Elm	4.3	30.0
Caesarea	1st A.D.	Pine	9.4	40.0
Nemi Barges	1st A.D.	Pine	10.0	71.0
Anse de Laurons 2	2nd A.D.	Pine/Cedar	2.5	13.3

The results suggest that smaller shorter hulls, under 20 m in length, tended to use softwood like pine for planking. The double-planked Madrague de Giens ship was constructed with hardwood inner and softwood outer planking layers, while both layers of the Mahdia ship were of hardwood. On the other hand, the Caesarea hull and the Nemi Barges were constructed with a single layer of softwood planking that was twice as thick as the individual planking layers of the Madrague de Giens and Mahdia vessels.

It is therefore possible to state that large hulls measuring 30 m or more with a single layer were constructed with thick planking and mortise-and-tenons spaced no farther apart than their own width (Fitzgerald 1995:117). Ships built with single layers of planking and lengths of about 30 m or more were built with planking averaging about 9.7 cm thick. Double-planked hulls and hulls with lengths 25 m or smaller were constructed with an average planking thickness of 4 cm or slightly less. This small sample of shipwrecks highlights previous correlative studies of plank thickness and timber usage relative to hull sizes (Fitzgerald 1995:128–133).

It seems unlikely for a warship intended to be fast and light to be constructed with a double-planked hull. Although it could increase the hull's defense against a ramming attack, it would require greater resources and take longer to build a double-planked vessel. A double-planked ship would also require double sets of mortise-and-tenon joints, increasing the weight of construction materials which, in turn, would limit the ship's speed and its maneuverability. Since there is no archaeological evidence of thick 9 – 10 cm thick planking in the mid-3rd century B.C., potential planking thickness of the Egadi 10 warship needed to fall within a range of contemporary ship dimensions while factoring in comparative data regarding ship size to planking thickness ratios.

If the Egadi 10 was approximately 28.7 m in length with a beam of about 4.4 m, then it is probable that it would have been constructed with a single layer of planking, made of pine or fir averaging between 5.0 and 7.0 cm in thickness (Table 12). Garboards and bottom strakes were reconstructed with a 6.5 cm thickness in order to provide strength along the bottom of the hull. The wales were projected out to a maximum thickness of 12.0 cm and a maximum width of 21.0 cm and were constructed of pine following the dimensions of the Egadi 10 ram and the suggestions of using pine for warship planking by Theophrastus (HP 5.7.1–3) (Table 13). The larger size of the bottom stakes and the taper of the wales is also supported by the timbers of the Athlit ram (Steffy 1991:6–15).

TABLE 12

Planking Dimensions of Egadi 10 Reconstruction

Timber	Wood Type	Width (cm)	Thickness (cm)	Strake Length (m)
Main Planking	Pine	21.0-22.0	5.0	9.0
Garboards and Bottom Strakes	Pine	21.0	6.5	9.0

TABLE 13

Wale Dimensions of Egadi 10 Reconstruction

Timber	Wood Type	Width (cm)	Thickness (cm)	Angle at Exit of Ram
Port Wale	Pine	21.0	12.0	166
Starboard Wale	Pine	21.0	12.0	166

Frames

In order for a long, slender timber hull to withstand the physical stresses of rowing and ramming, it required reinforcement through a framing system that supplied additional longitudinal strength. Greek and Roman shell-based mortise-and-tenon built ships relied on a framing pattern of half frames alternating with floor timbers and futtocks, inserted along the length of the ship as the planking was built up. This framing system assisted the mortise-and-tenon joinery in dispersing hogging, sagging, and transverse stresses exerted along the length of the hull. The Ma'agan Michael, Kyrenia, and the Madrague de Giens hulls had framing sequences with paired floor timbers and futtocks alternating with half frames and top timbers. Frames were fastened to planking by clenched copper or iron nails driven through treenails from the outside (Table 14).

Floor timbers spanned the keel and generally extended approximately to the turn of the bilge, from there, futtocks extended up to the sheer. Half-frames did not cross the keel and generally extended from the lower strakes up to the sheer. The Egadi 10 reconstruction follows this pattern. It is likely that the frames of the Egadi 10 were chosen from naturally curved timbers (compass timbers), like the Kyrenia Ship's frames, to better fit the curvature of the hull (Steffy 1985:84). An estimate of 94 frame stations could fit along the length of the reconstructed hull.

TABLE 14

Framing Dimensions of Selected Vessels

Shipwreck	**Date (century)**	**Wood Type**	**Sided (cm)**	**Molded (cm)**	**Spacing (cm)**
Ma'agan Michael	5th/4th B.C.	Pine	-	-	75.0
Kyrenia	4th/3rd B.C.	Pine	8.0	8.0	25.0
Marsala	3rd B.C.	Oak/Maple	-	-	-
Capestillo	3rd/2nd B.C.	-	16.0	10.0	15.0
Madrague de Giens	1st B.C.	Oak/Elm/Walnut	14.0	13.0	23.0
Mahdia	1st B.C.	Elm	20.0	20.0	60.0
Caesarea	1st A.D.	Pine	18.0	26.0	25.0
Nemi Barges	1st A.D.	Oak	30.0	40.0	50.0
Laurons 2	2nd A.D.	Pine/Oak	17.0	9.0	55.0

Calculating an average frame spacing between 25.0 and 35.0 cm for the selected merchant vessels, the Egadi 10 vessel was reconstructed with frames spaced at the lower end of 25.0 cm center to center (Table 15). The archaeological evidence of larger ships indicates they had proportionally larger framing that was more closely spaced, providing greater hull support (Fitzgerald 1995:145). In order to provide additional support and to reinforce the hull against the violent nature of ramming warfare a closely spaced pattern of thicker frames would have been necessary. On the other hand, if the framing was too thick or too closely spaced the vessel would be overweight and ineffective. Also, if the frames were placed too close together it would restrict space for rowers and oar ports. The reconstructed size and spacing seems a reasonable interpretation, given these limiting factors.

