PIRATES IN THE GRAVEYARD OF THE ATLANTIC: CONSERVATION AT THE *QUEEN ANNE'S REVENGE* LAB

by

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The Anthropology Department at East Carolina University offers an internship option for the partial fulfillment of the requirements of a master's degree. As a result of the academic partnership between East Carolina University and the *Queen Anne's Revenge* Conservation Laboratory, an internship in archaeological conservation was made possible. While conservation and archaeology are often viewed as separate disciplines, the methods and theory in conservation are integral to the goals of archaeology both in the field and the laboratory. Since 2003, the *QAR* Conservation Lab on ECU's West Research Campus has served as the primary facility for the management and conservation of artifacts recovered from the *Queen Anne's Revenge* shipwreck in Beaufort Inlet, North Carolina. An internship at the *QAR* Lab provides students with hands-on exposure to the routine operations of a conservation facility. This includes daily and weekly duties, as well as personal projects and special artifact treatments. The skills developed as a result of this experience are highly important for archaeologists in both field and laboratory settings, but also for archaeologists responsible for the management of museum collections.

PIRATES IN THE GRAVEYARD OF THE ATLANTIC: CONSERVATION AT THE *QUEEN ANNE'S REVENGE* LAB

A Thesis

Presented to the Faculty of the Department of Anthropology

East Carolina University

In Partial Fulfillment of the Requirements for the Degree

Master of Arts in Anthropology

by

Brandon Eckert

July, 2020

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Chapter 1 – Introduction and Background

Although the two are often referenced as separate entities, the disciplines of archaeology and conservation are inextricably linked in their overarching goals, purpose, and importance in the recovery and preservation of cultural heritage. In historical archaeology, contemporary documents are often used during the course of a research project. While ultimately helpful in creating an image of the past, these historical records are often biased, incomplete, or exclusionary (Little 2016: 29). In an effort to arrive at a more complete interpretation of the past for both the public and future researchers, historical archaeologists rely on the analysis of corresponding archaeological material to corroborate, confirm, correct, or supplement the documentary record. In their ability to mitigate the shortcomings of the written historical record, these artifacts can be seen as unbiased historical objects, providing "the nearest thing to an objective past" (Caple 2000: 13; Lipe 1987).

It is the duty of all archaeologists to act as stewards of these cultural resources to ensure that future generations benefit from their further study and continued curation. The field of conservation is vital to achieving this goal. At East Carolina University (ECU), the intersection of field archaeology and conservation is evident at the *Queen Anne's Revenge* Conservation Lab. Located on the school's West Research Campus, the lab began operations in 2003 as part of a partnership between the North Carolina Department of Natural and Cultural Resources and ECU (Watkins-Kenney 2018: 188). In the years since its official designation, the lab has served as the primary facility for the processing, documentation, and conservation of artifacts recovered from the *Queen Anne's Revenge* shipwreck site off the coast of Beaufort, North Carolina. As a result of the partnership between ECU and the *QAR* Conservation Lab, an internship focusing on the conservation of archaeological material was made possible. The internship began in Spring 2019

and concluded in Spring 2020, and encompasses numerous conservation tasks, both routine and specialized. The abilities learned and practiced during this internship provide a significant foundational skillset integral not only to laboratory conservation, but also the care and preservation of archaeological materials in the field in both maritime and terrestrial contexts.

The History of *La Concorde* and *Queen Anne's Revenge*

Although the *QAR* Conservation Lab is equipped for the treatment of a variety of archaeological materials from both maritime and terrestrial sites, activities at the lab are primarily focused on the artifacts recovered from Blackbeard's infamous flagship, the *Queen Anne's Revenge*. Before being discovered by the private research firm, Intersal Incorporated in 1996, the wreckage of the ship sat beneath the waves in Beaufort Inlet for more than two centuries. In addition to studies of the material culture related to the wreck, significant historical research also takes place at the lab to generate a more complete history of the ship's past. While much of this research has been dedicated to understanding the characteristics of the ship and crew while sailing under the black flag of piracy, this work is accompanied by exhaustive review of surviving documents and artifacts related to the ship's original identity. Before serving as the flagship of Blackbeard's pirate flotilla, *Queen Anne's Revenge* was known as *La Concorde*, a French light frigate built for privateering and later converted for participation in the transatlantic slave trade.

Much of what is currently understood about *La Concorde* comes from surviving primary documents of both French and English origin. Though the French documentary evidence does provide a great deal of information concerning the ship's early activities, it must be noted that, like much of the archaeological record at the site, these documents remain fragmentary and

incomplete. Those records that have been identified and analyzed, however, reveal that *La Concorde* was owned by Rene Montaudoin, a prominent businessman based in the French port city of Nantes (Wilde-Ramsing 2009: 4).

While a great deal of documentary evidence exists for the vessel's slaving and privateering voyages, the exact time and place of the ship's construction are not mentioned in any known documents. Nevertheless, three theories have been put forth by French maritime historian, Jacques Ducoin (2001) to determine *La Concorde*'s origin. The first theory posits that the frigate *La Concorde* was built by the French Royal Navy and loaned to Rene Montaudoin during Queen Anne's War (Ducoin 2001: 15). According to Ducoin (2001), this means of acquisition was not unprecedented as Montaudoin acquired the ship *La Valeur* in 1709 as a loan from the Royal Navy. However, no construction records of a ship named *La Concorde* exist for the royal arsenals of Rochefort and Brest on the Atlantic coast, making this theory unlikely (Ducoin 2001: 15). The second hypothesis suggests that *La Concorde* was originally an English frigate captured by privateers from Nantes (Ducoin 2001: 15). Two English ships of similar tonnage, *The Koucker* and *The Hampton Galley*, held the most promising potential for an identifiable connection to *La Concorde*. However, despite the similarity in size between these vessels and Montaudoin's ship, *The Koucker* was returned to the English after the payment of a ransom, and *The Hampton Galley* was captured in 1712, two years after *La Concorde*'s first appearance in French records (Ducoin 2001: 15). The third and final hypothesis proposed by Ducoin (2001) postulates that the ship was constructed in Nantes, where several similar privateering vessels were built during the first decade of the eighteenth century. While no definitive evidence of *La Concorde*'s construction in Nantes is available, Ducoin (2001) remarks that another frigate partially owned by Montaudoin, *La Content*, was constructed in the port.

Though these hypotheses offer tantalizing notions regarding the ship's possible origins, the exact construction details of the French vessel remain a mystery.

Despite the scarcity of records regarding the ship's time and place of construction, *La Concorde* begins to appear in official French documents by 1710 as part of a list of privateering vessels owned by Montaudoin during the War of Spanish Succession. Along with those of the other eight ships on the registry, *La Concorde*'s armament and tonnage were recorded. According to the document, the privateering vessel was a ship of three hundred tons and sailed with twenty-six guns in 1710 (Ducoin 2001: 13). From 1710 to 1711, *La Concorde* embarked on a lengthy privateering voyage in the Caribbean, targeting and capturing several enemy vessels during the expedition.

With the conclusion of Queen Anne's War after the signing of the Treaty of Utrecht in 1713, *La Concorde*'s role as a privateering vessel ended. Just days after the war's conclusion, Rene Montaudoin returned *La Concorde* to service, this time as a slaving vessel (Wilde-Ramsing 2009: 6). From 1713 until its eventual capture in 1717, the ship embarked on three known slave-carrying voyages in the Caribbean, all of which were recorded in Jean Mettas' eighteenth century directory of French slave shipments (Mettas 1978; Ducoin 2001: 11). The first of these voyages departed from Nantes on April 13th, 1713 with a tonnage of 250 to three hundred tons, sixteen cannon, and sixty-two crewmen (Ducoin 2001: 11). By July of 1713, *La Concorde* reached Judah on the west coast of Africa, where 418 enslaved Africans were added to the ship's cargo (Thomas 1714). Those slaves that survived the ship's Atlantic crossing were eventually sold at the slave market in Martinique.

This initial slaving voyage was followed by two more in 1715 and 1717. The 1715 voyage mirrored the initial 1713 expedition in many ways, and eventually proved to be the ship's

final successful slaving assignment. Much like the first slaving mission undertaken by *La Concorde*, the ship once again departed from its home port of Nantes and set sail for the west coast of Africa. According to the February 27th, 1715 *Armament Role of La Concorde*, the ship was listed at 250 tons, carrying eighteen guns, and a crew of sixty-five men (Wilde-Ramsing 2009: 7; Denys 1715). After reaching the African coast, 331 African slaves were purchased, to once again be sold across the Atlantic Ocean at Martinique. Following the sale of the human cargo, Captain Mathieu Denys gave the order to set sail for the return journey back to France. The vessel was recorded as having returned to Nantes in October 1716, marking the end of *La Concorde*'s good fortune in the transatlantic slave trade (Denys 1715).

Captained by Pierre Dosset of Nantes, the final slave voyage of *La Concorde* departed port in March of 1717 with a crew of seventy-five and an artillery complement of fourteen to sixteen guns (Dosset 1717; Ernaut 1718; Wilde-Ramsing 2009: 7-8). The voyage began much like the previous two, with the ship making its way to the port of Judah on the African west coast, where 516 African slaves and "fourteen ounces of gold powder" were collected by the French crew (Ernaut 1718). On October 9th, *La Concorde* departed from Judah and set a course for the island of Martinique across the Atlantic Ocean. To this point, the slaving journey was relatively routine for the French crew. Apart from an encounter with severe weather and the need to replace a damaged anchor cable (Ernaut 1718), *La Concorde*'s third voyage to the slave coast of Africa was carried out unimpeded. However, as the ship made the Atlantic crossing, the fortunes of the crew changed dramatically.

At eight o'clock in the morning on November 28th, the French vessel encountered "two boats of pirates, one of which was armed with 12 guns and equipped with 120 crewmen and the other armed with 8 guns and equipped with 30 men" (Ernaut 1718; Mesnier 1717). In official

depositions given after the ship's fateful expedition, *La Concorde*'s captain Pierre Dosset and first lieutenant, Francois Ernaut, revealed that sixteen men of the ship's seventy-five crew and sixty-one of the vessel's 516 African slaves perished in the weeks after their departure from Africa (Ernaut 1718; Dosset 1718). Additionally, thirty-six men fell ill with cases of scurvy and the "bloody flux" (dysentery)—diseases highly common among sailors and captive slaves during the early eighteenth century (Rediker 2007: 274-275)—leaving only twenty-one men in able condition to maneuver and defend the vessel (Watkins-Kenney 2018: 199; Ernaut 1718). As a result of the severely weakened state of the French crew, *La Concorde* was surrendered after only two cannon and musket volleys from the pirate sloops.

Following the short engagement and capture of the ship, the pirates under Blackbeard's command then deposited the battered French crew and *La Concorde*'s slave cargo on the small island of Bequia in the Grenadines (Ernaut 1718). After looting numerous items of value and even daily necessities from the sailors, including their clothes and the gold dust the ship was carrying (Wilde-Ramsing 2009: 14; Ernaut 1718; Virginia Colonial Papers 1718), Blackbeard's company exchanged the smaller of the two pirate sloops with the French. While the former crew of *La Concorde* used this small sloop to ferry the remainder of the enslaved Africans to the markets in Martinique (Mesnier 1717), Edward Teach and his band of ruffians set out with their new prize, now renamed the *Queen Anne's Revenge*. Along with the ship, the pirates took multiple members of the French crew including a pilot, two carpenters, three surgeons, a caulker, a cook, one sailor, and a gunsmith (Ernaut 1718).

Now armed with a large flagship to lead his criminal flotilla, Blackbeard began relentlessly attacking and robbing merchant vessels in the Caribbean before eventually travelling to the eastern coast of British America. The high cargo capacity, speed, and size of the former

slave ship made the *Queen Anne's Revenge* a force to be reckoned with (Rediker 2007: 50-51; Moore and Daniel 2001: 16). For the remainder of the ship's life, the pirates continued to augment these favorable characteristics with an expanding artillery complement, ultimately reaching a reported total of forty guns (Knight 1717; Bostock 1718; South Carolina Court of Vice Admiralty 1719). In the months after its capture, the *Queen Anne's Revenge* served as the centerpiece of Blackbeard's personal pirate fleet. Accompanied by multiple smaller sloops including *Revenge* and *Adventure*, Edward Teach's flagship attacked several large merchant ships in its voyage from the Caribbean to the Atlantic coast of North America (Wilde-Ramsing 2009: 9-10).

This reign of terror was marked by intensity but also brevity as British authorities increasingly recognized and reacted to the threat of piracy across the Atlantic seaboard (Spotswood 1716). After passing through the Bahamas, the pirates arrived off the coast of Charles Towne in May 1718 (Moore 1997). In a daring act, Blackbeard's fleet blockaded the town and seized several ships attempting to enter and leave the port. Famously, the crew and passengers of the ship *Crowley* were detained until being ransomed for a chest of medicine (Lee 1995). Following the blockade of Charles Towne's port, the *Queen Anne's Revenge* immediately set sail for the relative safety and seclusion of Old Topsail Inlet (now Beaufort Inlet). Unfortunately for Blackbeard and the pirates, the June 1718 journey into the inlet resulted in disaster, with both *Queen Anne's Revenge* and the sloop *Adventure* running aground on one of the inlets many dangerous sandbars (South Carolina Court of the Vice-Admiralty 1719: 45). Following the grounding, the two ships were abandoned and left at the mercy of the sea. While the ship's hull likely remained visible above the surface in the months after the grounding

(Wilde-Ramsing and Carnes-McNaughton 2018: 47), the remnants of the wreck eventually disappeared beneath the waves as a result of structural deterioration and coastal weather patterns.

Archaeology at Site 31CR314: The *Queen Anne's Revenge* Shipwreck Project

For more than two centuries, the remnants of *Queen Anne's Revenge* lay hidden below the water's surface in Beaufort Inlet. In 1988, the private research firm Intersal Incorporated was given a permit by the North Carolina Department of Natural and Cultural Resources' (NCDCR) Underwater Archaeology Unit (UAU) to search for the wrecks of *Queen Anne's Revenge*, *Adventure*, and the Spanish ship *El Salvador*. Surveys were conducted by the research firm for nearly a decade before a promising shipwreck was identified on November 22nd, 1996 (Lawrence and Wilde-Ramsing 2001: 3-4). Assigned the site number 0003BUI as the third identified site in Beaufort Inlet (BUI) by the North Carolina UAU, the wreckage was found approximately 1.3 miles from nearby Fort Macon and about 1,500 feet from the inlet's present-day shipping channel (Figure 1) (Wilde-Ramsing and Carnes-McNaughton 2018: 41). In the time since its initial discovery, the site has also been assigned the Smithsonian trinomial designation of 31CR314. This coding identifies the *Queen Anne's Revenge* wreck site as being located in North Carolina (North Carolina is the 31st state in the system) in Carteret County (CR) and is the 314th identified site in the state (North Carolina Office of State Archaeology Archaeological Site Form Handbook).

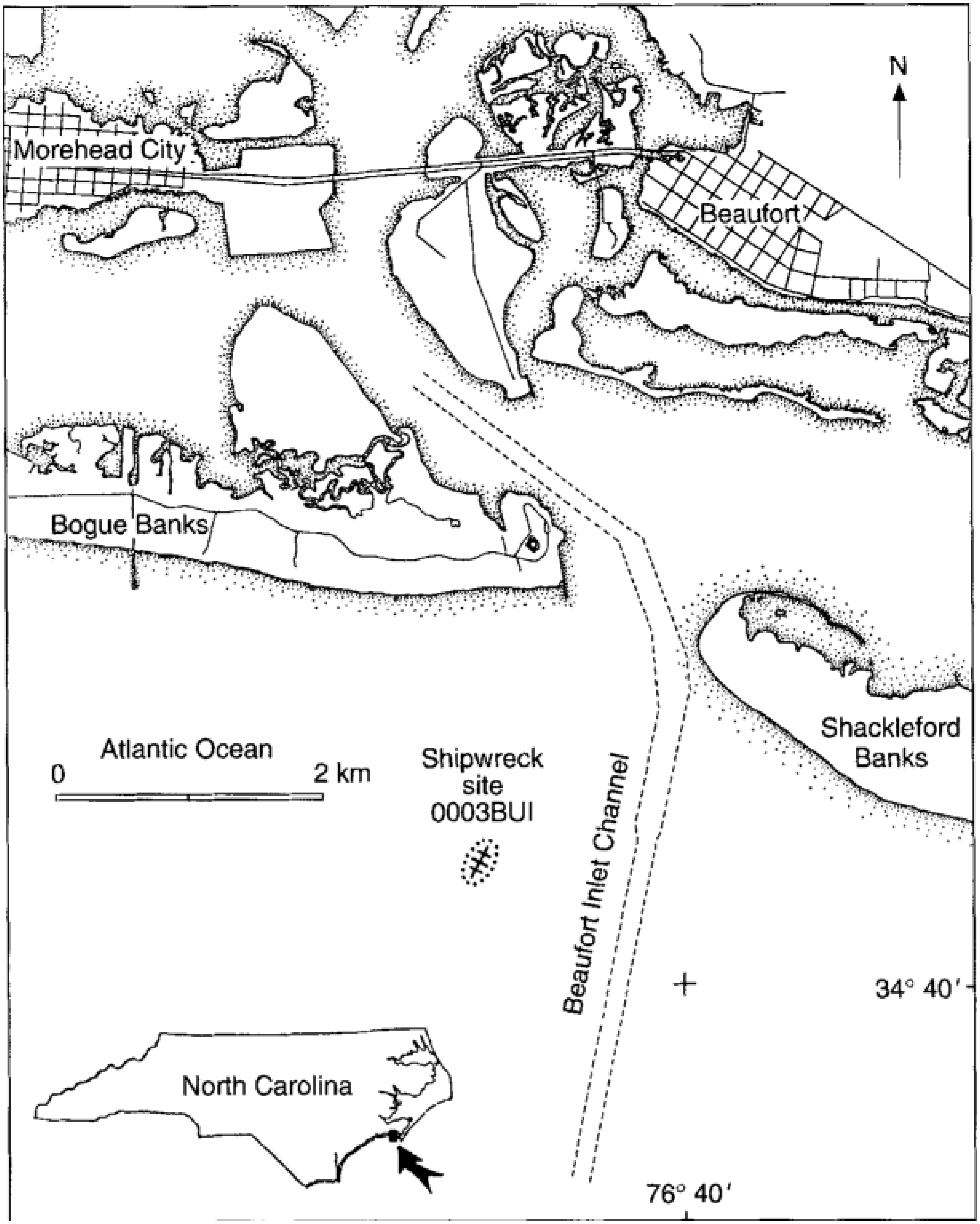

Figure 1. Location of shipwreck 0003BUI. Drawing by David Moore. Taken from Lusardi (2000).

Upon finding the wreckage, divers recovered a handful of artifacts including a lead sounding weight, multiple cannon balls, the barrel of an English blunderbuss, and a bronze bell with a date inscription of 1705 (Wilde-Ramsing and Ewen 2012: 113). The discovery of the vessel's remains and the preliminary recovery of artifacts generated significant public interest and media attention (Lawrence 2011: 14). By 1997, management of the archaeological site was transferred to the North Carolina Office of State Archaeology's Underwater Archaeology Branch. Preliminary surveys conducted in the fall of the same year sought to identify the type of vessel at the site, the vessel's period of use, the ship's country of origin, and the vessel's function (*QAR* Fall 1997 Assessment Plan). The 1997 field season also resulted in the creation of a preliminary site plan that identified several *in situ* artifacts including fifteen of the ship's guns, a pile of ballast stone, and three anchors (Figure 2) (Lusardi 2000: 59).

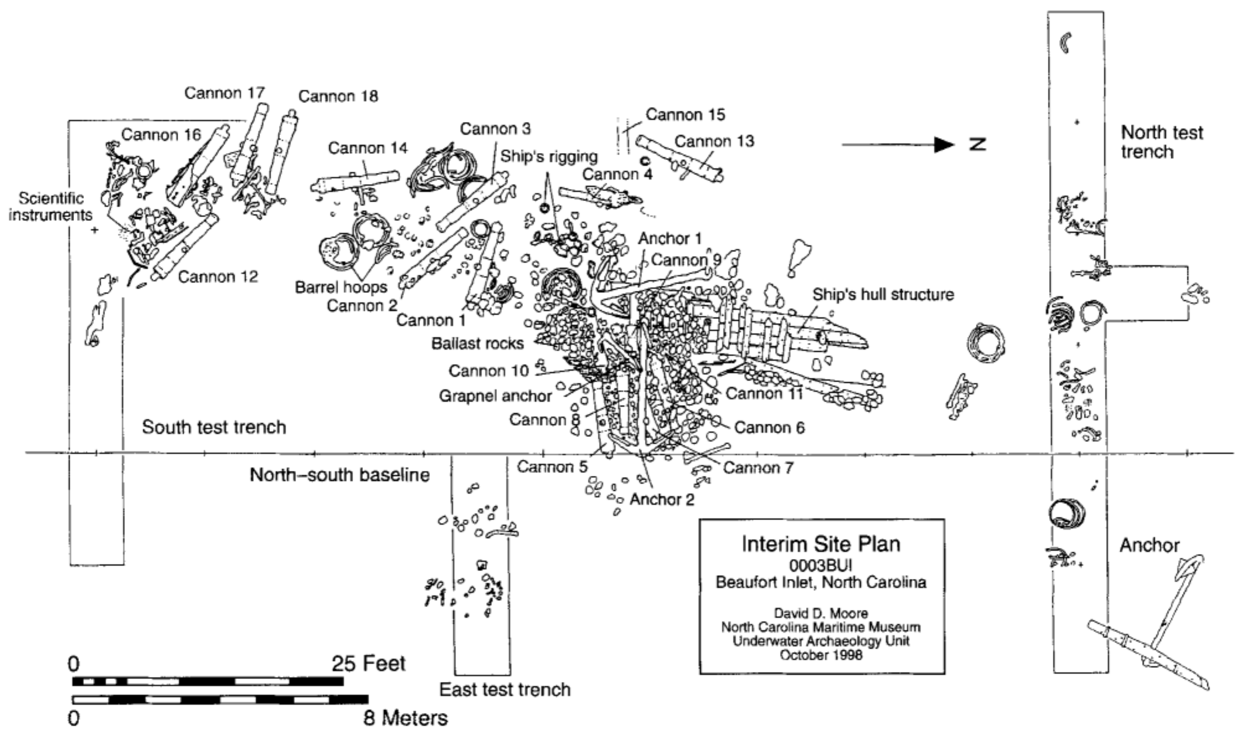

Figure 2. Site plan from 1997 field season. Drawing by David Moore. Taken from Lusardi (2000).

Survey and limited data recovery at the site continued in the following two field seasons in 1998 and 1999. The 1998 field season focused on test excavations along three transect lines at the site. Using dredges, divers identified and recovered numerous artifacts from each of the transects including ballast stone, additional cannons and rigging equipment (Lusardi 2000: 59). In 1999, work at the site was highlighted by an extensive magnetometer survey covering an area of 90 feet X 150 feet. Combined with the results of corresponding test excavations, the magnetometer survey managed to provide a more accurate understanding of the wreck's artifact dispersion and the site's boundaries (Lawrence and Wilde-Ramsing 2001: 7-8).

Following the results of the 1998 and 1999 field seasons, a management plan was developed by the Underwater Archaeology Branch, which both recognized the strong material evidence for the identification of the wreckage as the *Queen Anne's Revenge* and recommended the complete recovery of artifacts from the site (Wilde-Ramsing and Lusardi 1999). However, this plan required a sizable facility for the curation and conservation of the numerous artifacts expected to be recovered from the site. In response to this need, the North Carolina Department of Natural and Cultural Resources reached an agreement with ECU in 2003 to establish the *Queen Anne's Revenge* Conservation Lab (Watkins-Kenney 2018: 188). In 2004, after several field seasons, the wreckage at site 31CR314 was formally recognized as the *Queen Anne's Revenge* and listed on the National Register of Historic Places.

Systematic excavations with the goal of total recovery began in the fall of 2006, recovering numerous artifacts ranging from large iron cannons to small glass beads (Lawrence 2011: 14). In fall 2014, it was estimated that sixty percent of the site had been excavated, resulting in the identification and recovery of approximately 400,000 artifacts (Watkins-Kenney

et al. 2015: 6). Since 1997, the designated repository for the curation and display of *QAR* artifacts has been the North Carolina Maritime Museum (Shannon 2001). However, before these materials are ready for display, they are processed, stored, and treated at the *QAR* Conservation Lab to prevent further deterioration and ensure stabilization.

The *Queen Anne's Revenge* Conservation Lab Internship

In partial fulfillment of the requirements for a master's degree in Anthropology, ECU graduate students have the option of completing an internship. The internship option involves a traditional research proposal, 180 hours of supervised work, and a final internship report to be defended at the conclusion of the project. As a result of the partnership between ECU and the *QAR* Conservation Lab, graduate students in the Maritime Studies and Anthropology programs have the opportunity to work as both graduate research assistants and interns at the lab. While students do not engage in the *QAR* Shipwreck Project's tasks to the same degree as professional conservation staff, interns take part in daily and weekly routine tasks, and are also assigned personal projects to complete during the internship.

The goals of this internship included participation in elements of each stage of the conservation process, and the acquisition of a basic conservation methodological toolset to be used in future terrestrial fieldwork. The various tasks and methods of artifact treatment that have been encountered during the course of the internship can be grouped into five primary categories:

1. **Recovery and Post-Recovery of Artifacts**
2. **Treatments in Process**
3. **Final Documentation, Recording, and Stable Storage**
4. **Preparation for Transfer to Museums**

5. Monitoring of Post-Transfer Artifacts at Museums

In addition to discussing experiences with each of these stages of conservation in the following chapters, remaining sections of the report will focus on personal assigned projects completed during the internship. This includes the analysis and results of the conservation and stabilization of a wooden cask hoop recovered from Brunswick Town in 2015, the breakdown (via air scribing) of two concretions, participation in public outreach and education programs, and the development of a first-aid conservation protocol for the recovery of artifacts at Brunswick Town during ECU's annual summer field school in archaeology.

This internship addresses the value of conservation in archaeology and demonstrates the transferability of laboratory methods to traditional terrestrial fieldwork. The final portion of this report includes the entirety of the Brunswick Town conservation protocol, illustrating both the results of the internship, and the benefits of the partnership between ECU and the *QAR* Conservation Lab.

Chapter 2 – Archaeological Conservation: An Overview

Artifact conservation is now an integral part of the research design for most archaeological projects. In both maritime and terrestrial undertakings, significant resources are dedicated to the care of artifacts at all stages of an excavation. This includes planning for the funding, facilities, personnel, and equipment necessary to properly manage cultural material from the moment it is excavated to its eventual laboratory treatment and long-term curation. All of these efforts are concentrated on a singular goal: counteracting the processes of deterioration that inevitably occur once an artifact is removed from its burial context. Without taking measures to properly conserve recovered archaeological material, any potential information that the artifact may have provided is lost forever (Cronyn 1990: 4). The discipline of conservation is still very young relative to other varieties of laboratory science. While conservation-minded approaches to archaeological excavation and artifact treatment date back centuries, the field as it is characterized today experienced the most significant growth and development in the last fifty years. Much like archaeology, conservation continues to develop and expand to this day.

A Precursor to Conservation: The Rise of Collections

Although the science of conservation is a consistent presence in contemporary field and laboratory work, its development as a field of study within archaeology occurred gradually over the past several decades. However, approaches to conservation can be traced back even further in history with the creation of material collections in the ancient world. One of the earliest known attempts at museum practice and basic preventive conservation occurred in 490 B.C. with the establishment of the Greek temple of Delphi. Following the Battle of Marathon, the temple of Delphi became a repository for objects related to the battle, celebrating the Athenian victory over

the Persians (Caple 2000: 46). The trend of amassing "treasuries" of objects of symbolic and historical importance continued in the following centuries with powerful leaders and wealthy aristocrats such as Henry III of England and the Medici family of Florence developing substantial private artifact collections to reflect both their wealth and their appreciation for historical knowledge (Caple 2000: 47). While the assembly of these large personal collections did not yet include attempts to preserve the artifacts, it illustrated two core tenets of modern conservation: the appreciation of an object as an aesthetic entity and a historic document (Caple 2000: 30). This appreciation was exemplified by the creation of purpose-built buildings—essentially early museums—to house and care for these collections (Caple 2000: 47). As interest in the past continued to grow in the following centuries, these attitudes toward historical objects provided an early foundation for the development of conservation into an academic discipline.

As the power of the monarchy, the church and the aristocracy diminished in the centuries after the Renaissance, the exclusivity of artifact collections waned. By the eighteenth century, several national museums were established including the British Museum in 1759 and the Louvre in 1793 (Caple 2000: 47-48). For many of these new public museums in the eighteenth and nineteenth centuries, the artifacts they held were largely sourced from the extensive cataloged personal collections of "gentlemen intellectuals" like Britain's General Augustus Pitt Rivers. The connection between national identity and the monuments and structures of the past further influenced the development of conservation and preservation in the nineteenth century as several governments across western Europe enacted measures to protect sites and structures emblematic of the nation's cultural heritage. This attitude was represented very clearly in various pieces of legislation including Great Britain's 1894 National Trust, which sought to protect "places of historic interest or national beauty" (Swenson 2008).

Following the conclusion of the First World War, advances in both transportation and communication technologies contributed to the development of a more international approach to museums and collections. This was highlighted by the emergence of The International Museum Office (later the International Council of Museums or ICOM) in the 1930s, and the wider distribution of journals and academic literature related to museums and collections management in the remainder of the twentieth century (Caple 2000: 48). In the following decades, numerous conferences on the subject took place, bringing archaeologists and curators together from across the globe to participate in discussions concerning archaeological excavation, restoration, conservation and museology (Caldararo 1987: 88). As national museums continued to grow at this time, so too did local and folk museums across the globe. This included the establishment of several museums for native groups in the last quarter of the twentieth century, which Caple (2000) suggests was a direct response to the growth and globalization of "Americana" culture after the Second World War.

Conservation: From Craft to Science

Paralleling the centuries-long global development of the museum system was the gradual growth of conservation science. Much like the early history of these museums, initial attempts at conservation of historically important objects can be traced back to several notable figures in antiquity. One of the earliest instances of this attitude toward artifact care can be found in the writings of Roman military officer and natural philosopher, Pliny the Elder. In his book *Natural History*, Pliny the Elder discusses the restoration of monuments and works of art after years of deterioration (Sease 1996: 157). While the volume does not specify the methods used to restore

these objects, it instead reveals the reason for the recovery, retention and restoration of such artifacts: reverence for the past (Caple 2000: 50).

For much of the history of conservation, the reverence for historical objects demonstrated in *Natural History* has proved to be the motivating factor behind numerous early experiments in artifact treatment and restoration. The development of these ideals became evident during the Renaissance period in western Europe. Financed by various wealthy patrons including the Catholic Church, artists such as Michelangelo, Verrocchio, and Cellini were enlisted to restore sculptures and other works of art from the Classical period (Sease 1996: 157). For these restoration projects, the artists were instructed to imitate, as closely as possible, the style of the ancient artisans that originally crafted the object (Sease 1996: 157). While desires for aesthetic beauty eventually overcame the instruction to imitate ancient style during the later Renaissance period, this attention to the object's original state reflects the present-day conservation principle of preserving and revealing the "true nature" of an artifact (Cronyn 1990; Caple 2000).

Further attempts at early conservation occurred in the eighteenth and nineteenth century following the archaeological rediscovery of Pompeii and Herculaneum. Of particular note during this time was the recovery of papyrus scrolls from Herculaneum in 1752. Upon discovery of the papyri, antiquarians made efforts to unroll the scrolls via both chemical and mechanical means. Many of these methods yielded little success until the Genoese monk, Padre Antonio Piaggio created a complex machine to aid in the unrolling process. Though the process was labor intensive and slow, the machine remained in use through the nineteenth century. At the same time, Sir William Hamilton published an account of his attempts to unroll Egyptian papyri by dipping the scrolls into boiling water (Sease 1996: 157-158). Though both Piaggio and Hamilton were successful in unrolling the ancient papyri, both men did so in the interest of curiosity rather

than scientific conservation. Despite this fact, their decision to record the treatment processes in detail foreshadowed the field of conservation's future emphasis on artifact documentation.

As the national museum system grew across western Europe, so too did scientific interest in the conservation of artifacts. While Piaggio and Hamilton had more in common with antiquarianism than actual science, the nineteenth century saw the increased involvement of scientists and scientific museums in the preservation of antiquities. The earliest examples of a more scientific-minded approach to artifact treatment can be seen in the Danish National Museum's establishment of the "Commission for the Preservation of Artefacts" in 1807 (Clavir 2012: 11) and C.J. Thomsen's 1831 pamphlet on artifact preservation, *On Nordic Artifacts and their Preservation* (Sease 1996: 158). In 1888, the field of conservation took significant strides toward becoming a professional scientific discipline with the appointment of Friedrich Rathgen as the director of the Royal Museum of Berlin's chemistry laboratory. During his time as the head of the laboratory, Rathgen was tasked with determining treatment methods for a collection of decaying Egyptian artifacts that were excavated in the 1830s. As Rathgen worked with these materials, he carefully documented any treatments used with the artifacts and diagnosed the underlying reasons for deterioration. Rathgen's efforts with the Egyptian artifacts included the implementation of several groundbreaking conservation procedures that are still in use today including the desalination of stone artifacts and the use of synthetic polymers to coat treated artifacts (Caple 2000: 53). The scientific approaches utilized by Rathgen were eventually included in his 1898 book, *The Preservation of Antiquities*. After being translated to English in 1905, this book served as the basis for the work of numerous subsequent conservators in the twentieth century.