TABLE 15

Framing Dimensions of Egadi 10 Reconstruction

Frame Type	Wood Type	Sided (cm)	Molded (cm)	Length (m)	Spacing (cm)
Floor Timbers	Pine	16.0	10.0	2.5	25.0
Half Frames	Pine	16.0	10.0	1.13	25.0
Futtocks	Pine	12.0	8.0	1.6	25.0

In addition to floor timbers, futtocks, and half frames, there is good evidence that stringers alternating with thinner ceiling planking provided additional longitudinal support. The Madrague de Giens ship had preserved stringers, alternating with thinner ceiling planking, measuring about 20.0 – 30.0 cm wide and 6.0 – 10.0 cm thick. A stringer preserved at the turn of the bilge measured 12.5 cm in thickness (Pomey 1978:84). A timber found on the Capestillo wreck measuring 30.0 cm wide and 6.0 cm thick may have served as a stringer; however, due to the depth and conditions of the excavation this is not certain (Frey, Hentschel, and Keith 1978:293-294). The Nemi Barges' stringers, which also alternated with thinner ceiling planking, measured an average of 25.0 cm thick and 31.0 cm wide (Ucelli 1950:155). The Caesarea wreck did not yield direct evidence of stringer preservation, however, study of fastening patterns suggested that the wreck may provide evidence of an 8 cm thick stringer (Fitzgerald 1995:148–149).

Interior Structures

The last issue facing the completion of the vessel's reconstruction was the interpretation of the interior structures. These included the *hypozomata*, an undergirding made of cables or ropes running the interior length of the ship and connected at the bow and stern to alleviate hogging and sagging stresses, rowing benches providing adequate space for efficient rowing, mast and rigging, and appropriate deck space for commanding officers and marines. Some of the best archaeological evidence of Roman deck structures comes from the Anse des Laurons 2 ship (Gassend, Liou, and Ximenes 1985: figure 17c). A basic rowing station assembly was designed based on the *Olympias* rowing models (Morrison, Coates, and Rankov 2000:198–199). The rowing station had a width of 49.0 cm according to the *interscalmium*, including oars, benches for the rowers, 10 cm stanchions and 5 cm stringers to support the deck structures, and an outrigger to allow for the use of long oars. Since there is no archaeological evidence that could provide any better projections, the remaining interior structures of the Egadi 10 were modeled on the *Olympias* reconstruction (Figure 30) (Morrison, Coates, Rankov 2000:194–198).

The reconstructed midships sections is a representation of the three-dimensional model used in order to determine a weight of the construction materials. The final hull had a total of six wales, three per side including the main wales projected from the Egadi 10 ram wale pockets. It

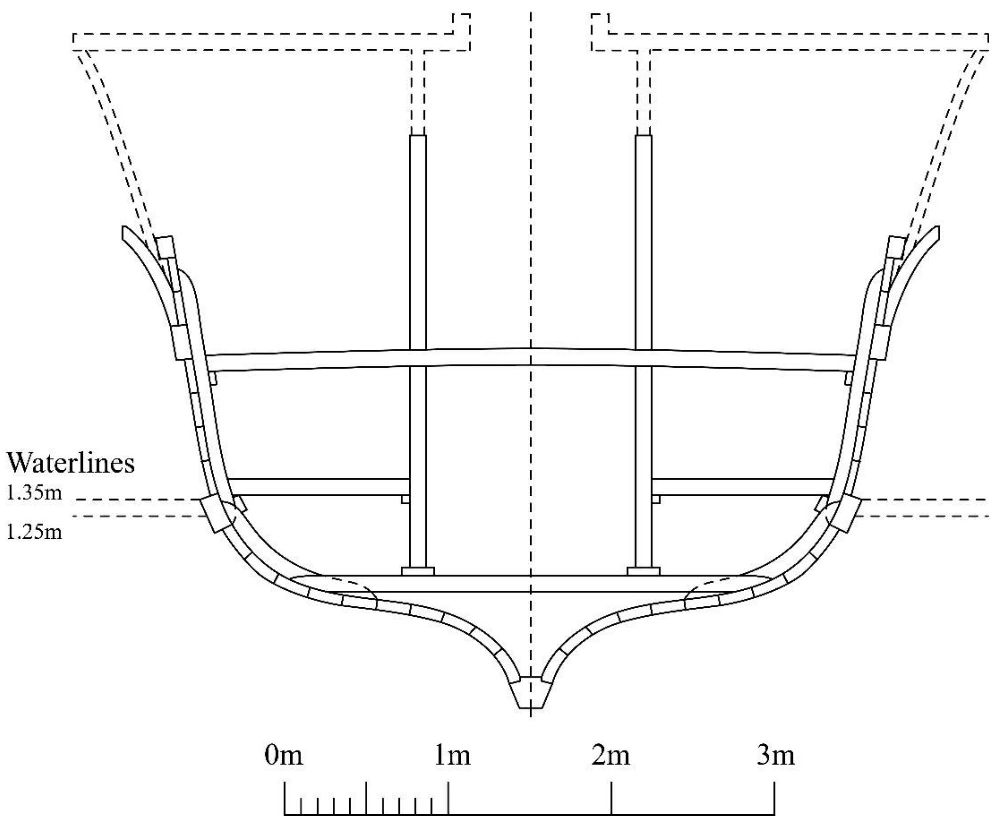

FIGURE 30. Reconstructed mid-ship section based on the *Olympias* design, showing hypothesized interior hull structure and projected superstructure (Image by author, 2016)

had a total of thirty-two planks, sixteen per side with a total of twenty planks being of the thicker bottom planking dimensions and twelve being of the thinner upper dimensions. Four stingers supported deck structures that included areas for the rowers. The decks structures including stanchions, outrigger, and projected superstructure were modeled using the designs developed for the *Olympias* trials (Morrison, Coates, and Rankov 2000: figures 54–57).