The continued development of conservation in the early twentieth century was highlighted in the work of Dr. Alexander Scott, a chemist and member of Britain's Department of Science and Industrial Research. Scott was contacted by the British Museum in the 1920s after it was discovered that the museum's collections had deteriorated significantly while in storage in the London Underground during World War I (Caple 2000: 54). While working with the museum's collections, Dr. Scott wrote multiple reports regarding the preservation of the materials, all of which were collectively published under the title *The Cleaning and Restoration of Museum Exhibits* in 1921 (Sease 1996: 159). While still working for the British Museum, Scott also participated in the founding of an official research laboratory at the facility in 1931, where several significant publications and influential members of the scientific conservation community later originated from (Caple 2000: 54).

Beginning in the 1930s and continuing through the remainder of the twentieth century, the field of conservation saw significant growth in published literature and international conference participation. Current research of the day and advances in the young science of conservation were disseminated in new museum journals such as *The Museums Journal* and *Curator*, and also included in the International Council of Museums' (ICOM) conferences on museum studies in Rome in 1930 and in Athens in 1931 (Caple 2000: 54). The field's rapid development continued after the Second World War with the creation of an official conservation organization, The International Institute for Conservation of Historic Objects and Works of Art (IIC), in 1950 and the production of the first conservation-focused academic journal, *Studies in Conservation*, in 1952.

In the 1960s and 1970s, the field of conservation became increasingly specialized, with dedicated conservation organizations such as the IIC and ICOM's Conservation Committee

hosting their own conferences separate from larger, more general museum studies-focused conferences. Paralleling the more specialized nature of conservation in the late twentieth century was the establishment of additional organizations including the American Institute for Conservation (AIC) and the Canadian Conservation Institute in 1972 and the Getty Conservation Institute in 1985 (Caple 2000). As a result of these significant developments in the field, numerous educational and training programs for conservators are now offered at universities in both the United Kingdom and the United States. While present-day American conservation education is comparatively less developed and organized than its British counterpart (Johnson 1993), the field continues to grow in both field and laboratory settings.

Conservation and Archaeology in North Carolina: The Underwater Archaeology Branch

Paralleling the continued development of the field of archaeological conservation in recent decades, North Carolina has also seen a significant degree of advancement in state conservation facilities and available technologies. Much of the conservation research carried out in the state is primarily associated with maritime archaeological projects. One of the earliest events of significance for the growth of the field in North Carolina was the discovery of the Confederate blockade runner *Modern Greece* in March 1962 after the shipwreck was uncovered by a storm. Upon being notified of the discovery, the North Carolina Department of Archives and History immediately enlisted the aid of the Naval Ordnance School and the U.S. Coast Guard in the recovery of artifacts from the wreck. By 1963, excavations at the site had resulted in the recovery of more than 10,000 artifacts. However, Bright (1977) and Lawrence (2011) note that the manner in which the artifacts were recovered was more akin to a salvage operation than a traditional underwater archaeological excavation, with little attention paid to artifact

provenience and site mapping. Among the numerous artifacts recovered from the wreck were bars of tin and lead, a number of Whitworth artillery shells, Enfield rifles and their corresponding ammunition, kitchen and eating utensils, and various tools including medical kits and bullet molds (South 2005: 170-171).

Once the archaeological materials were removed from the wreckage of *Modern Greece*, questions relating to the storage and care of the recovered artifacts came to the forefront of the discussion. Unfortunately, the state had little experience in storing and treating an underwater collection and also lacked a proper conservation facility to manage the assemblage. This changed in 1963 after the North Carolina Department of Archives and History received funding from both the state legislature and the Confederate Centennial Commission for the construction of a proper conservation laboratory on the grounds of Fort Fisher State Historic Site (Townsend 1965; Lawrence 2011: 2). In the years after its construction, the Fort Fisher Preservation Laboratory became a highly important facility for early investigations into a variety of artifact treatments using the *Modern Greece* assemblage as a basis. Aided by a copy of H.J. Plenderleith's *The Conservation of Antiquities and Works of Art* and the assistance of archaeologist Stanley South, who was the manager of the Fort Fisher State Historic Site at the time, participants at the lab began attempts to stabilize the collection using multiple experimental processes including electrolysis, blast furnace heating, passive desalination and the use of polyurethane resin coating as a sealant (South 2005: 161, 178; Lawrence 2011: 2). While many of the conservation treatments carried out at the lab have evolved significantly in the past fifty years, the lab remains in operation today at Fort Fisher and neighbors the main offices of the North Carolina Underwater Archaeology Branch. Included on the property is a museum that displays many of

the artifacts from both Fort Fisher and the *Modern Greece* that have been conserved at the preservation lab.

The UAB's Role Expands: New Sites, Field Schools and the *Queen Anne's Revenge*

In the decade following the excavation of the *Modern Greece*, underwater archaeology and conservation continued to expand with the discovery of additional sites of interest and new partnerships between the Underwater Archaeology Branch and universities in eastern North Carolina. The next major archaeological site to managed by the UAB was the wreckage of the U.S.S. *Monitor*, which was found and definitively identified after two surveys in 1973 and 1974. Soon after its discovery, the *Monitor* was nominated to the National Register of Historic Places by the Department of Archives and History and was also nominated by the governor as a National Marine Sanctuary. Between 1975 and 1984, the UAB was contracted by the National Oceanic and Atmospheric Administration (NOAA) to both conduct research at the wreck site and assist in its management. This resulted in significant financial support for the UAB and allowed for the addition of new staff positions at the preservation lab (Lawrence 2011: 6).

The expansion of both the UAB and the Fort Fisher Preservation Lab eventually brought both entities in contact with the University of North Carolina at Wilmington (UNCW) and East Carolina University (ECU). In both cases, the UAB was attached to programs at each university to host summer field schools in maritime archaeology. From 1974 to 1977, the UAB and UNCW cooperatively organized a series of field schools that instructed students in the fundamentals of underwater archaeology, which included historical research, site mapping, and artifact conservation. After a brief hiatus in 1978, the UAB returned to hosting summer field schools, this time in cooperation with ECU. Lasting from 1979 to 1982, these field schools concentrated

on surveying a number of North Carolina's colonial ports, including Bath, Edenton, New Bern, and Beaufort. This new relationship between the UAB and the universities was highly significant in the continuing expansion of the Fort Fisher Preservation Lab and the discipline of underwater archaeology and conservation in North Carolina. Additionally, the UAB's association with ECU was instrumental in the later establishment of the university's graduate program in maritime studies (Lawrence 2011: 6-8).

For the next two decades, the UAB remained at the forefront of maritime archaeology and conservation in North Carolina. By the 1980s, projects at the UAB were smaller in scale and shorter in duration to adhere to a limited operating budget, but survey and monitoring of underwater cultural resources nevertheless continued. Projects conducted during this period included inspection dives on newly discovered wrecks such as the U.S.S. *Huron* and *Oriental* in the Outer Banks, and the expansion and management of the UAB's database of known underwater sites (Lawrence 2011: 9-10). While these projects were undeniably important to the UAB's role in the archaeology of the state's maritime resources, the discovery of the wreckage of *Queen Anne's Revenge* in 1996 proved to be one of the most significant milestones in the history of the UAB. Following the decision to completely recover all artifacts at the wreck site, the UAB helped to establish the *Queen Anne's Revenge* Conservation Lab to manage, conserve, and store all *QAR* material (Lawrence 2011: 14; Wilde-Ramsing 2009). During systematic excavations from 2006 to 2008, staff from both the UAB and the *QAR* Conservation Lab worked together to map, excavate and recover over half of the site's artifacts (Lawrence 2011: 14).

Following the discovery of the wreckage of *Queen Anne's Revenge* in 1996 and the establishment of the *Queen Anne's Revenge* Conservation Lab in 2003, the *Queen Anne's Revenge* Shipwreck Project has become a central figure in maritime archaeology and artifact

conservation in North Carolina. Today, the project is equipped with state-of-the-art equipment and technologies to assist in the recovery, stabilization, and preservation of *QAR* artifacts. Since the UAB and the Fort Fisher Preservation Lab's initial spearheading of archaeological conservation in the 1960s and 1970s, the discipline has evolved significantly to become a central component of North Carolina archaeology. After these decades of growth in the state's approach to maritime archaeology and conservation, the *QAR* Conservation Lab may be seen as the most tangible and significant result of that development. In the next chapter, the activities carried out by the *QAR* Conservation Lab will be discussed, with a focus on research that has been generated as a direct result.

Chapter 3—Methods at the *Queen Anne's Revenge* Conservation Lab

Ever since attempts to completely excavate site 31CR314 began in earnest in 2006 (Wilde-Ramsing and Lusardi 1999; Lawrence 2011: 14), the *Queen Anne's Revenge* Shipwreck Project has recovered thousands of artifacts comprising an extremely wide range of material types. In recent years, the project's focus has shifted somewhat to include a more practical approach to site management, focusing on *in situ* preservation of the materials at the wreck site with limited exploration and recovery of the site's cultural resources. While the adoption of this strategy may appear to indicate that the volume of recovered artifacts has decreased during recent field seasons, this is not the case as thousands of artifacts are still recovered regularly. For example, following the 2014 field season, it was estimated that approximately 400,000 artifacts had been recovered from the wreck, accounting for an estimated 60 percent of the site's total assemblage (Watkins-Kenney et al. 2015: 6). In 2015, it was anticipated that much of the remaining 40 percent of the site's material would be recovered by 2018, resulting in an assemblage of about 620,000 total objects. In addition to this prediction, the lab's 2015 conservation plan also projected that roughly 435,000 of these artifacts would be in various stages of wet storage and treatment by fall 2018 (Watkins-Kenney et al. 2015: 6).

In order to manage the daunting number of artifacts and material types recovered from *QAR*, the lab has implemented a simple, but highly effective system to track the progress of treatment for each object, from the moment of its recovery to the eventual monitoring of the stabilized artifact once it has been transferred to a museum. This system is applicable to all material types as each step in the listed processes includes specific treatments for metals, organics, and inorganics. As mentioned briefly in Chapter 1, the lab's approach to the conservation of the *QAR* assemblage can be broken down broadly into five stages:

1. **Recovery and Post-Recovery of Artifacts**
2. **Treatments in Process**
3. **Final Documentation, Recording, and Stable Storage**
4. **Preparation for Transfer**
5. **Monitoring of Post-Transfer Artifacts at North Carolina Museums**

While the heading for each category is largely general in describing the stage of an artifact's treatment, more detailed conservation tasks specific to certain material types are included in each of these five stages. During the internship, this system has been used to keep track of participation in the various treatments and activities carried out at the lab (Appendix 1.1).

Each of the five categories contains conservation tasks that are performed on a more regular basis (i.e. daily, weekly, or monthly) and also those procedures that are much more infrequent (i.e. yearly). While these more infrequent tasks were not a core focus of the work, the internship resulted in exposure to many of the methods and processes utilized in the five activity stages at the *QAR* Conservation Lab. The remainder of this chapter will provide greater detail for each stage and also include highlights of routine activities that received attention during the internship.

Stage 1: Recovery and Post-Recovery of Artifacts

<u>Field Recovery</u>

For every artifact conserved at the *QAR* Conservation Lab, the journey to stabilization and curation begins with their recovery at the wreck site in Beaufort Inlet. Since the initial 1997 field season, *QAR* Shipwreck Project staff have visited site 31CR314 numerous times to both monitor and excavate the remains of the ship. These expeditions to Beaufort Inlet may occur

intermittently over several months, or last only for a single day. For many of the field seasons, excavations have been carried out in the fall to take advantage of the relatively fair weather (Lawrence and Wilde-Ramsing 2001: 4). These excavations are made possible through the use of several research vessels, including the Underwater Archaeology Branch's (UAB) dive boat, *Snap Dragon II* and the North Carolina Marine Fisheries Division's R/V (research vessel) *Shell Point*. Further logistical support for fieldwork was eventually found at Fort Macon, a U.S. Coast Guard Station near the site. Since 2005, USCG Station Fort Macon has provided facilities for short-term storage of artifacts, dock space for the project's vessels, and supplemental support personnel (Wilde-Ramsing and Carnes-McNaughton 2018: 58-59; Kenyon 2017).

Once the artifacts to be recovered are mapped and tagged *in situ*, several methods may be employed to assist in their retrieval. The method to be used is largely dependent on the artifact's size, material composition, and weight. Before any objects are excavated from the site, a dredge system is used to remove layers of sediment covering the materials. Any exposed artifacts that are small or light enough for divers to recover by hand are placed into crates and carried to the surface. However, the *QAR* assemblage is also comprised of much larger artifacts, such as the ship's cannons and anchors, that are impossible to lift without the use of heavy equipment (Figure 1). For example, during the 2014 field season, several of the ship's cannons were targeted for retrieval. In order to recover one of the cannons, C28, the gun was first fitted with two eight-foot lifting straps before being attached to a 250-pound lift bag. Lift bags are large, sealed, air-filled bags that help to lift heavy objects from a marine environment using their buoyancy. Calculations are performed before raising the object to determine the number and size of lift bags required for the controlled ascent of a heavy object (Bevan 2005) After the cannon reached the surface, the lift straps were attached to R/V *Jones Bay*'s shipboard davit. The ship's

winch then raised C28 from the water and carefully placed it on a set of prepositioned wood supports on the research vessel’s deck (Kenyon 2017: 12-13).

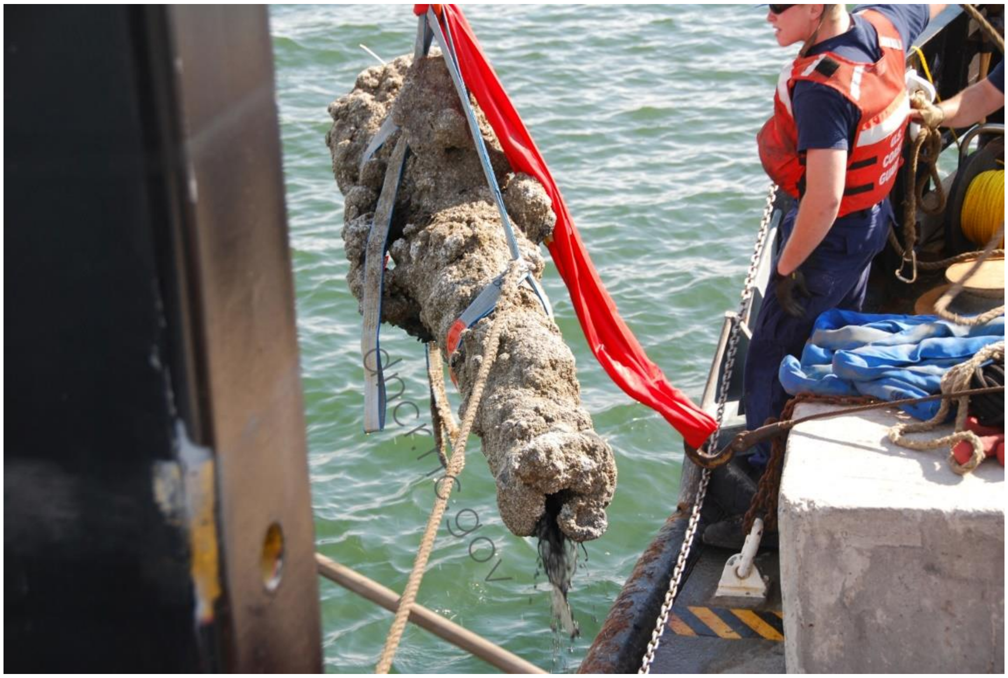

Figure 1. Raising a cannon at site 31CR314. Courtesy of NCDNCR.

For the thousands of small artifacts at the site, a series of sluices and screens on the deck of the research vessel are used. The material recovered by the ship’s dredge hose is brought to the surface and passed through these screens. As the sediment is processed, small objects such as glass beads, lead shot, and gold grains are revealed. This ensures that all artifacts are recovered from the site, not just those that can be visually identified by the dive team (Watkins-Kenney et al. 2015: 16).

Post-Recovery Storage

After three hundred years on the ocean floor at site 31CR314, the majority of the *QAR* assemblage's artifacts are waterlogged and impregnated by soluble salts. Once these artifacts are recovered, they are at significant risk for deterioration if not stored properly. For example, when waterlogged archaeological wood is recovered, such as *QAR*'s hull timbers, it begins to shrink and crack almost immediately (Hoffman 2013: 10). If left to dry in the open air, the water that has permeated and replaced much of the wood's deteriorated cellular structure will evaporate, leading to the object's collapse. Metal objects, like the ship's armament, also must be attended to quickly, as the soluble salts will oxidize and gradually destroy the artifact's surface if exposed to air (Hamilton 1999a: 44).