Summary

The reconstruction process began by modeling the bow timbers based on the interior contours of the Egadi 10 ram. Using those projected dimensions with the sizes of the Carthaginian shipsheds and the ratios needed to maintain oared galley performance, the lines were drafted using Rhinoceros and the naval architectural plugin Orca3D. Using secondary archaeological evidence collected from merchant vessels and previous research into ancient Mediterranean galleys, a basic hull structure was developed in order to test possible weights and resulting displacements. With the reconstruction complete, it is now possible to test different rowing arrangements in order to determine if the reconstructed could hold a crew of 300 rowers as attested by Polybius (1.59, 1.61).

Assigning Weight Properties

Assigning proper weights to the structures of the reconstructed Egadi 10 vessel was the first step in determining the possible numbers of rowers that could effectively operate this hypothetical hull shape. A determined hull weight could be subtracted from the displacement tonnage and the remaining displacement was used to test hypothesized rower numbers. Using the remaining displacement as the unchanging factor, or control, the amount of rowers became the variable. The reconstruction calculated the weight of the hull by estimating the weight of structural materials and subtracting that total from the displacement. By combining the standard weight of a Roman man and estimating the water needed to sustain him, it was then possible to compare various arrangements to present the best hypothetical size of the ship's crew.

The Orca 3D program allows solids to be assigned properties including weight per cubic meter, volume, and cost estimates. For the purposes of this study, cost estimates were omitted because the focus of the study is the performance of the ship rather than the economic factors that constrained its construction. Weights were assigned to the keel, stem, sternpost, planking, ramming timber, framing, and rower structure according to the wood interpreted for each type (Table 16). Using dried and seasoned weights of timbers was appropriate considering that the effectiveness, speed, and efficiency of a warship depended on it not becoming heavily waterlogged (Morrison, Rankov, and Coates 2000:179–190).

TABLE 16

Weights of Timbers Used in the Egadi 10 Reconstruction (based on Tsoumis 1991:111–127)

Timber Type	**Weight (kg per cubic meter)**
Elm (*Ulmus minor*)	605.0
Oak (*Quercus*)	675.0
Pine (*Pinus halepensis*)	430.0
Silver Fir (*Abies alba*)	435.0
Cedar (*Cedrus libani*)	530.0

Table 17 shows the resulting weight calculations for the reconstructed hull:

TABLE 17

Calculated Weights from Orca3D Analysis

Component Timbers	**Individual Weights of Components (Metric Tons)**
Keel and Sternpost	0.426
Stem	0.091
Ramming Timber	0.008
Chock	0.001
6 Wales and 4 Stringers	2.22
Planking	7.6
Frames	5.0
Egadi 10 Ram	0.163
Equipment and Fittings	4.0

Total Weight of Hull Components	**19.5**

The calculation of equipment and fittings posed a problem since there is a lack of evidence regarding cargo size and the basic necessities onboard warships (Table 17). Factored into these supplies was a general estimate of copper, bronze, iron, and wood fasteners, and rigging. The weight of the frames was estimated by designing a pair of floor timbers and half frames with futtocks in Rhinoceros around the widest section of the hull. Calculations based on frame sizes and spacing estimated 94 frame stations along the length of the hull. Together all frame pairs within the hull resulted in a total of about 5.0 tons of timber. Each individual reconstructed rowing station weighed an average of 178.0 kg.

Maintaining oarsmen during operations required adequate hydration and caloric intake. During the *Olympias* rowing trials, researchers determined that 1 liter of water per rower per hour was needed to sustain basic rowing (Morrison 1995:130). Therefore, the construction of a galley needed to factor for weight of water and food required to sustain rowers. This also meant that an increase in rowers meant an additional weight of water and food needed per rower. Estimating that a cleared for battle warship was carrying enough water for four hours of action meant, at minimum, four liters of water were needed per rower in order to sustain a basic level of hydration. The circumstances of the battle provided the Romans with an advantage. While the Carthaginian ships were laden with supplies and weary from the sail across from northern Africa, the Roman ships only needed to dispatch their ships once the Carthaginians were close enough to the islands. This meant that the Roman ships would have been weighted only with supplies needed for this single day of battle.

For the purposes of weight calculations, rowers were represented by a square meter box following the *interscalmium* measurements provided by Vitruvius (1.2.4) and known cross-culturally for oared ships (Coates 1995:128–129; Alertz 1991: 144–148; Olsen and Crumlin-

Pedersen 1978). The average weight of a Roman male was set at 60 kg based on anthropological work of Roman burials and dietary habits (Woodson 1981:715, 737; Roth 1999). With an interpreted vessel size and weight of timbers, the weights of rowers and the water necessary to keep them alive, along with their corresponding rowing stations, became the variables used to determine the possible sizes of the crew. The rowing arrangements were based on designs developed by Coates (1995:138). They were not meant to be definitive rowing arrangements or indicate a specific categorization of the hull; instead they provided basic organization structures for the interior of the hull.

Rowing Arrangements

"Oarmen geometry is dictated by the vital statistics of the oarsmen and not by the hydrodynamics" (Welsh 1988:156). Since the Egadi 10 vessel was an oar-powered galley, it required a design that factored the ship's size proportional to the amount of propulsion produced by its oarsmen. Therefore, galleys like the Egadi 10 could only be as effective as the power provided by the crews operating them. The physical demands of the rowers constrained the development and construction of oar powered warships.

Rowers were the human engine that powered the Egadi 10 warship. A staggered arrangement of rowers was necessary in order to fit each individual rower while providing adequate space for efficient rowing. Experimentation of rowing spaces and human capacities was conducted during the *Olympias* trials. To date, these results still provide the best insight into potential rowing systems and their physical constraints (Morrison 1995:63; Morrison, Coates, and Rankov 2000:211–230).

The placement of rowers resulted in higher centers of gravity that diminished optimal speed, but their location was necessary in order to provide rowing stations with appropriate rowing angles. Oar lengths of 9 (4.41 m) and 9.5 (4.66 m) cubits, based on the Naval Inventories from Piraeus, are most effective at a minimum 30 degree horizontal angle, limiting the angle and position of rowing benches above the waterline (Shaw 1995:163). During the design and construction of a warship, the shipwright would need to account for the size of the crew and the position as well as the angle of rowing stations in order to produce an effective rowed warship. With a delicate balance of speed, power, and hull strength, an oared galley was only as effective as the men that operated it.

One of the research questions addressed by this study is to determine the possible size of the crew of the Egadi 10 warship and how it compares to Polybius' accounts. Polybius (1.61) claimed that the warships that took part in the Battle of the Egadi Islands were *quinqueremes*, rowed by crews of 300 men. However, according to studies conducted on the Actium Monument (Murray 1989, 2012), the Egadi rams seem to belong to much smaller vessels. The monument, commissioned by Octavian in 29 B.C., commemorated his naval victory over Marc Antony and Cleopatra. The monument held between 36 and 37 rams of varying sizes placed in sockets at the base of the temple running along the façade (Murray 2012:38–39). The Athlit ram, which is about twice the size of the Egadi rams, fits onto the smaller sockets of the monument (Murray and Petsas 1989), strongly suggesting that the Egadi rams would have fallen into a much smaller class of vessels. In order to produce a comprehensive analysis, three, four, and five rower arrangements were selected to represent potential rowing systems.

If the classification system of ancient warships was based on rowers, then these arrangements would represent *triremes*, *quadremes*, and *quinqueremes*. Based on previous research (Coates 1995:127-141), these arrangements were selected to provide a constant structure for the varying amounts of rowers. In order to fit the most potential rowers along the length of the vessel, partial rower stations were used towards the bow and stern where the narrowing of the hull no longer allowed for full rowing stations.

This maximized the use of ship's hull space allowing for more files of oarsmen to row effectively during battle when speed was of the utmost importance. It was necessary to test the possibility of these classification systems based on rower arrangement in order to determine what kind of ship the Egadi 10 potentially was. Since the shape and size of the reconstructed Egadi 10 hull remained constant, the amount of rowers became the variable used to determine which arrangement was the best possible option.

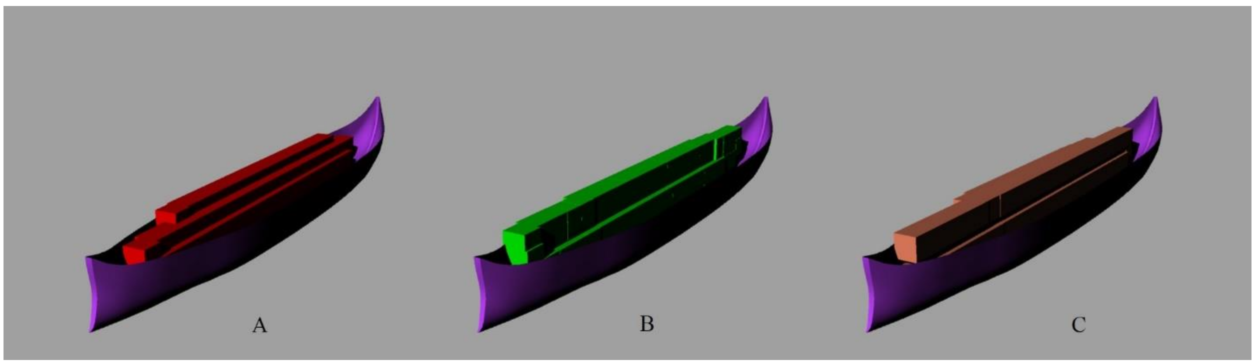

FIGURE 31. Rowing systems (*a*) three rowers per station (*b*) four rowers per station (*c*) five rowers per station (Created by author, 2016)

In order to characterize the oarsmen for weight calculations, each rower was represented by a 1 m^2 box with the assigned 60 kg weight of an average Roman male (Figure 31). This provided an easy way to adjust the rower arrangements while maintaining the correct distance between rower stations based on the *interscalmium*. The first arrangement tested was a *trireme*, which had three rowers per station. This arrangement showed that a total of 120 rowers could fit into the confines of the hull, divided among 17 full rowing stations, 3 partial stations at the bow, and 2 partial stations at the stern. These 120 rowers would add an additional weight of about 7.0 metric tons, while their rowing benches added another 4.0 metric tons. Testing a *quadreme* arrangement (four rowers per station) with 17 full rowing stations, 3 partial stations at the bow, and 2 partial stations at the stern yielded a total of 160 rowers equaling an average weight of 9.6 metric tons. Rowing benches added an additional 4.5 tons. Testing Polybius' claim of *quinqueremes* (five rowers per station) gave a total of 192 rowers divided among 14 full rowing stations, 5 partial stations at the bow, and 3 partial stations at the stern. This would equal a weight of about 11.6 metric tons, with rowing benches adding another 5.0 metric tons (Table 18).

TABLE 18

Weight Estimates of Rower Arrangements

Rowing Stations	**Number of Rowers**	**Rower Weight (Metric Tons)**	**Rowing Bench Weight (Metric Tons)**	**Total Water Needed for 4 Hours of Rowing (Metric Tons)**	**Total Weight (Metric Tons)**
3 Rowers per Station	120	7.0	4.0	0.48	11.5
4 Rowers per Station	160	9.6	4.5	0.64	14.2
5 Rowers per Station	192	11.5	5.0	0.77	17.3

Displacement Analysis

The next step was to test each hypothesized rowing arrangement to see which one provided the best interpretation for the Egadi 10 warship. This was done by analyzing the displacement that each rowing arrangement resulted in when added to the weight of the reconstructed hull, equipment, and supplies. To be accurate, the interpretation needed to sink the hull to a displacement level that would place the ram at or very close to the intended load waterline (LWL). This concept can be thought of using the following equation:

Weight of Hull, Equipment, & Supplies + Weight of Rowers = Displacement at LWL

In this equation, total weight of the ship and displacement at the load waterline serve as constants against which to test variable weights of rowing arrangements.