In order to prevent further deterioration after recovery, the object is placed into wet storage to limit exposure to the dry air. This involves the use of small tubs and large tanks filled with a solution that will vary depending on the material type. Organic materials like wood, rope, and textiles are stored in containers with tap water that are usually sealed to prevent biological growth through the intrusion of light, insects, or oxygen (Watkins-Kenney et al. 2015: 16). Inorganic materials such as glass and ceramics are similarly stored in covered containers with tap water, beginning the desalination process almost immediately. Finally, metal objects such as the ship's iron cannons and numerous concretions are placed into tanks containing an alkaline solution that inhibits further corrosion (Hamilton 1999). At the QAR Lab, the solution used is 2.5% sodium carbonate in tap water, with a pH of 10.5-11 (Watkins-Kenney et al. 2015: 17). Without attention to proper inhibitive wet storage, the ferrous compounds within the iron will oxidize to a ferric state, increase in volume, and ultimately cause the surface of the object to scale off (Hamilton 1999b: 294). In recent field seasons, tanks with appropriate solutions are set

up in the lab before fieldwork even begins in anticipation of the storage needs for recovered artifacts (Kenyon 2015: 7).

Initial Artifact Documentation and Recording

Once the artifacts have been recovered and placed into wet storage, the next stage of the process can begin. Occurring both in the field immediately after recovery and in the lab, artifact documentation and recording is an incredibly important step in the conservation process. These records often detail the methods of recovery, any examinations or observations of the object, methods of cleaning, and naturally any treatments performed to stabilize or restore the object (Cronyn 1990: 94). According to Caple (2000: 70), creating a conservation record "recognizes that conservation and restoration work…are part of a series of ongoing processes which will last for the whole of an object's life" and that these records are necessary for any future conservators that seek to carry out further preservation or investigation of the object.

The first entries into the conservation record are written after the object has been identified and recovered in the field. *QAR* Shipwreck Project archaeologists and divers follow a simple, but well-defined protocol to record the artifacts during processing. For many of the larger artifacts at the site, such as the cannons, a Tyvek tag labeled with a catalog number (QAR number) is attached to the object by a diver *in situ* before it is brought to the surface. Once any object, regardless of size, has been brought onboard the research vessel, an artifact field log is completed to record more detailed information. This includes the date of recovery, the object's QAR number, the number of the excavation unit the artifact was recovered from, the object's exact East and North provenience, a short preliminary description of the artifact's condition or appearance, and finally a photograph once the artifact is placed into storage on shore.

Eventually, the recovered artifacts are transferred to the *QAR* Conservation Lab to be further documented and to undergo preliminary treatments. Upon arrival at the lab, the field records are reviewed to determine if any information is missing. This includes the creation of new artifact tags or taking pre-treatment photographs if none already exist. Once this is completed, pre-treatment measurements of the artifacts are taken, including the weight (in grams for small objects, and kilograms for large objects), length, width, and thickness of the object where applicable. Finally, any additional details about the object's material composition, identity, and composition may be added to the record. This new information is recorded on an artifact lab activity record sheet, or "blue sheet" as it is known at the lab. The details recorded on these sheets are then entered into an electronic database managed by the North Carolina Office of State Archaeology. Keeping both electronic and paper records ensures that a redundancy exists in case either of the databases are damaged or inaccessible. Furthermore, the use of an electronic database allows conservators to easily search for specific artifacts that have undergone treatment at the lab.

For some recovered objects, X-radiography is also necessary at this stage. This is mostly done for artifacts that are encased in dense layers of concretion. This hard, rock-like outer layer results from metal corrosion in salt water and is comprised of precipitates of calcium carbonate and magnesium hydroxide intermixed with sand, marine life and corrosion products (Hamilton 1999b: 293). This dense coating prevents visual identification of any artifacts encased in the concretion without the use of analytical instruments. To overcome this, the *QAR* Lab uses a large industrial X-ray machine to penetrate these outer layers and create an image of the artifacts within. This image provides general locations of both small and large objects within the concretion and their relative proximity to one another.

Stage 2: Treatments in Process

Once the recovered artifacts have been properly stored and documented at the *QAR* Conservation Lab, treatments to stabilize each object can begin. As a result of the wide range of material types comprising the *Queen Anne's Revenge* assemblage, a number of different processes are used to conserve metals, organics (bone, wood, textile, etc.), and inorganics (glass, ceramics). Generally, the tasks associated with Stage 2 of the conservation process include artifact cleaning, desalination, consolidation, dehydration, and the application of protective coatings (Watkins-Kenney 2015: 17). This stage serves as the basis for most regular lab activities.

Cleaning

For almost all of the artifacts treated at the *QAR* Conservation Lab, the "cleaning" step marks the beginning of their journey to stabilization. As stated earlier, numerous objects are recovered in the field in a state of dense concretion (also referred to as "encrustation"). This concreted outer layer results from the chemical degradation, or corrosion, of metals in salt water. Chemically, the outer layer is composed of a high degree of calcium, magnesium carbonate, and hydroxide precipitated by the surrounding sea water, while the inside of the concretion is largely made of hydrated iron oxides (Cronyn 1990: 181). As these concretions form, additional artifacts may become embedded within, accompanying the original corroding iron object.

Cleaning of encrusted objects can either be chemical or mechanical in nature. In chemical cleaning, the artifact is immersed for a period of time in a chemical solution that gradually removes the encrusted layer. For example, encrusted lead artifacts at the lab are immersed in a solution of hydrochloric acid to remove lead carbonates, lead monoxide, lead sulfide, calcium carbonate, and ferric oxide (Hamilton 1999b: 303). While chemical cleaning can be effective for

certain artifacts and material types, Cronyn (1990: 66-67) notes that it is difficult to control, with the cleaning agents sometimes penetrating micro-cracks to reach the weakened artifact. In addition to being potentially damaging to the artifact, chemical cleaning is also slow and ineffective for removing most larger encrustations (Hamilton 1996: 11). The alternative to these treatments is mechanical cleaning. Using tools rather than chemicals, mechanical cleaning is generally more controllable when performed by a skilled conservator (Cronyn 1990: 64). For these reasons, mechanical cleaning is the chosen process at the *QAR* Lab to recover objects encased in concretion.

While hammers and chisels are sometimes used to break through these hard outer layers (Cronyn 1990: 193), mechanical cleaning of concretions is performed with an air scribe at the *QAR* Lab. These handheld pneumatic tools function very similarly to a small jackhammer and are much more efficient and precise in removing small artifacts, such as the glass beads and lead shot that are often found within *QAR* concretions (Hamilton 1999b: 296). Using the X-ray images taken during initial documentation as a guide, conservators use these tools to slowly and delicately remove the encrustation and reveal the artifacts within (Figure 2).

Figure 2. Cleaning the concreted surface of an expanding bar shot projectile with an air scribe. Courtesy of NCDNCR

Concretions broken down in this manner vary wildly in size. Small concretions may contain a single half-pound cannon ball and measure just a few centimeters wide, while the largest concretions processed at the lab often encase entire iron cannons. However, regardless of the size, the process of air scribing is often very slow, as small bits of concreted material are removed during each cleaning session. While smaller cannon ball concretions may be completely broken down in a matter of weeks or months, cannon concretions take months or even years to clean completely. The duration of cleaning can be attributed both to the overall surface area of the object being cleaned and to the frequency at which the object is able to be worked on. In the case of cannons, cleaning is mostly performed once a month on "cannon day", when a large portion of the main lab space, room 114, is set aside specifically for air scribing a single cannon.

Desalination

As a result of immersion for three centuries in a salty marine environment, soluble salts have penetrated many of the artifacts in the *QAR* assemblage. The removal of these salts from *QAR* artifacts is arguably the most important step in the entire conservation process, as it ensures that the object will remain stable after conservation treatment (Watkins-Kenney et al. 2015: 17). The artifacts most susceptible to the intrusion of salts include porous materials such as ceramics, wood, and bone, and metals including iron and copper alloys. As mentioned previously, failure to attend to the presence of soluble salts can lead to the extreme degradation and even total loss of an artifact. For metals, once exposed to oxygen, hydrated chlorides eventually form ferric hydroxide and hydrochloric acid. The hydrochloric acid then oxidizes the remaining uncorroded metal, beginning a cycle that will continue until all of the metal has disappeared (Hamilton 1999b: 294-295). For non-metals such as ceramics and bone, soluble salts will similarly

crystallize if left to air dry, causing surface flaking and potentially leading to the complete destruction of the artifact (Hamilton 1999a: 15).

In order to remove the soluble salts from these artifacts, the *QAR* Lab uses two primary treatments: reverse osmosis (RO) baths and electrolytic reduction. Baths of RO water are used for non-metal artifacts including ceramics, bone, organic materials, wood, and glass. Placing artifacts into these baths is a lengthy, but very simple process. At the beginning of the treatment, the object is immersed in tap water. The artifact will remain in the container of tap water until the chloride level of the material is equivalent to that of the solution. Following this, the tap water is replaced with RO water (Hamilton 1996: 16). The very low salinity of the purified RO water creates a steep diffusion gradient for the removal of salts from the artifact. As the object soaks, the soluble salts will continue to move from the higher concentration in the object into the much lower concentration of the water until an equilibrium is reached. Once this is detected, the water in the container is changed to create a new diffusion gradient, beginning the process again. The series of baths persists until it is no longer possible to remove any more soluble salts from the artifact.

Widely regarded as the most effective conservation treatment for marine iron (Hamilton 1999b: 297), electrolytic reduction (ER) can be used to desalinate both wrought and cast iron artifacts recovered from *Queen Anne's Revenge*. While electrolytic reduction shares some similarities with the series of water baths described above, this process differs in its use of an electrical current and electrolytic solution to drive salts out of the artifact.

To set up ER treatment, the object is first placed into a tank with an electrically conductive solution. At the *QAR* Lab, this solution is either 1% sodium hydroxide in tap/RO water or 2.5% sodium carbonate in tap/RO water (Watkins-Kenney 2015: 18). After placing the

artifact into the tank, two sacrificial steel plates are added on either side. The artifact is then wired to the negative terminal of a D.C. power supply, while the sacrificial steel plates are connected to the power supply's positive terminal (Figure 3).

Figure 3. Iron artifacts after being placed into tubs and connected to a power supply. Courtesy of NCDNCR.

When the power supply unit is turned on, the artifact becomes negatively charged and the steel anodes hold a positive charge. This reversal in polarity causes the negatively charged corrosive chloride ions to leave the iron artifact and travel into the solution toward the positively charged steel anodes (Hamilton 1999b: 298). Throughout the process, the steel anodes absorb the soluble salts and sacrificially corrode.

Much like the baths of RO water used for non-metal artifacts, the solutions used in ER also require periodic changing as soluble salts leave the iron artifact and enter the solution. The chloride content of this solution is monitored throughout the process to determine the progress of

desalination. This stage of treatment is considered complete when several consistently low measurements of chlorides in the solution are recorded (Watkins-Kenney 2015: 18).

Consolidation

The *QAR* artifact assemblage includes thousands of wooden artifacts, ranging from large, partially articulated segments of the ship's hull, to small bits of planking and the remnants of tools and firearms. Regardless of size, all of the wood recovered from the wreck is waterlogged, and, as such, requires consolidation to reach stable status. While in its burial context at Site 31CR314, *QAR* wood is subjected to degradation from the intrusion of biological organisms such as shipworms (from the *Teredo* species) and various types of fungi (Hoffman 2013: 25-26). As these organisms colonize the wood, the cellulose in the cell wall gradually disintegrates, leaving a lignin network to support the remainder of the wood structure (Hamilton 1999a: 24). In a marine context, the missing cellular structure is replaced by water, stabilizing the object's brittle structure and allowing the wood to retain its shape and dimensions (Hoffman 2013: 27). The wood will continue to retain these dimensions if kept wet. If left to dry in the open air without treatment, however, the excess water in the artifact will evaporate and the resulting surface tension forces will cause the weakened cell walls to collapse. Visual evidence of this process is significant shrinking and distortion of the artifact (Hamilton 1999a: 24).

In order to prevent shrinkage and total destruction of wooden artifacts, the *QAR* Lab employs PEG treatment. PEG, or Polyethylene Glycol, is a wax compound that is used as a bulking agent to strengthen the deteriorated structure of waterlogged wood. The treatment begins by placing the wooden artifact in a solution of 5% PEG 400 (low molecular weight) in RO water. During this process, the PEG slowly penetrates the wood, displacing the water occupying the artifact's cellular structure. As the treatment continues, the amount of PEG in the solution is

increased in gradual 5% increments. For most of the wooden artifacts treated with the PEG method at the *QAR* Lab, the target concentrations for completion of the treatment are 25% PEG 400 and 40% PEG 4000 (high molecular weight) (Kimberly Kenyon 2019, personal communication).

Once a given artifact's solution reaches the requisite PEG percentages, the PEG that replaced the water within the cellular walls of the object begins to harden, strengthening the artifact's structure. The final stage of the process involves placing the treated artifact into a freeze dryer at a temperature of -32 to -40°C. When the temperature of the artifact reaches -25°C, a vacuum seal is applied to the chamber. This causes the remaining water in the artifact to freeze and eventually evaporate from the object's structure. Throughout the process, the weight of the object is recorded to determine the amount of water that has been removed. When the weight-loss from water removal eventually stabilizes, the consolidation of the wooden artifact is complete (Hamilton 1999a: 28).

Dehydration

After soluble salts have been sufficiently reduced or removed, artifacts of all material types must undergo a drying or dehydration step to remove any excess water left over from previous treatments. This phase is represented both in the freeze-drying of wooden artifacts after PEG treatment mentioned above and in the processes that must occur after an iron artifact completes electrolytic reduction treatment.

Once these iron artifacts are removed from ER, they are placed into a series of RO water baths. In a similar fashion to the passive desalination of non-metal artifacts, these baths establish a diffusion gradient to slowly remove any residual electrolyte (sodium hydroxide or sodium carbonate) and chlorides that may be left over from the ER process (Hamilton 1999a: 70). The

removal of these agents is monitored by recording pH readings of both the solution and the surface of the artifact. Three stable readings of a pH of 6 indicates that all residual hydroxide has vacated the artifact (Kimberly Kenyon 2019, personal communication). After this process is completed, the artifact is ready for dehydration.

For the majority of the iron artifacts in the *QAR* assemblage, dehydration occurs in small, airtight desiccators. According to Hamilton (1999a: 71), drying the artifacts in an oxygen-free environment ensures that the metal will not rust during the process and that any ferrous compounds within the object will not oxidize to a ferric state. Throughout the process, "drying weights" are recorded to detect weight loss as excess water is removed. After several consistent measurements of the same weight, the object is considered dried. This same monitoring procedure is applied to non-metal objects, such as ceramics, that are left to air dry.

Application of Protective Coatings

Following the drying stage, artifacts that are at continued risk for degradation from environmental factors must be safeguarded through the application of a protective coating. This coating insulates the object from the potentially deleterious effects of moisture, chemically active vapors, and gases (Hamilton 1999b: 299). The protective coating used most often at the lab is tannic acid. Before the tannic acid is applied, any remaining corrosion product is gently removed from the surface of the artifact with a toothbrush. Once this material is removed, the first coat of tannic acid is applied under a fume hood. This coat is left to dry for an hour before the application of a second coat. After the second coat dries for a period of 24 to 48 hours, the application of the third and final coat of tannic acid can take place (Elise Carroll 2019, personal communication).

To further protect the artifact, it is recommended that a final sealant is added to provide a barrier to moisture and prevent future corrosion. According to Hamilton (1999b: 300), this sealant should ideally be "1) impervious to water vapor or gases, 2) natural-looking so that it does not detract from the appearance of the artifact, 3) reversible, and 4) transparent or translucent so any corrosion of the metal surface can be quickly detected". For the iron artifacts at the *QAR* Conservation Lab, Paraloid B-72 resin is used. This layer is applied approximately one week after the final coating of tannic acid has dried (Elise Carroll 2019, personal communication). Once the B-72 layer is finished drying, the treatment of the iron artifact is complete.

Stage 3: Final Documentation, Recording, and Stable Storage

Throughout the course of an artifact's treatment in Stage 2, extensive written and visual records are kept. These records detail every process that the artifact is subject to, including physical measurements, visual observations, chemical treatments, passive and active desalination, and pre- and post-treatment photography. In most cases, a final record of treatment is produced. This document first provides a description of the artifact, including any details or photographs of its condition before undergoing treatment. These details are accompanied by any relevant examinations or observations of the object's form, function, or identity. This portion of the final record of treatment often includes detailed illustrations of the artifact to highlight any areas of interest. This is followed by a section describing any methods of mechanical cleaning that have been used and the measures taken to stabilize the artifact. The document concludes with a description of the artifact's post-treatment condition and a section that details the artifact's environmental storage and handling requirements (Cronyn 1990: 95).