Results

Once each rowing arrangement was designed, the weights of rowers and their corresponding oar stations were calculated using the Orca3D weight calculation tool. Both the 1.25m LWL and the 1.35 m LWL were tested, but the 1.25 m LWL was designated for the final result. In order for this warship to be functional, it needed to be versatile; it needed to perform optimally during naval engagements, but it also needed to be able to sail with supplies and carry extra troops when not in combat. The 1.25 m LWL represented the ship if it were stripped for battle carrying only its crew and supplies to sustain it for a day of battle, as was the situation of the Roman fleet at the Battle of the Egadi Islands (Table 19). The 1.35 m LWL provided comparative evidence and could be used to indicate the versatility of these warships. It was designated as a secondary waterline because the ram would have been fully submerged, reducing the performance of the ship in the water (Table 20). It also provided an estimate of the additional weight the ship could carry if it were transporting additional supplies or troops.

The resultant weights revealed that only two of the three proposed rowing arrangements were viable in a vessel of the proposed dimensions. More precisely, it provided an average number of men that could fit in a hull of the proposed size while retaining hull stability and performance. Arrangements of three and four rowers per station fell within an acceptable weight variation from the displacement of the vessel at the 1.25 m LWL. Overweighting the vessel with 192 rowers in a *quinqueremes* arrangement would sink the vessel too low and reduce its ability to ram effectively.

TABLE 19

Weight and Displacement Calculations at the 1.25 m Waterline (LWL)

Rowing Stations	Weight of Hull (metric tons)	Weight of Rowers and Corresponding Rowing Benches (metric tons)	Total Weight (metric tons)	1.25 m LWL Hull Displacement (metric tons)	Remaining Weight to Match Intended 1.25m Displacement (metric tons)
3	19.5	11.5	31.0	32.3	1.3
4	19.5	14.2	33.7	32.3	-1.4
5	19.5	17.3	36.8	32.3	-4.5

TABLE 20

Weight and Displacement Calculations at the 1.35 m Waterline (LWL)

Rowing Stations	Weight of Hull (tons)	Weight of Rowers and Corresponding Rowing Benches (metric tons)	Total Weight (metric tons)	1.35 m LWL Hull Displacement (metric tons)	Remaining Weight to Match Intended 1.35m Displacement (metric tons)
3	19.5	11.5	31.0	39.8	8.8
4	19.5	14.2	33.7	39.8	6.1
5	19.5	17.3	36.8	39.8	3.0

Based on the figures projected, the Egadi 10 and the other Egadi rams do not coincide with the ships described in Polybius' descriptions of the *quinqueremes* with 300 member crews. Displacement analysis of the reconstructed hull shape reveals that the Egadi 10 warship would not have been large enough to house the amount of rowers described by Polybius. Based on the combined weights of construction materials and rowers, the Egadi rams are more likely to have come from *triremes* or possibly *quadremes*, but definitely not from *quinqueremes*. Although the weights of equipment, fittings, food, and water could affect these results, both the three and four arrangements provided enough variable tonnage to make these results acceptable.

Ongoing research conducted by William Murray (2012) on the Actium Monument has provided greater context into the relative sizing of warship rams. After careful study, Murray

(2015, pers. comm.) has determined that the Egadi rams came from much smaller and lighter ships than those represented on the monument. Aside from the physical restrictions of placing 300 men on a boat meant to carry about half their weight, the conclusions reached by Murray support the results of the present reconstruction.

The question then becomes, is there any way to reconcile this interpretation with Polybius' statements? Although Polybius does not mention that any other vessel types took part in the battle, it is possible that smaller ships were omitted from the record in order to highlight the prominence of the bigger, more expensive *quinqueremes*. It is also very likely that the large fleets operating throughout the course of the war had contingents of support units which are omitted from the general overview provided by Polybius. The simplest explanation would be that Polybius was writing much later and made either an anachronistic error or a deliberate attempt to enhance the histories he was writing about the Romans.

It seems very likely that the ship represented by the Egadi 10 ram was a smaller, lighter, and faster light attack galley. Comparing the results of the reconstructed hull design and the analysis of historical evidence, there is no way that a vessel the size of the reconstructed Egadi 10 warship could carry a crew of 300 rowers and be classified as a *quinquereme*. Although ancient evidence states that it was *quinqueremes* that took part in the Battle of the Egadi Islands the archaeological evidence does not support this.

Chapter 6: Discussion and Conclusions

With a small amount of direct archaeological evidence, this contributory reconstruction of the Egadi 10 warship relied on the structural elements of hull construction published on shipwrecks illustrating building traditions of mortise-and-tenon ships in the ancient Mediterranean. Correlative data produced average sizing of hulls in relation to their composite timbers. Discussion of structural components characterized the considerable skill required to build these vessels.

The aim of this thesis was to develop a contributory reconstruction (Steffy 1991:216–218), based on archaeological evidence, of a hypothetical Egadi 10 hull. Then, by comparing it against historical accounts, this reconstruction was used to argue a more accurate interpretation of the warships by using hull capacity in relation to crew sizes. Previous chapters presented the historical research and the data collected, culminating in a contributory reconstruction of the Egadi 10 warship. This chapter reexamines the goals of this thesis and the data generated from the reconstruction. It compares the results of experimental testing against Polybius' statements and classification and capacities of the Egadi 10 warship. Finally, it discusses some of the limitations of this study and puts forth suggestions for future research.

The Problem of Classification

One of the greatest challenges facing a reconstruction of ancient oared galleys is their classification. Historical accounts attesting to ship classes ranging from 'ones' all the way up to 'fortys' remain an enigmatic mystery. The basic concept used to determine this classification system seems to have relied on the rowing arrangements of oarsmen. With each increasing number, there seems to have been a corresponding increase in the amount of rowers per rowing station. The debate over the classification system has narrowed its definition down to two prevailing theories. The horizontal classification system, based on the *alla sensile* system, placed multiple rowers seated at the same level on one oar per rowing station. This system drew on Mediterranean galley arrangements used from the thirteenth to sixteenth centuries A.D. (Anderson 196:52–60; Alertz 1995:142–62). The vertical classification system placed men at different levels pulling their own individual oars (Murray 2012:7).

Using historical, iconographic, and experimental evidence, most scholars now accept that ancient Mediterranean galleys employed a vertical arrangement. The successful trials of the *Olympias* (Morrison, Coates, and Rankov 2012) further proved the feasibility of this system (Murray 2012:7). The problem arises with discussion of the larger polyremes because neither interpretation can sufficiently accommodate the rowing stations. In a larger polyreme, such as a five or a six, the necessary height to accommodate the rowing sections would produce a very tall and very unstable ship. Therefore, it is likely that larger galleys used a combination of these two prevailing possibilities, creating rowing stations that had multiple rowers per oar, staggered at different heights along the length of the hull (Figure 32).

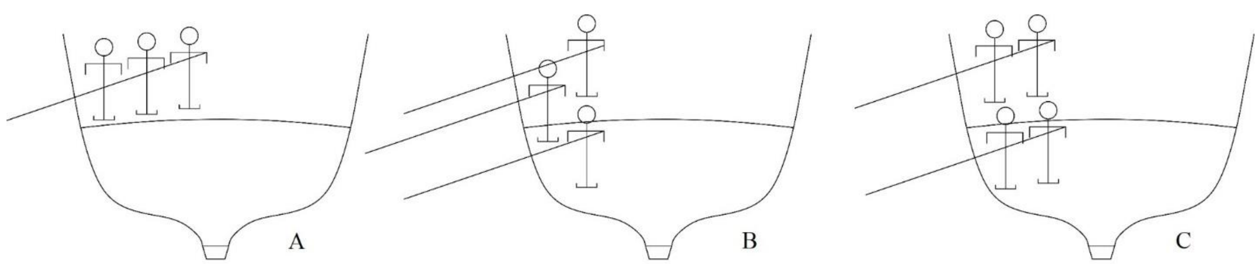

FIGURE 32. Examples of hypothetical rower arrangements (a) Horizontal i.e. *alla sensile* (b) Vertical (c) Combination of horizontal and vertical theories (Drawing by author, 2016)

Rowing arrangements were repeated along the length of the hull spaced accordingly to an *interscalmium* described by Vitruvius (1.2.4). Vitruvius stated that the Roman *interscalmium* was a unit of length, equivalent to two Roman cubits, or roughly 90 cm. The *interscalmium* marked the distance between tholepins, which were vertical pins used to hold oars in place and act as fulcrums for rowing (Shaw 1995:164). This unit of measurement determined the basic proportions of the ship as well as the sizes of the crew based on the number of oarsmen that could fit into the space between tholepins (Murray 2012:6).

According to current interpretations of ancient Mediterranean ship construction, the sizes of the Egadi rams best equate with theorized dimensions of *triremes* (threes), rather than *quinqueremes* (fives) (Murray 2012:38-68; 2014). These claims are based on the extensive study of the Actium Monument, which once displayed the prows of Marc Antony's defeated fleet (Murray 2012). This presented a problem because Polybius (1.61) stated that only *quinqueremes* were present at the Battle of the Egadi Islands. Diodorus' (17.115.1–5) discussion of Hephastion's tomb described the gilded prows of *quinqueremes* lining the sides of the tomb, each prow measuring about 3.26 m (Morrison 1995:69). This further complicates the issue of classification and its relation to ship size and rower arrangement. Could ships of two different sizes hold the same classification if they operated with the same number of rowers per file? Or were ships differentiated based on their size alone, or did it depend on a combination of both rower arrangement and size? In order to determine a possible interpretation that factored both of these variables, this study applied the measurement parameters of the average known weight of materials and men with the *interscalmium* measurement system.

The combined weights of the construction material and the rowers needed to provide enough weight to sink the hull to the intended waterlines of 1.25 m or 1.35 m. Stability of a hull relies on a balance between the buoyancy of water pushing the hull up and gravity pulling the hull down. If a hull is not properly weighted, it cannot reach its optimal performance and runs the risk of capsizing. In order for the hull to be stable, the weight of the ship's structure, supplies, rowers, and rowing benches needed to be equal to the hull's displacement in order to create a stable floating plane.

Unfortunately, ancient historians did not find the need to delve into the explanation of ship classification, resulting in a lack of modern understanding in regards to their classification or construction. This leaves the classification of the Egadi rams unclear, but most likely belonging to the *trireme* class. Until archaeological or historical evidence can provide further context, these classifications will continue to torment researchers and plague interpretations of these vessels.

Primary Research Question: Reconstruction

Using primary evidence from the Egadi 10 ram and secondary archaeological and iconographic evidence, this study was able to develop a contributory reconstruction that projected basic hull dimensions and the combined average weight of the Egadi 10 warship's structural components. Using that information, it was able to determine that the reconstructed hull could house between 120 and 160 rowers in order to float at the predetermined 1.25 m load waterline. A secondary load waterline set at 1.35 m showed that those same crew estimates allowed for additional cargo capacity when not cleared for battle.

The main characteristics of a ship are its shape, weight distribution, method of propulsion, and its construction. Together, these factors affect the stability, strength, and performance of a vessel (Marsden 1993:137). Most approaches to ship reconstruction follow a pattern of developing ship lines and construction from archaeological remains, and then attempt to recreate characteristics of the ship in the water with the cargo found in connection with the wreck.

The current reconstruction was unable to follow this process because there was a limited amount of direct archaeological evidence to support any detailed reconstruction of the hull structure. The only form of direct archaeological evidence pertaining to hull shape were the angles and interior contours recorded from the interior of the Egadi 10 ram. For this reason, this research had to approach the reconstruction of the vessel through reverse engineering. Potential load waterlines were set at the beginning of the reconstruction and the general hull shape was defined by the need to house rowers down the length of the hull while maintaining a hull size and shape that fit into shipsheds and met the requirements for fast, sleek vessels. Although there is not enough remaining evidence for an exact replica at this time, there is enough data to attempt partial or contributory reconstructions in order to continue testing hypotheses regarding ancient Mediterranean warships.