When an artifact's treatment program is completed at the *QAR* Lab, several procedures must take place before the object goes into stable storage. The first of these steps is post-treatment photography (Figure 4). After being placed on a flat, black background and accompanied by a centimeter scale, the artifact is photographed from two perspectives. For most objects, this involves placing the object flat on the background for the first perspective, then completely flipping the object so that the reverse side is photographed for the second perspective. Each perspective is photographed using a wide range of shutter speeds, usually from 1.3 to 6 seconds. Once these images are opened in Adobe Photoshop, one photograph for each perspective is chosen and cleaned. It is important that the chosen photograph is neither too bright nor too dark that important artifact surface details are obscured (Elise Carroll 2019, personal communication; NC *QAR* Archaeological Conservation Lab Standard Protocols for Photography).

Figure 4. Cannon C4 in preparations to receive final photographs after treatment. Courtesy of NCDNCR.

After these final images are taken and processed, final post-treatment measurements of the artifact can be recorded. This step generally involves the use of scales and digital calipers to weigh the artifact and measure its dimensions before it enters into a storage environment. While several different measurements may be taken depending on the artifact, the length, width, and thickness of the artifact are the most commonly recorded dimensions. These measurements are accompanied by any additional notes and observations that the conservator wishes to include in the final documentation. These details may consist of observations of surface markings, like maker's marks, or notes regarding diagnostic features visible on the artifact, such as pour marks or casting seams on cannon balls. All of these details provide a wealth of information to current and future conservators, the museum staff working with the artifact, and any researchers that may use the artifact as part of a data set for publication.

Following the completion of final documentation, the artifact is ready to be stored. The *QAR* Lab stores treated artifacts in a series of climate-controlled cabinets. As each cabinet contains artifacts of a particular material type, storage environments will differ between cabinets. For example, the iron cabinet contains several trays of silica gel to desiccate the cabinet's micro-environment and lower the relative humidity (RH). The target RH for iron storage lies between 65% for iron with no chlorides, and as low as 50% for iron artifacts still containing chlorides (Cronyn 1990: 201; Hamilton 1999a: 72; Cornet 1970). To monitor this, hygrometers are placed into the cabinet to record any fluctuations in RH (Cronyn 1990: 74). Every month, these meters are collected, and their data is transferred to a computer to determine if the storage environment is maintaining a regular and safe RH.

Stage 4: Preparation for Transfer

Following an artifact's treatment and final stabilization, it may be sent to a museum to become part of an exhibit. While the North Carolina Maritime Museum in Beaufort, North Carolina is the primary repository for *QAR* artifacts (Shannon 2001), elements of the assemblage can be found in exhibits across the state. As of 2015, approximately 400 conserved artifacts were on display at the North Carolina Maritime Museum (NCMM). This collection included six cannons, two bells, several pewter objects, ceramic and glass vessels, medical instruments, numerous cannon munitions and portions of the ship's hull architecture (Watkins-Kenney et al. 2015: 23). In addition to the display at the NCMM, *QAR* artifacts have also been previously transferred to the Museum of History in Raleigh, North Carolina, the Museum of the Albemarle in Elizabeth City, North Carolina, and even the Smithsonian in Washington, DC.

Before artifacts are transferred to one of the above museums, their associated records must be reviewed to ensure that all relevant data is present before the objects leave the *QAR* Lab. This includes confirming that final, post-treatment photographs have been taken, and that any missing documentation is completed. For many of the artifacts that are transferred for the purpose of exhibition, annotated measurements are often taken before transfer. These measurements are significantly more detailed than standard final measurements and provide specific information about individual components of an artifact.

For example, before the most recent artifact transfer to the NCMM on March 4th, 2020, annotated measurements were performed for an iron gun lock plate. Using digital calipers, the dimensions of each individual screw hole were taken, and multiple dimensions of the pan were recorded in addition to several measurements of length, width, and thickness at different points across the object. The areas where these measurements were taken were then labeled on a printed

photograph of the lock plate using a silver, fine point Sharpie marker. Finally, these annotated photographs were copied and included with the completed artifact record.

After any missing documentation is completed, the artifacts are packed into padded, sealed polyethylene containers for transport. If cannons are being transferred, the bores are packed with containers of silica gel to maintain a stable relative humidity within the object. These containers remain inside the cannons after transfer to help regulate the conditions of the storage environment in the museum.

Once the artifacts are packed, *QAR* conservators perform a final review of the list of artifacts undergoing transfer to ensure that all are present and accounted for. Finally, all conservation records associated with each artifact are gathered so that they may accompany the collection to the museum. These records remain with the artifacts for the duration of their stay at the museum to provide museum staff with detailed information on previous treatments and important handling instructions.

Stage 5: Monitoring of Post-Transfer Artifacts at Museums

Although the transferred artifacts have left the *QAR* Conservation Lab, their continued preservation is continually monitored by the lab's conservators long after the transfer is finished. If scheduling allows, these check-up visits occur on a monthly basis at any museum that is currently in possession of *QAR* artifacts (Kimberly Kenyon 2020, personal communication). The monitoring performed is simple, but highly significant in ensuring that no further corrosion is occurring and that no new corrosion processes can begin. This stage usually consists of cannon checks (for museums in possession of cannons) and condition assessments.

When carrying out a cannon check, the conservator first performs a visual inspection of the cannon's surface using a flashlight. Cracks or physical distortions of the cannon's surface may be indicative of corrosion, necessitating either a reassessment of the storage environment or the retreatment of the artifact. In addition to the surface of the cannon, the bore of the gun is also examined for signs of deterioration. To perform a condition assessment, photographs are taken of both the cannon's surface and bore/muzzle area for comparison with previous records and to document any visible degradation.

After visual inspections are performed, the silica gel containers that were placed into the bore of the cannon are removed to be examined and replaced. This process was most recently encountered during a cannon check at the Museum of the Albemarle on February 19th, 2020. During this stage of the cannon check, four containers of silica gel were removed from the six-pound cannon's bore. RH strips had been previously attached to both the container near the muzzle and the container near the breech of the gun. These strips were examined to determine the RH of the bore area. Once these measurements were recorded, the silica gel containers were opened to empty the saturated gel into two empty buckets. The containers were then filled with new silica gel and returned to the bore of the gun to continue desiccation. Finally, the buckets of spent gel were taken back to the lab to be dried in an oven for future use. While this recent cannon check at the Museum of the Albemarle is just one example of this process, the same methods and procedures are utilized at any other museum in possession of artifacts from the *QAR* collection.

Routine Internship Tasks and Responsibilities

Throughout the course of the internship at the *QAR* Lab, several routine tasks have come to form the weekly structure of the work. While many of these tasks can be associated with any of the five aforementioned conservation stages, these daily and weekly responsibilities are most closely tied to Stage 2: Treatments in Process and Stage 3: Final Documentation, Recording, and Stable Storage. Accompanying these routine activities were more specialized, but infrequent, tasks and projects. These will be discussed in greater detail in Chapter 4.

TDS Solution Testing and RO Solution Changeouts

As mentioned earlier while discussing Stage 1 and 2 of the conservation process, one of the *QAR* Lab's primary concerns during conservation is the removal of soluble salts from artifacts. If the artifact is left to dry without proper treatment, the soluble salts within the object will eventually crystallize and destroy the artifact's structural integrity. For most organic artifacts in the *QAR* collection, such as those made of wood, leather, or plant fibers, the first step of treatment is passive desalination.

In order to accomplish passive desalination, the artifact is placed in a container with RO (reverse osmosis) water. RO water is highly useful in this process as it possesses much lower salinity than either tap water or the sea water that the artifacts were originally recovered from. This allows conservators to establish a gradient between the high salt content of the artifact and the low salt content of the solution. Once placed into the solution, the container holding the artifact is stored in a refrigerator to prevent deterioration through biological growth. As the artifact sits in the container, the salts are leeched out of the object and deposited into the RO water (Cronyn 1990: 81).

Monitoring of this process is performed every Monday at the lab and involves the use of a TDS (total dissolved solids) meter (Figure 5). This device measures the number of solid particles (in parts per million), including soluble salts, that have been dissolved into the RO water solution (Hamilton 1999a: 15). The TDS meter also provides a reading of the conductivity of the solution in microsiemens (uS). As more chlorides are removed from the artifact and deposited into the RO water, both values will increase.

Figure 5. Using a TDS meter to monitor desalination. Courtesy of NCDNCR.

After three stable measurements where both values plateau, the decision is made to change the solution to fresh RO water. This establishes a new gradient for the further removal of salts from the artifact. Changing of the solution usually occurs a day or two after the TDS testing has taken place. To complete this task, the artifact(s) is taken from the container and placed on a safe surface, usually the removed lid of the container. The old RO water is then slowly poured down a drain, with care taken to keep small artifact fragments from leaving the container. Finally, the container is filled with fresh RO water before the artifact(s) is reintroduced into the

solution. The passive desalination process is considered complete when TDS testing shows that no further salts are being removed from the artifact and deposited into the solution.

PEG Monitoring

In addition to monitoring the passive desalination of artifacts through TDS testing, all of the active Polyethylene Glycol treatments are monitored on a weekly basis. In addition to monitoring the Brunswick Town cask hoop solution (which is discussed in further detail in Chapter 5), artifacts undergoing PEG treatment in four separate buckets and one large warehouse tank are tested every Thursday. The monitoring process involves measuring the refractive index (nD) of each solution to determine the amount of PEG that has entered into the artifact. In order to do this, a refractometer is used.

The process begins by establishing a control measurement using RO water. A pipette is used to drop 1mm of RO water on the lens of the refractometer. This RO sample calibrates the refractometer by providing a base refractive index measurement (usually ~1.3333 nD). With the refractometer calibrated, the RO water is removed, and the lens is cleaned before a sample of the PEG solution is tested. The refractometer then provides a reading of the PEG solution's refractive index. After three stable readings are recorded, more PEG can be added to the solution.

When the solution is ready for the addition of more PEG, the computer program PEGCON is used to determine the amount of solution to be removed and the amount of PEG to be added to increase PEG concentration by 5%. The PEGCON program can calculate these concentrations using several variables including the species of the wood and the level of degradation. The targeted concentrations for all moderately-degraded *QAR* wooden artifacts is

25% PEG 400 and 40% PEG 4000. Once these desired concentrations are reached, the artifacts are ready for freeze drying.

Artifact Documentation

As artifacts enter into each stage of the conservation process, extensive and detailed documents are created to record the artifact's current status and the progress of the treatment. This internship has resulted in exposure to several methods of artifact documentation used at the lab. The most basic and frequent method of documentation used by *QAR* conservators are Object Activity Record Sheets, or "blue sheets". These blank sheets are used to record measurements, observations, and new conservation steps as artifacts undergo treatments and analysis. For example, before an artifact can finally be stored at the end of Stage 3, its final measurements are taken and recorded on one of these activity record sheets. After work with the artifact is completed, the conservation details on the blue sheet are entered into the OSA electronic database.

The creation of detailed records occurs at every stage of the conservation process and, therefore, will be an integral step in any given treatment. To organize all of the different entries in the electronic database, each activity performed at the lab is assigned to one of several categories. These categories include but are not limited to "Examination and Analysis" for measurements and observations, "Desalination" for RO solution changeouts, "Dehydration" for drying artifacts after wet treatment, "Handling" for when an artifact is moved, and "Cleaning" for any chemical or mechanical treatment to remove corrosion products or concretion. In addition to listing the type of activity being performed, keeping records at the *QAR* Lab also involves recording the date that the action was performed on, the QAR Catalog Number of the artifact, the initials of the conservator performing the action, and a detailed description of what

exactly was done to the artifact. When entered into the electronic database, this information contributes to a thorough and complete record of an artifact's entire treatment process from recovery to museum display.

For almost every artifact that passes through the *QAR* Lab, some form of monitoring or documentation is performed during the course of treatment. Both of these procedures ensure that the treatment is progressing effectively and that the artifacts themselves remain stable. As these tasks occur on a regular basis, they form a bridge between the larger steps in the conservation process that occur on a more intermittent basis. In the next chapter, these specialized tasks will be discussed in detail.

Chapter 4—Additional Tasks and Personal Projects

In addition to all of the routine tasks carried out at the *Queen Anne's Revenge* Conservation Lab discussed in Chapter 3, this internship has also involved numerous specialized tasks that occur on a more infrequent basis. The majority of these activities are performed monthly, rather than daily or weekly. This includes the chelation of organic artifacts before undergoing passive desalination, solution testing for electrolytic reduction (ER) tanks, casting of artifact voids found in concretions, the creation of molds for making artifact copies, cannon cleaning, and participation in public outreach events and tours.

Accompanying these tasks are personal projects that are often limited to one conservator. In many cases at the lab, these projects are focused on the conservation of a single object. During the process, the conservator becomes highly familiar with all aspects of both the treatment and the object. It is usually necessary for this individual to see the treatment of the artifact to its conclusion as they are the most familiar with its condition and all procedures used during the process. While overseeing and conducting all treatments, detailed records are compiled along the way.

During the course of the internship at the *QAR* Lab, personal projects have included the conservation of a wooden cask hoop recovered from Brunswick Town during East Carolina University's 2015 archaeology field school, the breakdown and management of two concretions: QAR 1821.000 and 3166.000, and the writing of two blogs for the *QAR* Lab website (https://www.qaronline.org/blog/2020-04-01/artifact-month-bt-hoop and https://www.qaronline.org/blog/2020-04-15/my-story-brandon-eckert). While the treatment of the cask hoop will be focused on in Chapter 5, the breakdown of both concretions and the two blog posts will be discussed in detail in this chapter.

Additional Treatments at the *Queen Anne's Revenge* Conservation Lab

Chelation of Organic Artifacts Using Ammonium Citrate: Background

As discussed in Chapter 3, almost all artifacts recovered from the *Queen Anne's Revenge* wreck site are at severe risk of deterioration and destruction if the soluble salts that have penetrated their structure are not removed. Several methods are employed at the lab to remove these salts from a wide variety of artifact material types. While most metal objects, such as the ship's cast iron cannons, are placed into an electrolytic reduction treatment program, organic artifacts enter passive desalination. This process involves placing the artifacts into a bath of reverse osmosis (RO) water. The low salinity of the RO water creates a diffusion gradient to leech the soluble salts out of the artifact (see Chapter 3).

Although this method is highly effective in removing soluble salts from organic artifacts, many of these objects require an additional process to also remove any latent iron content before further treatment can occur. This iron content results either from the artifact's proximity to iron while encased in concretion, or, in the case of wood artifacts, from the presence of partially corroded iron fasteners. If left untreated, the iron will continue to corrode, and will likely lead to the further degradation or destruction of the organic artifact (Almkvist et al. 2013: 4).

The source of this destruction is the combination of mineral salts of iron and sulfur diffused into the wood from the marine burial environment (Karsten et al. 2018: 40; Hoffman 2013: 76). When these sulfur compounds and iron ions are exposed to air, oxidation occurs, producing a damaging acid in the structure of the organic artifact (Fors and Sandstrom 2005: 399). The presence of this acid in the artifact triggers the hydrolysis of polysaccharides in the wood, contributing to further degradation (Almkvist et al. 2013: 4). Almkvist et al. (2013: 4) also highlight two additional threats that are common when dealing with iron contaminated wood.

The first threat involves the propensity of inorganic compounds to accumulate in the surface region of a contaminated object. If left to dry without proper treatment, mechanical damage of the object will occur. The second threat mentioned by Almkvist et al. (2013) is the potential for iron compounds to catalyze various chemical reactions, with the most severe being oxidative degradation. This phenomenon is most harmful to wood that has already been conserved, as it leads to the depolymerization of wood components and preservation agents, such as PEG. Therefore, it is imperative that any iron contamination is dealt with before active consolidation of the wood can occur.

In order to remove these components from the organic object and prevent acidification, a chelating agent is used. Also known as a sequestering agent, chelating agents are chemical substances that form soluble bonds with certain metal ions, especially those of iron and copper (Karsten et al. 2018: 59; Cronyn 1990: 66). Examples of these substances include the disodium salt of ethylene-diamine-tetraacetic acid (EDTA) and ammonium citrate. While some EDTA treatments are utilized at both the lab and the North Carolina Maritime Museum, the ammonium citrate treatment was focused on during the internship.

Case Studies: *Vasa* and *Mary Rose*

The contamination of iron in archaeological waterlogged wood is not a phenomenon that is unique to the *Queen Anne's Revenge* assemblage. In fact, iron contamination and all of the associated risks that accompany it are highly common in all archaeological contexts. The occurrence of iron contamination is especially high in shipwrecks, where wood is often found associated with iron, "either as fastenings or as objects found nearby" (Almkvist et al. 2013: 4). In recent years, such contamination has become a cause for concern for two high profile ships: the *Vasa* (Figure 1) and the *Mary Rose*.

Figure 1. The *Vasa* hull on display at the *Vasa* Museum in Stockholm. From Hocker et al. 2012

The *Vasa* is a seventeenth century Swedish warship that capsized and sank at the entrance of the Stockholm harbor at the beginning of her maiden voyage on August 10th, 1628 (Fors and Sandstrom 2005: 399). After resting on the bottom of the harbor for more than three hundred years, the *Vasa* was recovered on April 24th, 1961 in remarkable condition, mostly as a result of the cold and brackish waters of the Baltic Sea preventing the survival of the destructive shipworm (*Teredo Navalis*) (Hocker et al. 2012: 175). However, after decades of conservation work using large-scale PEG application and ten years of display at the *Vasa* Museum in Stockholm, white and yellow patches began to appear on the ship's timbers and on wooden artifacts recovered from the wreck (Hoffmann 2013: 76; Hocker et al. 2012: 178). Researchers with the project quickly employed sulfur K-edge XANES spectroscopy at the Stanford Synchrotron Radiation Laboratory to definitively identify the precipitant. After analysis, it was revealed that nearly two tons of sulfur in reduced forms was oxidizing to sulfuric acid in the timbers of the *Vasa* (Fors and Sandstrom 2005: 400; Sandstrom et al. 2002).

After the identification of the acid in the *Vasa* timbers, attention also turned to the timbers of the *Mary Rose* which was experiencing similar chemical precipitation during conservation. The *Mary Rose* was a Tudor warship, serving for 35 years in Henry VIII's navy.

However, her period of service to the English crown was cut short in 1545, when she suddenly and disastrously sank while maneuvering to engage the French navy outside of Portsmouth, U.K. Salvage of the *Mary Rose*'s hull remains began in 1982, leading to the recovery of large portions of the ship and approximately 20,000 artifacts (Fors and Sandstrom 2005: 401; Jones 2003). Like the *Vasa*, the *Mary Rose* was treated with repeated sprays of PEG to consolidate the hull remains. From 1994 until 2006, a low molecular weight PEG 200 solution was used to penetrate the structure of the hull timbers. This was followed from 2006 until 2013 with spray treatments using a higher molecular weight PEG 2000 solution to further consolidate the wood (Preston et al. 2014).

The discovery of the acid in the *Vasa*'s wood led to two separate conservation initiatives: "Preserve the *Vasa*" from 2003 to 2006, and "A Future for *Vasa*" from 2008 to 2011 (Hocker et al. 2012: 178). During this period of research, several experimental methods and analytical techniques were used to determine the extent of sulfur and iron contamination in the *Vasa*'s timbers. These included the aforementioned use of sulfur XANES spectroscopy to determine the types and concentrations of sulfur groups in the wood, X-ray micro-spectroscopy to map the locations of reduced and oxidized sulfur species within the wood, X-ray fluorescence line-scan analysis to obtain concentration profiles for total sulfur and iron, and X-ray photoelectron spectroscopy to obtain an overview of all elements present in the wood samples (Fors and Sandstrom 2005: 403-407). According to Fors and Sandstrom (2005: 411), the amount of reduced sulfur content revealed through the analyses of both *Vasa* and *Mary Rose* timbers had the potential to produce an additional 5-6 tons of acid through oxidation.

Further analysis of the data generated from these processes revealed that two factors were at fault for the high degree of acidification in the *Vasa*'s timbers. The first of these factors can be

traced back to the initial salvage of the ship in 1961, when the decision was made to temporarily place new iron bolts in the voids of the timbers where original iron bolts had corroded. This choice to use epoxy and zinc-coated iron bolts was made in the interest of strengthening the hull before it was raised in 1961 (Håfors 2010: 16). After the salvage of the hull, the temporary bolts were again replaced by more durable galvanized iron bolts (Håfors 2010: 30-31). In the years that *Vasa* underwent conservation, these new bolts began to corrode as well, combining with the oxidizing sulfur and contributing to the production of acid (Fors and Sandstrom 2005: 410). Although there is now a program underway to replace the corroding iron bolts with carbon fiber bolts, the hull's shrinkage during drying prevents the removal and replacement of all corroding iron (Fors and Sandstrom 2005: 410).

The second factor identified in the acidification of the *Vasa* timbers was the project's failure to periodically renew the PEG solution used in consolidation treatments. Rather than replacing the solution at regular intervals, the PEG was recirculated for 13 years, continuously carrying iron hydroxides into the larger cavities of the wood (Fors and Sandstrom 2005: 410). The decision to use the recirculating automatic spray system was made in 1964 in the hopes that its implementation would both reduce costs and the time required to treat the ship's hull (Håfors 2010: 58).

In order to address these issues for both the *Vasa* and *Mary Rose*, the first course of action was to adopt a regimen of periodic PEG changeouts to avoid the buildup of contaminants and reduce the risk of further oxidation. For the *Mary Rose*, the remainder of the ship's conservation program saw the changing of the PEG solution every three to six months (Hocker et al. 2012: 180). In addition to the closer monitoring and periodic changing of PEG solutions, results from examinations of the *Vasa* and the *Mary Rose* highlighted the importance of

analyzing and treating iron content in organic artifacts before any additional conservation activities take place, such as the application of PEG.

In 2006, a chelation procedure was developed for the large-scale, simultaneous removal of iron content and acids from the *Vasa*'s timbers. Authored by Almkvist and Persson (2006), this procedure utilizes multiple sequestering agents in solutions including EDDHMA acid and diethylenetriamine penta-acetic acid (DTPA). While this treatment is very effective in extracting the iron content from the wood timbers, Almkvist and Persson (2006) note that complete removal of iron may take years for large objects (p.681), and that the process also removes impregnated PEG from the artifact (p.682). This means that any PEG-treated objected will be required to undergo PEG retreatment after the chelation process (Hocker et al. 2012: 181). Although the lessons of the *Vasa* and *Mary Rose* were learned from the treatment of large fragments of the ships' hull timbers, the resulting principles and approaches apply to all organic artifacts recovered from a marine site. Naturally, these principles extend to the chelation of organic artifacts at the *QAR* Lab.

Chelation Processes at the *QAR* Lab

As demonstrated by the results of the *Vasa* and *Mary Rose* projects, it is imperative that the removal of iron and sulfur compounds occurs before any further active conservation procedures can begin. At the *QAR* Lab, the chelation of organic materials occurs in parallel to passive desalination and before PEG consolidation begins. During the internship, I participated in this procedure several times and eventually began to instruct volunteers in the execution of these tests by the Spring 2020 Semester.

The process begins by placing the artifact into a bath of 2% ammonium citrate (dibasic) in RO water. In this case, the ammonium citrate is the chelating agent that will form soluble

bonds with the iron ions within the artifact. The container with the 2% ammonium citrate solution and artifact is then placed into a refrigerator. Much like standard passive desalination, this is done to prevent harmful biological growth in the container. Once stored in the refrigerator, the artifact soaks in the solution for one month.

After a month of soaking, the container(s) in chelation is briefly removed from the refrigerator to prepare for testing of the iron content. The first portion of the testing process involves removing the solution of 2% ammonium citrate and replacing it with standard RO water. Once the fresh RO water has been added to the container, it is returned to the refrigerator for 24-48 hours. Placing the chelating object into fresh RO water and letting it sit for a short period of time ensures that no inaccurate measurements of the iron content are produced from testing the old, high iron content 2% ammonium citrate solution. Additionally, RO water is necessary for testing purposes as the chemical content of the 2% ammonium citrate solution may skew testing results.

After the 24 to 48-hour period ends, the container(s) is removed from the refrigerator and prepared for monitoring. At the *QAR* Lab, La Motte Iron Testing Kits are used to monitor the iron content of the artifacts in parts per million (ppm). This test kit is a form of colorimetric analysis, meaning that a color reagent helps to indicate the concentration of iron during testing (Figure 2). Contents of the kits include a 30 mL bottle of Iron Reagent #1, a 4.5g bottle of Iron Reagent #2 Powder, one plastic spoon for measuring exactly 0.05g of the reagent powder, two 2.5-10 mL plastic test tubes, one Octa-Slide 2 Viewer, and one Iron Octa-Slide 2 Bar with a range of colors that equate to 0.5 ppm at the lightest and 10.0 ppm at the darkest.

Figure 2. La Motte Iron Testing Kit. Contents from L to R: Octa-Slide 2 Viewer with test tube and Octa-Slide 2 Bar inserted, Iron Reagent #1, 0.05g measuring spoon, Iron Reagent #2

Before testing of the iron content begins, the test tubes are rinsed with RO water to prevent contamination. Then, using a pipette, the test tube is filled with solution from the container for an additional rinse. After this rinse, the pipette is used to add 5 mL of solution to the test tube. Once the appropriate amount of solution is in the test tube, 5 drops of Iron Reagent #1 are added. The conservator then caps the test tube and shakes the sample to facilitate mixing. Once the solution is mixed with Iron Reagent #1, the kit's plastic spoon is used to measure out exactly 0.05g of Iron Reagent #2 Powder. The powder is then added to the test tube and mixed until it is completely dissolved in the sample. After the powder is dissolved, a timer is set for three minutes and the sample is set aside to wait for the colorimetric reaction to occur. Once three minutes have passed, the sample solution in the test tube will have turned to a shade of red. To measure the iron concentration, the test tube is placed in the Octa-Slide 2 Viewer and compared with the range of colors printed on the Octa-Slide 2 Bar, with darker colors indicating

greater iron concentration. The *QAR* Lab's target iron concentration for the completion of chelation is less than 2 ppm. If the artifact has reached this target concentration, the container is refilled with fresh RO water to begin standard passive desalination. If the iron content is still above this threshold, a new solution of 2% ammonium citrate (dibasic) in RO water is prepared so that the artifact can undergo further chelation treatment (Elise Carroll 2019, personal communication).

Electrolytic Reduction Tank Solution Testing

As described previously in Chapter 3, electrolytic reduction (ER) and reverse osmosis (RO) baths are the two primary methods used at the lab to desalinate artifacts recovered from the *Queen Anne's Revenge* wreck site. While RO baths are essential for the removal of soluble salts from non-metal artifacts, ER is the most effective treatment for desalinating marine iron (Hamilton 1999b: 297). Although the processes differ both mechanically and chemically, each treatment functions similarly with the same end goal: the establishment of a steep diffusion gradient to leech salts from the artifact and into the solution. Because of this, the need for regular monthly changeouts and solution testing also applies to ER treatments.

However, rather than the simple TDS monitoring process described in the previous chapter, ER solution testing is more complex. The first step in this procedure is the collection of 100 mL samples from all ER tanks at the lab. Each of the mason jars used to collect the samples are labeled with the date of collection, the tank that the sample is taken from, and the type of solution in the tank (either 1% sodium hydroxide in RO water or 2.5% sodium carbonate in RO water). The collection of these samples is then recorded as a task/activity on a Chloride Testing Object Activity Sheet. Once the samples have been collected, they are left to sit for 24 hours to ensure that all are at room temperature for testing (Watkins-Kenney 2015: 85).

Once the samples are ready for testing, the necessary equipment is assembled. This equipment includes a chloride measuring electrode with a digital display, a bottle of chloride ionic strength adjustment (ISA) solution, an Accumet AP63 pH/mV/Ion meter, and a 1000 ppm Chloride Standard solution. Depending on the number of solutions being tested, multiple 250 mL beakers will also be required.

Testing begins by first placing 100 mL of each tank sample into a beaker and measuring the pH with pH paper. These values are then recorded on a Solution Testing Record Sheet. To prepare the sample for testing with the chloride electrode, 30 to 40 drops of nitric acid are added to the sample under a fume hood to neutralize the solution. Once the sample is neutral (pH of 7), 2 mL of chloride ISA solution is deposited into the sample using a pipette to prepare the solution to react with the chloride electrode. After this is completed, five chloride standard solutions in separate 250 mL Erlenmeyer flasks are created to help calibrate the electrode. 100 mL of the Chloride Standard solution is used to make five different concentrations: 1000 ppm, 100 ppm, 10 ppm, and 1 ppm. Each of the lower concentrations is reached by increasing the ratio of RO water to Chloride Standard in the solution. Like what was done with the tank samples, each of the chloride standard solutions will receive 2 mL of chloride ISA via pipette to allow them to interact with the electrode during the calibration process. Finally, the Accumet meter is connected to the chloride electrode to begin calibration. To calibrate the instrument, the electrode is first placed into the 1000 ppm standard solution to establish a controlled baseline. This is repeated for each successive standard solution until the Accumet meter has baselines for each ppm measurement (Watkins-Kenney 2015: 86-87).

Once the Accumet meter and electrode are calibrated, each of the sample solutions can finally be tested for chloride content. This is accomplished by placing the electrode in a sample

solution until the screen of the Accumet meter displays the word "STABLE" beneath the measurement for five seconds. The electrode is then removed from the sample and rinsed with RO water to prevent cross-contamination. This process is repeated for the remaining tank samples until all have been tested. The results of each test are recorded on the Solution Testing Record Sheet. The measurements recorded during this process help to determine the chloride concentration remaining within a given iron artifact. Like with passive RO desalination, the decision is made to change out the ER solution after three stable measurements (Watkins-Kenney 2015: 88).

Void Casting and the Creation of Artifact Molds

Although operations at the *QAR* Lab often focus on surviving artifacts from the *Queen Anne's Revenge*¸ there are cases where an artifact does not survive while in concretion. Although the original artifact has corroded away completely, voids are left in the space that the artifact once occupied and are sometimes discovered during mechanical cleaning. Thankfully, the void provides an almost perfect mold of the artifact's original surface and form. This makes it possible to create an identical copy of the corroded artifact through casting (Hamilton 1999a: 89). The use of this procedure is incredibly important in preserving as much data as possible in a marine archaeological assemblage. For example, the *QAR* assemblage features numerous casts of tools, fasteners, barrel hoops and shipboard equipment that would otherwise be lost without this procedure.

When a void is encountered during the cleaning of a concretion, the first course of action is to carefully, and strategically, open an access hole to the void with the air scribe. The void is then cleaned out with both a thin metal rod and running water to remove any debris. This includes removing any remaining fragments of corroded metal, as they may continue to corrode

and cause conservation concerns in the future if left in place. Once the void has been completely cleaned of all debris, acetone is applied to the area under a fume hood and left for a short time to evaporate any excess water that might hinder the casting process. When the void is finally dried, any additional openings are dammed with clay and the concretion is placed into a bucket filled with sand. The sand also acts as a dam and an emergency sealant if leaks occur during casting. Next, Hysol epoxy resin is mixed in a solution with 30% epoxy hardener. Once mixed, the epoxy resin and hardener are poured into the open end of the void. The epoxy sits in the void for 24 to 48 hours until it hardens. Once the resin has completely solidified, an air scribe is used to remove the remaining marine concretion surrounding the cast (Hamilton 1999b: 296). After removal from the concretion, the cast can be measured and analyzed for important diagnostic details.

In addition to creating casts of corroded artifacts, conservators at the *QAR* Lab also create molds of existing artifacts using silicone rubber. To develop a mold, an artifact is first surrounded by clay to act as a dam and prevent leakage of silicone during hardening. The liquid silicone mixture is then poured into the dammed enclosure until the artifact is partially enveloped (Figure 3). The first pour of silicone is left to harden before additional silicone is added to cover the remainder of the object (Figure 4). The two separate additions of silicone rubber create two halves that can be separated after both have hardened (Figure 5). After hardening, the halves are separated and the object is removed, leaving behind a perfect impression of the original artifact (Figure 6) (Elise Carroll 2019, personal communication; Kimberly Kenyon 2020, personal communication).

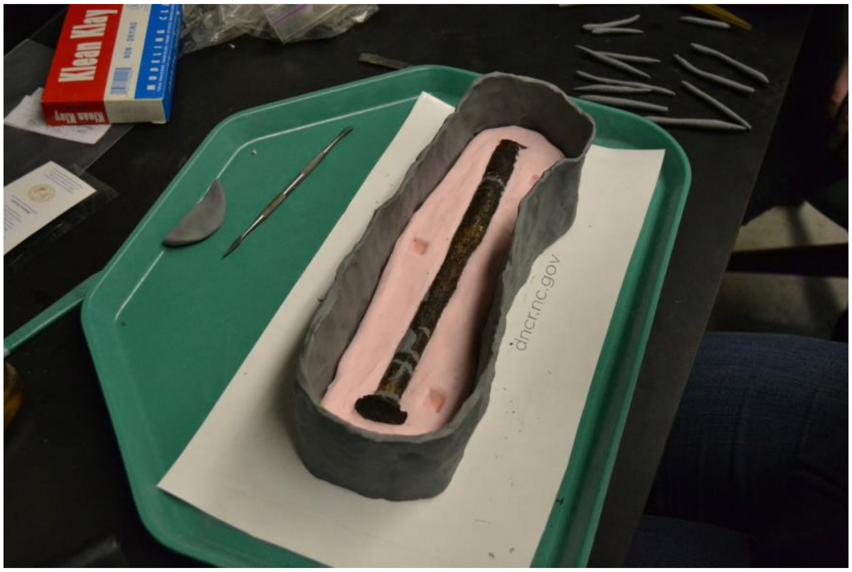

Figure 3. Iron gouge surrounded by silicone rubber after the first pour. Impressions in the rubber are created to facilitate the release of the two halves. Courtesy of NCDNCR.