Use of Rhinoceros and Orca3D software provided the necessary tools to develop the partial hull structure. The great advantage of using this software over hand-based drawing was the ability to quickly change and alter hull shapes while producing highly accurate hydrostatic tests. Following the research, design, and reconstruction process, any attempted reconstruction of the Egadi 10 warship beyond a basic hull shape remains somewhat conjectural. Contributory and partial reconstructions are nonetheless useful experiments in combining corresponding pieces of evidence to produce results that can provide new perspectives into warship construction, operation, and classification.

Secondary Research Question: Historical Analysis

Testing the archaeological reconstruction has revealed that ships that sank at the Battle of the Egadi Islands were not the massive galleys described by Polybius, but were actually much smaller and faster assault craft. Understanding the context which frames the history of the First

Punic War aided in the interpretation of the technical aspects of the warships. Polybius' accounts of the early Roman ships stated that they were badly outfitted and difficult to manage (1.22). Inexperienced crews may have resulted in slower speeds, but it seems that the quality of the ships was much better than is credited to them. As previously stated, the Romans relied on their coastal alliances to patrol the waters of the Tyrrhenian Sea. Even if Roman shipwrights had little experience in building warships, their allies would have provided skilled shipwrights with the knowledge necessary to build warships. It may also be the case that the first Roman warships built during the war were not based on a captured Carthaginian ship. Instead of building ships they knew would be unable to operate effectively, the Romans built ships that would utilize their strengths.

The historical accounts of Polybius and Diodorus aided in understanding the social and economic aspects that framed the processes of shipbuilding. Attempts to identify the Roman naval infrastructure helped provide a context for the various logistical processes needed to construct and maintain fleets of such magnitude. Theophrastus' *Enquiry into Plants* and Vegetius' *Epitome of Military Science* gave historical insight into logistical aspects of ship building processes. The continuation of experimental contributory reconstructions, made possible through three-dimensional modeling software, can enable the continued study of these shipwrecks, providing greater understanding of these ancient warships.

Shipbuilding is not a monolithic institution. It is constantly changing and adapting to a variety of external forces. Although oared galleys are subject to many of the same limitations, like the logistical support of rowers, there is no doubt that these warships were adapted to meet new requirements and apply different tactics. Polybius' accounts of the naval battles that took place during the war draw a distinct impression of the innovation of Roman shipwrights to adapt their construction techniques, even if that meant reverse engineering captured Carthaginian ships.

Prior to the war, Rome relied on coastal city-states (*Socii Navales*), brought under their control during the Roman consolidation of the Italian peninsula, to provide a quota of ships to be used as transports and warships (Scullard 1980:145). While these naval forces were not directly produced by Rome, they would necessitate constant maintenance and repair, leading to the establishment of the *Duoviri Navales* and the shipyards needed to house the vessels. In 267 B.C., the regulatory body responsible for Rome's naval functions, the *Duoviri Navales*, expanded to comprise two *Duoviri* (fleet administrators) and four *Quaestores* (treasurers). Each of these officers was given the duty of maintaining naval installations, including ship building and repair, as well as managing allied contributions (*Socii Navales)* (Pitassi 2009:44). The increase of this regulatory body should be indicative of certain preemptive actions taken by Rome in preparation against a potential conflict. It also suggests that it was already common for Roman fleets or squadrons to consist of various vessels.

The decision to build ramming warships, like the Egadi 10 vessel, may have been as much a tactical one as an economic one. The war had already dragged on for nearly twenty years and both sides were struggling for continued monetary support. The Roman treasury was empty. The Roman Senate had to resort to private funding provided by wealthy citizens in order to build the new ships (Polybius 1.59). The key advantages possessed by Rome were its large amounts of available natural resources and labor, unlike the Carthaginians who relied on paid mercenaries.

If the early Roman *quinqueremes* were of a heavier build in order to compensate for the added weight of boarding parties and *corvi*, they would likely have been more expensive. At this point in the war, the Romans had experienced rowers, able to effectively execute ramming maneuvers. This could have been a deciding factor when Rome set about building its third fleet of the war. They may have been disinclined to build the heavier and more expensive ships. Economics may also be applied to the smaller ships sunk at the Egadi Islands. That the Romans had *quinqueremes* is entirely possible, if not very likely; however, the cost of war had drained the Roman treasury. Rather than sending their expensive capital ships against a relief fleet, the Romans may have opted to send their smaller and faster vessels that could more quickly intercept the heavily burdened Carthaginian fleet.

The analysis of the development of the Roman navy highlights important issues overlooked by Polybius. The conflicts and expansions of Rome in the preceding century indicate a continuous naval element within the Roman armed forces. Ship construction is a long as well as continuous process and can explain the reasons for breaks between the large-scale naval engagements. Throughout the course of the war, the infrastructure provided by Roman shipyards was able to refit and rebuild the fleet several times. The development of specialized weapons and supporting tactics implies prior knowledge and a level of experience with the maritime environment. Finally, the building capacities of the navy portray a continuous development of the Roman navy throughout the course of the First Punic War (264–241 B.C.). Analyzing the development of Roman naval capabilities was an important step in appreciating and attempting to reconstruct the art and skill of ancient shipwrights.

Limitations

The single greatest limitation to this thesis was the small amount of direct archaeological evidence relating to warship construction. While there have been countless historical and archaeological studies discussing detailed aspects of these ships, the experimental nature of this thesis needed to rectify those studies by producing a manageable and relevant synopsis of information. A reconstruction is a large undertaking requiring the combined expertise of shipwreck archaeologists, shipbuilders, and practical sailing experience. The reconstruction was therefore limited by the experience of the researcher and the scope of the work. Having to rely on secondary archaeological evidence and lacking the time for more extensive research into the various aspects of a warship's function and construction limited the results and conclusions developed during the course of the study.

Finally, it must be acknowledged that the resulting reconstruction is not meant to represent a perfectly accurate replica of a warship that sank at the Battle of the Egadi Islands. The present study can only present projected average hull dimensions and their comparison with historical accounts. The prioritization of archaeological and experimental evidence over historical records is not meant to give more credit to one over the other, but rather to present the discrepancies that arise from vague accounts.