Figure 4. Addition of second layer of silicone rubber. Courtesy of NCDNCR.

Figure 5. *QAR* Chief Conservator Kimberly Kenyon separates the two halves of the silicone mold. Courtesy of NCDNCR.

Figure 6. The two halves of the gouge mold filled with epoxy to create a cast of the original object. Courtesy of NCDNCR.

Once these molds are taken of an artifact, additional epoxy copies can be produced for either display or for part of the lab's "handling collection". This array of objects includes epoxy casts of cannon balls, pewter spoons, and various shipboard tools (Figure 7). These objects are normally used in educational outreach programs so that members of the public can handle exact copies of artifacts without the worry of damaging the original artifact. The practice of casting artifact copies is also highly useful in situations where it is predicted that an original artifact may not survive active treatment (Kimberly Kenyon 2020, personal communication). If destruction of the artifact occurs during treatment, the cast is still available for study and display. For these purposes, the epoxy casts are often painted to reflect the color of the original object (Figures 8 and 9). The molds can be reused multiple times for the creation of additional casts. When not in use, the silicone molds are stored in a cabinet at the lab.

Figure 7. Original pewter spoon QAR 2959.002 (left) and its epoxy copy QAR 2959.002.03 (right). Courtesy of NCDNCR.

Figure 8. Epoxy cast of iron gouge created from the mold
pictured in Figures 3-6. Before painting. Courtesy of NCDNCR.

Figure 9. Epoxy cast of iron gouge
after painting. Courtesy of NCDNCR.

Cannon Cleaning

Cannon cleaning is an incredibly important, though somewhat infrequent task carried out at the *QAR* Conservation Lab. Briefly mentioned in Chapter 3, cannon cleaning is very similar in practice to the mechanical cleaning of smaller concretions. For all of the cannons recovered and stored at the lab, the removal of encrustations via air scribe is necessary before the cannon can enter ER treatment. If the lab's schedule permits, mechanical cleaning of cannons usually occurs once a month on "cannon days". On these days, almost all of the conservators at the lab participate in the activity. The most recent cannon day occurred on March 5th, 2020 and focused on the air scribing of cannon C16 (Figure 10).

Figure 10. Air scribing C16 during the "cannon day" on March 5th, 2020. Courtesy of NCDNCR

The process begins by lifting the cannon from the stable storage tank with an A-frame manual crane. Support straps are wrapped around the front and rear of the gun and attached to a pulley system on the crane. The cannon is then lifted from the tank and placed on a sturdy platform in the center of the lab, near the air scribing stations. After donning protective face shields, lab coats, gloves, ear protection, and proper protective footwear, cleaning of the cannon can begin. While air scribing is in progress, artifacts are often encountered encased in the concretion surrounding the cannon. When an artifact is identified, photographs are immediately taken of its location and provenience on the cannon before removal. This helps to record any

associations between identified artifacts before and after removal. Throughout the process, notes are taken on Object Activity Sheets detailing the cleaning procedures, artifacts identified and recovered, and any remarks concerning the status of the cannon's surface. The cleaning process lasts for an entire day. When the day ends, final working photographs are taken of the cannon before it is once again lifted by the A-frame crane and returned to the stable storage tank (Elise Carroll and Kim Kenyon 2020, personal communication).

Public Outreach Events and Tours

Outside of the standard conservation work that occurs on a regular basis at the lab, conservators also engage in several public-facing events meant to educate and inform non-archaeologists about the history, methods, and purpose of the *Queen Anne's Revenge* Shipwreck Project. The duties expected of archaeologists in interacting with the public are outlined in the fourth principle of the Society for American Archaeology's (SAA) *Principles of Archaeological Ethics*. This principle states that archaeologists must "1) enlist public support for the stewardship of the archaeological record; 2) explain and promote the use of archaeological methods and techniques in understanding human behavior and culture; and 3) communicate archaeological interpretations of the past".

According to McGimsey (1972: 5), there is no such thing as "private archaeology". Indeed, the study of the past and the knowledge gained from that study should be considered a "human birthright" (McGimsey 1972: 5). As with all archaeological endeavors, the work done at the *QAR* Lab must be shared with the public. Non-archaeologists not only fund archaeological work (Meighan 1986) but are also key to its survival, as exposing the public to the world of archaeology generates interest and support for the continued preservation and study of

historically and culturally significant sites (Little 2012: 5). Without public support, it is unlikely that institutions such as the *QAR* Lab would be able to function as they now do.

The *QAR* Lab offers several opportunities throughout the year for the public to visit and engage with the project. These include general tours that occur on the first Tuesday of every month, the "Saturday at the *QAR* Lab" event held every November, and the *QAR* Open House every April. While all of these events allow members of the public to tour the lab, each event is different in structure and in the activities that they offer to guests.

General Tours

As mentioned above, the general tours occur on the first Tuesday of every month. Interested members of the public reserve these tours by calling in advance and scheduling a tour time. Tour group sizes generally range from 10 to 20 people in total of every age. In some cases, these tours are reserved by K-12 school groups. Upon completion of the internship, I participated in multiple tours, accounting for 60 visitors in total (Kim Kenyon 2020, personal communication).

Each tour begins with an introduction in the front lobby area of the *QAR* Lab. The guests are then brought into either the conference room or VOA 110 (depending on the size of the party) to listen to a brief talk recounting the background history of *La Concorde* and *Queen Anne's Revenge*. Once this is completed and any questions are answered, the group is brought into the main lab space (VOA 114) where they are directed to gather around the two large stable storage tanks. This portion of the tour includes a brief overview of the conservation practices utilized at the lab including recovery, stable storage, air scribing, and casting. The tour group then moves to the warehouse area where they are informed about the lab's larger artifacts including several cannons, one of the ship's anchors, and the sternpost. The tour group finally

returns to the main building and stops in VOA 110. In this room, an artifact tray is set up for the guests' viewing. The objects included on the tray include numerous ceramic sherds, organic materials, cannon balls, pewter plates, and various tools and medical instruments. While several of these artifacts are original, a number of the items on the display tray are epoxy casts. The tour ends after the items on the tray are discussed and any remaining questions are answered.

"Saturday at the *QAR* Lab"

"Saturday at the *QAR* Lab" is a special event that features numerous directed tours for multiple tour groups. The tours themselves last approximately an hour and a half and are structured in the same manner as the general tours. The highlight of this event is the number of visitors that tour the facility throughout the day. In total, the number of individuals touring the lab can reach the hundreds. This event was attended by 170 visitors in 2018 and 137 visitors in 2019 (Kim Kenyon 2020, personal communication). As a result of the high volume of visitors, tours are carefully timed and divided up among the *QAR* Lab staff and volunteers. Generally, this entails having two tour guides to manage each group, at least two greeters in the lobby area to direct arriving guests, and one photographer to document the event for the North Carolina Department of Natural and Cultural Resources (Figure 11). As an intern, participation in the most recent iteration of this event on November 2nd, 2019 allowed me to guide portions of two

tours. The segment I guided focused on all aspects of concretion breakdown, including air scribing, photography, and void casting. Each tour consisted of approximately 15 people.

Figure 11. *QAR* Lab Chief Conservator Kimberly Kenyon leads a tour during the "Saturday at the *QAR* Lab" event in 2015. Courtesy of NCDNCR.

QAR Lab Open House

The *QAR* Lab Open House is held every April and has a much looser structure than the standard tours offered on the first Tuesday of every month and during "Saturday at the *QAR* Lab". Rather than formally guided tours, guests at the open house can visit several activity stations throughout the lab to learn about different aspects of conservation. While every event at the lab is geared toward families, the *QAR* Lab Open House is organized with children in mind. The stations at the open house cover a wide variety of conservation-related topics including analytical techniques such as microscopy and x-radiography, concretion breakdown, underwater excavation, historical tool making and use, and casting. Each station features an activity related

to the topic that children can participate in. For example, the activity at the concretion breakdown station provided guests with an M&M cookie and a plastic fork. The participants then used the fork to remove the M&Ms, simulating the extraction of artifacts from concretion via air scribing. While participating in last year's open house, I managed the pH testing station. After providing a brief overview of pH testing and its usefulness at the lab, I guided visitors through an activity that involved using pH strips to test jars of vinegar and baking soda dissolved in tap water. The jars were unlabeled, and the visitors were instructed to decide if the jar's contents were acidic or basic based on the pH strip results. Like the "Saturday at the *QAR* Lab" event, the *QAR* Lab Open House regularly attracts hundreds of visitors. The most recent *QAR* Lab Open House in Spring 2019 saw the attendance of 414 members of the public (Kim Kenyon 2020, personal communication).

Personal Projects

While working as an intern at the *QAR* Lab, routine conservation activities have been accompanied by multiple personal projects. These include the PEG treatment of a wooden cask hoop recovered from Brunswick Town during the 2015 ECU field school, the mechanical cleaning of two concretions: QAR 1821.000 and 3166.000 and writing two blogs for the *QAR* Lab website. The procedures used to clean and break down these two concretions and the blogs that were written will be discussed below. For a detailed description of the treatment of the Brunswick Town cask hoop, see Chapter 5.

<u>QAR 1821.000</u>

During the internship, QAR 1821.000 (Figure 12) was assigned to me as a personal project in the Spring 2019 semester. Pre-treatment x-rays and photographs of the concretion

indicated that a cannon ball was present beneath the concretion. However, seeing as x-radiography only reveals metals beneath the surface of the concretion, it was also deemed likely that non-metal artifacts would be found during cleaning. Air scribing of the concretion began in January 2019 and continued through the remainder of the semester. During the process, photographs were taken after every cleaning session and whenever a new artifact was exposed. Each "task", such as photography and cleaning, was also recorded on an Object Activity Record Sheet. QAR 1821.000 was completely broken down by November 2019.

Throughout the cleaning process, several artifact fragments were recovered in addition to the cannon ball at the center of the concretion. Any artifact removed from a concretion receives a new QAR number. This new number uses the QAR number of the concretion as a base. For example, the first artifacts removed from 1821.000 received the QAR number 1821.001. These artifacts included numerous fragments of wood and rope, and several broken fragments of iron not associated with the cannonball. Upon recovery, the organic fragments were photographed and measured before being stored in containers with tap water. These containers were then placed on the wet rack in VOA 114 to await treatment. Once the concretion was completely broken down, the remaining debitage was bagged and placed on a storage shelf. All debitage produced during the concretion breakdown process is eventually x-rayed to determine if any small artifact fragments were not recovered during cleaning.

Figure 12. QAR 1821.000 at different stages of cleaning. From L to R: Pre-treatment, post-removal of cannon ball, cannon ball 1821.003 alone. Courtesy of NCDNCR

QAR 3166.000

After completing the breakdown of QAR 1821.000, the concretion QAR 3166.000 (Figure 13) was assigned as a follow-up project in January 2020. Unlike the previous concretion, x-radiography showed QAR 3166.000 to be much more complex in its contents and overall structure. In addition to a cannon ball, the x-ray also indicated the presence of an iron deadeye bolt with an accompanying clover-shaped ring passing through the hole. Interestingly, the x-ray signature of the bolt and the clover ring were both very faint. This “ghost” image is usually indicative of a corroded iron object as there is not enough remaining iron to produce a strong x-ray signature (Kimberly Kenyon 2020, personal communication). In addition to the potential void, a large bulge was identified on the clover ring. This was thought to be organic material, likely rope, wrapped around the ring.

Cleaning of QAR 3166.000 began on January 27th, 2020 and continued until the conclusion of the internship. Wood fragments were identified early in the process and were assigned the QAR number 3166.001. Eventually, rope fragments were also identified and recovered during cleaning. These fragments received the QAR number 3166.002. By March

2020, the surface of the cannon ball had been exposed. The next step was to completely expose the cannon ball and remove it before moving on to the deadeye bolt and clover-shaped ring at the other end. Unfortunately, this project was cut short as a result of ECU's closure during the COVID-19 pandemic. It is hoped that work may continue with this concretion in the future.

Figure 13. QAR 3166.000 pre-treatment (left) and after exposing the surface of the cannon ball (right). Courtesy of NCDNCR

<u>Blogs for *QAR* Lab Website</u>

An additional means of public outreach at the lab can be found on the *QAR* website. Here, conservators post updates on current projects and notifications for upcoming events. Included in this material are blogs that are written by *QAR* staff on a weekly to monthly basis. These blogs often highlight a particular artifact at the lab, discuss a relevant historical event or describe in detail one of the conservation procedures used to treat artifacts from the *QAR* assemblage. These entries are usually limited to 500 words and are written using as little scientific jargon as possible to make them more comprehensible for members of the public not familiar with archaeology or conservation.

During the internship, two blog posts were written and posted to both the *QAR* Lab website and the Lab's official Facebook page. In total, the blogs posted on Facebook reached 2,852 readers (Kim Kenyon 2020, personal communication). The first of these was a "My Story" entry (https://www.qaronline.org/blog/2020-04-15/my-story-brandon-eckert). The "My Story" blogs are generally written by every staff member, graduate assistant, and intern working at the lab. The text details the individual's educational background, the reasons for getting involved in archaeology, and the types of tasks and research they perform at the lab. These blogs are intended to familiarize the public with the staff at the lab and provide readers with a general idea of what projects each staff member is associated with.

The second blog was an "Artifact of the Month" blog. These posts are uploaded monthly and provide details on a specific artifact associated with the *Queen Anne's Revenge*. My blog described the process of treating the Brunswick Town cask hoop with PEG (https://www.qaronline.org/blog/2020-04-01/artifact-month-bt-hoop). The post included a brief background on the history of Brunswick Town and a thorough description of wood degradation and the utility of PEG treatment. "Artifact of the Month" blogs are a very useful tool in communicating the importance of conservation to the public and in helping non-archaeologists understand how and why certain treatments are used. The links to these blogs and the complete texts of each can be read in full in the appendix of this report (Appendix 1.2 and 1.3). Further discussion of the Brunswick Town cask hoop project will continue in Chapter 5.

Chapter 5—Conserving the Brunswick Town Cask Hoop

Upon first glance, the processes and methodology in use at the *Queen Anne's Revenge* Conservation Lab may appear to be limited to the treatment of the famous shipwreck's assemblage alone. However, the lab is equipped to treat at-risk artifacts recovered from sites all over North Carolina. This includes several artifacts from the former British-colonial settlement, Brunswick Town. Although this is largely a terrestrial site, its proximity to the Cape Fear River has led to the recovery of several waterlogged artifacts over a series of field seasons. One of these artifacts was a wooden cask hoop. The barrel hoop was initially recovered in 2015, and eventually brought to the *QAR* Lab for further treatment in 2019. From Spring 2019 to Spring 2020, the hoop was placed into the lab's conservation program for waterlogged wooden artifacts. In addition to the tasks and activities described in the previous two chapters, this treatment process was a central component of the internship. The successful stabilization of the cask hoop not only demonstrates the lab's versatility in treating artifacts from non-*QAR* sites, but also the relevance of laboratory conservation in the management of artifacts recovered from terrestrial contexts.

Discovery of the Brunswick Town Cask Hoop

Beginning in the summer of 2015, East Carolina University has held its annual field school in archaeology at the Brunswick Town/Fort Anderson State Historic Site in the Cape Fear Region of North Carolina, near Wilmington (Figure 1). The inaugural field school began on May 18th, 2015 and concluded on June 23rd. The central focus of the program was the survey and excavation of a large portion of the former colonial town's central waterfront area, including a wharf exposed by erosion. The stated goals of this field school were to "1) record the structural

components of the wharf, 2) excavate one [wharf] crib for analysis and recording, 3) determine the westernmost terminus of the structure and its linkage with the shoreline, and 4) investigate an anomaly on the first terrace adjacent to the wharf" (Harrup and Byrd 2015: 6).

Figure 1. Location of Brunswick Town/Fort Anderson State Historic Site along the Cape Fear River. Taken from Harrup and Byrd (2015).

In addition to recording exposed wharf timbers and ballast stone piles, excavations led to the recovery of several artifacts related to the site's colonial past. Included in this assemblage was one complete wooden cask hoop, discovered in remarkably good condition. The barrel band was found relatively early in the excavation and assigned the Field Specimen (F.S.) number 14 (Harrup and Byrd 2015: 54). Like much of the shoreline on the Brunswick Town/Fort Anderson grounds, the wharf area excavated by the 2015 field school is low-lying, marshy, and subject to both flooding from rainfall and tidal action from the bordering Cape Fear River (Harrup and Byrd 2015: 7). The proximity of the Cape Fear River and the conditions of the marshy soil

surrounding the cask hoop very likely contributed to its waterlogging and intact condition upon discovery. Encased in the watery, muddy soil, the hoop would have been penetrated by water from the river, while simultaneously being protected from significant biological degradation by the anaerobic conditions of its burial context (Figure 2).