Future Research Suggestions

This research represents a small fraction of the work conducted at the Egadi Islands site. It has helped in the identification of the warships represented in the archaeological record through the comparison of archaeological data and historical research. Consequently, there are many aspects stemming from the scope of this study that would benefit from future research.

The first and most needed research is study concerning the structural aspects of the warships that sank at the Battle of the Egadi Islands. Analysis of timber qualities, including tensile strengths, compression limits, and effects of stress, could greater assist any future reconstructions. It would be immeasurably helpful to physically test different bow configurations in order to determine how the structures of such warships were able to withstand and disperse the enormous forces generated during battles. In addition, identification and specific study of

FIGURE 33. Remains of the Marsala Wreck on display at the Regional Archaeological Museum Baglio Anselmi of Marsala, Sicily (Photo by author, 2016)

carpentry tools used in shipbuilding would greatly improve the results of any physical tests to be undertaken.

An attempt was also made to re-examine the remains of the Marsala wreck, currently housed at the Regional Archaeological Museum Baglio Anselmi of Marsala in Sicily, to determine whether it could aid in this reconstruction (Figure 33). Unfortunately, the current state of the ship does not allow for any detailed study of its structural components. Although the vessel was originally classified as a warship (Frost 1973; 1974), the vague nature of the published reports meant that a reliance on its information would require reanalyzing archaeological evidence relating to contemporary ship construction beyond the scope of this thesis.

The understanding of the ships that sank at the Battle of the Islands would also benefit from research further analyzing the social, political, and economic constraints that framed the construction of these ships. Further study of the various factors dictating the construction of these vessels, following Adams' (2001:301) interrelated constraints on form, function, and appearance, would greatly increase the scope of study for the Egadi Islands battle. Research looking into the timber trade and the forests supplying the building of these ships could provide useful insight into the scale and impact that the construction of the fleet had on the Italian peninsula. A socio-economic analysis of the funding required to build and maintain these fleets could also bring about fresh interpretations of Polybius' accounts.

There are many discrepancies in the approach to Mediterranean warship interpretation and reconstruction. Study of tactics has long been a contested topic. Interpretation of tactics is reliant upon historical analysis that lacks contextual evidence to understand the formations and events of a battle. A study of ram distribution across the site could potentially uncover the circumstances of these warships sinking so close to one another, and may be able to provide new insight into warships tactics. To better understand the site, artifact distribution studies could also produce greater insight into correlations between amphora finds and rams. These studies might be able to develop predictive models for distinctive spreads of amphoras, signaling the site of a warship wreck, either at the Egadi Islands battle site or elsewhere in the Mediterranean.

Site formation studies focusing on currents and sedimentation rates would provide a greater understanding of post-depositional impacts on the site and would provide further data for the study of artifact distribution across the site. Studies of current rates of illegal fishing across the site could produce more extensive protection and monitoring proposals to aid in the *Soprintendenza del Mare*'s attempts to protect the site. They could also determine current rates of site formation resulting from fishing activities.

There are countless avenues for further research into the mysteries of the galleys that once patrolled the wine dark sea. The Egadi rams offer new opportunities to continue the studies of ancient warships by allowing for greater comparative analyses because not only have they tripled the number of rams available for study, they have also provided a physical site to a historic battle.

Conclusions

In order to reconstruct the Egadi 10 warship beyond the ramming structures, basic interpretations of ship construction like timber and fastener types had to be supported through studies of secondary archaeological evidence. The shipsheds found at Carthage provided the maximum possible length and beam dimensions (Blackman and Rankov 2013). Contemporary merchant vessels, including the Kyrenia Ship (Steffy 1985), the Marsala Punic Wreck (Frost 1973), the Capestillo shipwreck, and the Ma’agan Michael shipwreck (Linder 1989, 1992), provided evidence for hull dimensions and construction. Other larger merchant vessels of later time periods, such as Mahdia (de Frondeville 1965), Madrague de Giens (Tchernia et al., 1978), and a Roman cargo vessel found in the port of Caesarea (Fitzgerald 1995), were used to support projected structural aspects.

Throughout the course of the reconstruction, it was crucial to consider the impact produced by modern ideologies, technologies, and methodologies. Modern naval standards pertaining to production standards, materials, and hydrostatic measurement form a network of ideological bias. Modern methods such as lines drawings, scale models, and three-dimensional design programs represent a specific cognitive and physical approach to naval construction. While these modern conventions are fundamentally different from how ancient shipwrights approached their trade, they do provide a basis for measuring the strength and performance characteristics of vessels built to modern specifications (Crumlin-Pederson and McGrail 2006:54). Addressing the impact of these modern concepts produced a navigable network of cultural compromises and technological restraints to guide the reconstruction process. The reconstruction of the Egadi 10 warship required extrapolation from a relatively small amount of direct archaeological evidence. In order to create a workable model, a database of supplementary evidence was used to narrow down the potential range of the reconstruction. In order for these supplementary examples to be effective, they needed to fall within the same technological scope of the original vessel (Crumlin-Pederson and McGrail 2006:55).

The ongoing excavations at the Egadi Islands provide a previously unavailable plethora of information on the ramming structures of ancient Mediterranean warships. This thesis has demonstrated the importance and worth of experimental archaeological reconstruction as a tool for analyzing the past. The use of historical sources in order to identify social, political, and economic aspects surrounding the warships of the First Punic War provided a greater context to analyze and compare the results of the reconstruction. While not as comprehensive as we might wish, contributory reconstructions are important to the continuing studies of ships and the cultures that produced them.

The developments of the Roman Navy in the First Punic War are a testament to the skill of Roman engineering and tactical innovation. It seems highly unlikely that the Romans were unfamiliar with the sea prior to the First Punic War. Aside from the Battle of Drepana and the two wreckings of the fleets due to storms, Rome’s ability to consistently claim naval victories over the Carthaginians should be viewed as a testament their prowess as seafarers. The Egadi 10 warship represents a tangible link to the prowess.

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