Figure 2. Retrieval of the cask hoop from Crib 1 by ECU graduate student Stephanie Byrd.

The wharf timbers were also noted as having a thin coating of tar on their surface. As Brunswick Town was a hub for the British Empire’s colonial naval stores industry (South 2010: 77), it is likely that this tar residue is a surviving remnant of the settlement’s once-thriving economy. Contemporary colonial records mention the practice of leaving barrels of tar on wharves and docks (Gamble 1921; Ward 1949; Outland 2004; Harrup and Byrd 2015: 29). Taking this into consideration, the field report for the 2015 field school posited that the tar liquefied and leaked from the barrels after being exposed to warm weather for long periods of time and subsequently entered the soil matrix of the wharf crib. In addition to the anaerobic conditions of the marshy burial environment, the surviving tar in the matrix likely contributed to the preservation of the artifacts in Crib 1 by acting as an additional protective layer against decay

(Harrup and Byrd 2015: 29). Furthermore, resins such as tar and pitch harden over time (Cronyn 1990: 240). It is possible that the presence of tar in the deposit not only protected the cask hoop from severe decay, but also helped to maintain its apparent structural integrity.

Despite these factors likely contributing to its preservation, the cask hoop was still at risk for further deterioration after being removed from its burial context. In order to prevent this, the barrel hoop was transported with other wet and waterlogged artifacts to the Phelps Archaeology Laboratory at ECU. Here, the artifacts were stored in water and desalinated (Harrup and Byrd 2015: 22). Passive storage continued until the cask hoop was placed into a solution of 15% Polyethylene Glycol (PEG) 400 with 0.1% Proxel, a biocide (Brunswick Town Hoop Record, see Appendix 1.4). This marks the beginning of active treatment for the cask hoop. Further treatment would continue during this internship.

Degradation of Waterlogged Archaeological Wood

Before active treatment of the Brunswick Town cask hoop can be described in detail, it is first important to discuss the factors that contribute to the degradation of waterlogged wood. Although unlikely to survive at sites with extreme environmental conditions due to natural cycles of decay (Cronyn 1990: 243), organic artifacts sometimes make up a portion of assemblages recovered from archaeological sites. Several different types of deterioration may negatively impact an organic artifact after it is deposited into the burial context. These categories include biological, physical, and chemical degradation.

Biodeterioration is any physical or chemical decay that is caused by an organism, such as an insect, an animal, or bacteria. This form of degradation is most common in burial environments that are conducive to the survival of these organisms, such as aerated marine and

terrestrial sites where oxygen is readily available (Cronyn 1990: 249-250). These organisms not only use the organic object as a food source, but may also secrete damaging chemicals, indirectly attacking the artifact (Cronyn 1990: 241). In maritime contexts, this is most evident in the boring and tunneling damage caused by *Teredo navalis*, also known as shipworm (Hoffman 2013: 25-26; Cronyn 1990: 250). Although archaeological wood is at the highest risk for biodeterioration in aerated contexts, there is still cause for concern in anaerobic deposits where erosion bacteria and tunneling bacteria may still survive and contribute to degradation (Björdal et al. 1998).

Physical degradation may occur as a result of multiple factors, often related to the site's environmental conditions. Burial environments that are subject to extreme changes in temperature and humidity pose a serious challenge to the survival of archaeological wood. As the ambient humidity rises and falls, the organic artifact will continuously drain and swell with water. The constant swelling and contraction as water enters and exits the artifact places severe structural stress on the object, leading to warping and cracking. In addition to these climatic concerns, the artifact may experience further degradation as a result of abrasion. For example, exposed ship timbers are at significant risk for surface physical degradation when exposed to moving water and sand (Cronyn 1990: 242). This is common at marine sites where tides or currents are extreme.

Finally, chemical decay often occurs in association with the factors of degradation described above. At sites where archaeological wood is recovered, the object's survival is often a result of the burial environment being either very dry or waterlogged (Hamilton 1999b: 306). In waterlogged contexts, such as the one that the Brunswick Town cask hoop was found in, the largely anaerobic environment protects the object from oxygen-dependent biological and physical deterioration, but chemical degradation actively continues (Cronyn 1990: 243). The

most common and documented process of chemical deterioration in archaeological waterlogged wood is hydrolysis (Florian et al. 1990: 165). During this process, the cellulose, hemicellulose and lignin polymers comprising the cellular structure of the wood begin to break down in the presence of anaerobic soft rot fungi (Cronyn 1990: 243; Hoffmann 2013: 22-23, 26). As the cellulose and hemicellulose disintegrate during hydrolysis, the lignin network is left as the last remaining structural component in the wooden object (Hoffmann 2013: 27; Hamilton 1999a: 24).

Following significant degradation of these materials, the amount of space between the molecules and cells in the wood increases, making the artifact more permeable to water. Eventually, water fills these empty spaces and, in concert with the remaining lignin network, will maintain the shape of the object (Hamilton 1999a: 24). When a waterlogged wooden artifact is encountered during an excavation, it is imperative that the object not be allowed to lose any moisture. If the water bulking the decayed object is permitted to evaporate, cell walls will collapse and surface details will be lost as the artifact begins to shrink, crack, and warp (Cronyn 1990: 254, 256). Therefore, it is advisable to immediately immerse the artifact in water in a closed container. Storage in a sealed container with water not only prevents further evaporation, but also protects the waterlogged object from biological attack by limiting exposure to oxygen and light (Cronyn 1990: 256). Although passive storage will temporarily safeguard the object against further degradation, active treatment is necessary to ensure the artifact’s stabilization once it arrives at the laboratory.

Consolidation of Waterlogged Wood using Polyethylene Glycol

Once the cellular structure of a wooden artifact degrades as a result of hydrolysis, the water occupying the empty space and the remnants of the lignin network maintain the object's shape. As long as the wood is kept wet, it will retain its shape. If left to dry, however, the water within the object will evaporate, resulting in surface tension forces that will cause the remaining cellular structure to collapse and the object to severely shrink and distort (Hamilton 1999a: 24). While passive storage in water in a sealed, temperature-controlled container is effective in stabilizing the wooden object through the prevention of evaporation and biological growth, hydrolysis will continue to degrade the artifact (Cronyn 1990: 245). In order to put an end to this process and facilitate study and display of the wooden artifact, active treatment is necessary.

A Brief History of Polyethylene Glycol in Conservation

For archaeological waterlogged wood, active conservation treatment involves the controlled removal of water and the introduction of a bulking agent to replace the water and strengthen the artifact's structure (Cronyn 1990: 245, 257-258). One of the oldest and most commonly used bulking agents is polyethylene glycol, a water-soluble polyether compound often referred to simply as PEG. The earliest use of PEG in the conservation of archaeological wood occurred in the 1950s with experimental treatments conducted by the Swedish chemists Bertil Centerwall and Rolf Morén (Morén and Centerwall 1960; Hoffmann 2013: 43).

Following the discovery of a 6000-year-old fishing net in a peat bog in 1951, Centerwall and Morén began attempts to conserve both the netting and a number of wooden pegs attached to the trap. During the experimental process, the two scientists attempted treatments with multiple substances including polyvinyl acetate, polyvinyl alcohol, and polyethylene glycol A4000. After these preliminary tests, Centerwall and Morén found that the use of polyethylene glycol resulted

in the most effective preservation of the wooden pegs, with only 2% shrinkage in diameter after treatment (Håfors 1990: 197). Building on this success, the pair began to use polyethylene glycol in the treatment of additional organic artifacts recovered by the University of Lund, including several wooden objects in various states of biological and chemical decomposition (Håfors 1990: 198; Morén and Centerwall 1960). Use of the PEG method continued to spread following Centerwall and Morén's pioneering work. In 1959, the wide adoption of the treatment was highlighted by several articles in the journal, *Studies in Conservation*. Of particular note was an article detailing the use of PEG by the University of Oslo in their conservation of the high-profile Oseberg Viking ship (Håfors 1990: 198; Rosenqvist 1959).

Over the next few decades, Centerwall and Morén's patented PEG method saw greater use in larger projects, particularly those that focused on the conservation of material from shipwrecks. Perhaps the most notable and influential of these cases is the conservation of the Swedish warship, *Vasa*. The *Vasa* capsized and sank while leaving the harbor of Stockholm on her maiden voyage on August 10th, 1628 (Fors and Sandstrom 2005: 399). Salvage of the ship began in 1958, with the hull eventually being raised by 1961 (Håfors 1990: 195-196). To prepare for the treatment of the *Vasa*'s hull and all additional wood components, a board of conservation specialists was formed in September 1960. The experts discussed several aspects of the treatment including the types of fungicides to be used during PEG treatment and the desired molecular weights for the PEG solutions (Håfors 1990: 200). After considering these variables, the decision was made to begin the treatment using PEG 4000 on April 9, 1962.

Following the use of pentachlorophenol in a dilute solution of PEG 800 to treat biological growth on the hull, spray application of a solution of 15% PEG 4000 and 4% borate mixture (biocide) began in July 1962 (Hocker et al. 2012: 176-177). Application of the solution was

largely carried out by hand until the implementation of an automatic spray system in March 1965. Following the introduction of the spray system, project leaders elected to change the solution to a less viscous, low molecular weight PEG 1500. The use of low molecular weight PEG not only facilitated more efficient circulation in the system, but also proved to be more effective in penetrating into the cellular structure of *Vasa*'s wood timbers (Hocker et al. 2012: 177; Håfors 2010). Spray treatments concluded in 1979, marking the beginning of a nine-year air-drying cycle for the treated hull. After drying, the ship was finally transported to the newly built *Vasa* Museum in 1988.

While issues related to iron and sulfur concentration were eventually discovered upon later reexamination of the hull (Hocker et al. 2012; Fors and Sandstrom 2005; Sandstrom et al. 2002), the *Vasa* project was an important step in the further development of PEG treatment. The overall success of the conservation program demonstrated the utility of polyethylene glycol in the large-scale conservation of waterlogged wood, and also provided a basis for further research on the subject, namely regarding the use of lower molecular weight PEG solutions (Hocker et al. 2012: 178).

The Two-Step Polyethylene Glycol Process at the *QAR* Lab

For most wooden artifacts conserved at the *Queen Anne's Revenge* Conservation Lab, the treatment involves the use of both low and high molecular weight PEG. In the early years of PEG treatment, the advantages of treating a waterlogged object with PEG of varying molecular weights was not yet known. As demonstrated by the decision to change to a lower molecular weight PEG solution in the treatment of the *Vasa* (Hocker et al. 2012), utilizing a two-step process has the potential to result in better penetration of the cellular structure, and therefore, a more stable and robust artifact after treatment. As is the case with many other hardwood artifacts

treated at the lab, the Brunswick Town cask hoop was first impregnated with low molecular weight PEG 400, and then further bulked by subsequent diffusions of PEG 4000.

The reasoning for the two-step process lies in the layered structure of degraded wood. Although the outer layer of the wooden object may show significant degradation, layers comprising the inner core will often be less degraded, and therefore, more difficult for larger molecules to penetrate (Hoffmann 1986: 103, 110). While smaller, more structurally uniform wooden objects (usually less than a few centimeters thick) can be treated using only one grade of PEG, larger artifacts require the two-step treatment to accommodate both slightly and heavily deteriorated layers (Hoffmann 1986: 103).

This process was tested by Per Hoffmann in a 1986 report using three groups of wood samples displaying distinct degrees of degradation: slightly degraded, moderately degraded, and heavily degraded. In order to determine the efficacy of treatment for each sample, shrinkage measurements and moisture contents of each wood fragment were recorded. After testing fragments of each sample type with single grade and two-step PEG treatments, results were achieved. Of the samples used in the project, the slightly degraded fragments responded very well to treatments using a single grade of low molecular weight PEG 200 and 300 (Hoffmann 1986: 104). However, the moderately and heavily degraded samples experienced the most stable impregnation when subjected to the two-step process (Hoffmann 1986: 108-109). According to Hoffmann (1986: 109), results of the tests indicated that "the degree of impregnation [after the two-step process] is generally higher than after one-step treatments of the same duration". Furthermore, this process allows conservators to stabilize all areas of a wooden object, regardless of the level of degradation, to the same degree of quality (Hoffmann 1986: 111).

The level of impregnation described by Hoffmann is accomplished by first stabilizing the slightly degraded wood at the core of an object using low molecular weight PEG. The smaller molecules are able to penetrate deeply into the cellular structure of the slightly degraded wood where the larger molecules of high molecular weight PEG would have difficulty. At the *QAR* Lab, the target concentration for the low molecular weight PEG 400 is 25% (Kimberly Kenyon 2019, personal communication). Once this concentration has been reached and smaller voids within the object have been bulked by PEG 400, the process moves to the use of high molecular weight PEG 4000. Unlike the liquid PEG 400, PEG 4000 is a powder and is highly useful for diffusing into the larger voids and lumens in the object "in a more mechanical fashion" (Ambrose 1990: 247). After replacing the water in the object, the PEG eventually hardens and braces the artifact's tissue against shrinkage during drying (Hoffmann 1986: 111). The two-step process is completed when PEG 4000 concentration reaches 40%.

Brunswick Town Cask Hoop Treatment Process

PEG Treatment

After spending time at the Phelps Archaeology Laboratory on ECU's campus in a solution of 15% PEG 400 with 0.1% Proxel BD, the hoop was transferred to the *QAR* Conservation Lab on May 2nd, 2019. Before consolidation with the two-step PEG process began, pre-treatment photographs were taken of the cask hoop on a black background (Figure 3). The artifact was then placed into a 40-liter tank with a 15% solution of PEG 400 in reverse osmosis (RO) water to begin treatment. During the process, the tank was covered with multiple folded layers of plastic sheeting to prevent the intrusion of insects and light.

Figure 3. Pre-treatment studio photograph
of the cask hoop. Courtesy of NCDNCR.

Monitoring the treatment followed the same process for all PEG solutions outlined in the "Routine Internship Tasks and Responsibilities" section of Chapter 3. This was performed every Thursday and involved the use of a refractometer to measure the refractive index (nD) of the solution to determine the amount of PEG that had diffused into the artifact and to establish whether the solution had reached equilibrium. As PEG is added to the solution, the number denoting the refractive index rises, indicating an increase in the solution's density and concentration. After attaining three consistent measurements, the solution was deemed ready for further PEG addition.

As with all PEG treatments at the *QAR* Lab, the concentration of PEG 400 (and later PEG 4000) was increased by 5% increments during each addition (Kimberly Kenyon 2019, personal communication; Watkins-Kenney et al. 2004). In order to add more PEG to the solution to reach the next target concentration, a portion of the solution must be removed and replaced with new

PEG. The amount of solution to remove and replace (in liters) is calculated by the Canadian Conservation Institute's computer program, PEGCON (Watkins-Kenney et al. 2015: 18). To operate the program, values are entered for the volume of the tank, the current percentage of PEG in the solution and the desired percentage for the addition. PEGCON then calculates the volume of the current solution to remove (in liters) and the amount of PEG to be added. For example, on November 7th, 2019, the concentration of PEG 400 was increased from 15% to 20%. After inputting the aforementioned values into PEGCON, the program advised the removal of 2.4 L of solution and the addition of 2.4 L of PEG 400 to increase the concentration by 5%. This process continued for the low molecular weight PEG 400 treatment until concentration reached 25% on January 3rd, 2020.

Once the 25% target concentration was reached for PEG 400, the solution was monitored for four weeks between January 23rd and February 13th, 2020 to ensure that the PEG 400 successfully diffused into the cask hoop. The second portion of the two-step process involving the introduction of high molecular weight PEG 4000 began on February 20th, 2020. Like the PEG 400 before it, the concentration of PEG 4000 was increased in 5% increments until reaching the target concentration of 40%. Monitoring the solution was carried out in the same way as before, through the use of a refractometer to measure the refractive index. Additions were also carried out in a similar manner using PEGCON. For the addition of PEG 4000, the volume of the container, the current PEG concentration and the desired PEG concentration were entered into the program.

While the use of PEGCON for PEG 4000 additions is functionally identical to the process used for PEG 400 additions, it differs slightly in the recommended volumes it generates for removal and addition. Rather than simply providing a volume of solution to remove and replace

with new PEG, PEGCON takes the continued concentration of PEG 400 into account when adding new PEG 4000. In order to maintain the same concentration of PEG 400 in the solution, PEGCON's calculations for replacing the solution include a value for the amount of PEG 400 to be re-added. For example, when the first addition of PEG 4000 began on February 20th, 2020, PEGCON recommended the removal of 2.5 L of solution. In order to maintain the same concentration of PEG 400 while adding 5% PEG 4000, the program also advised the addition of 0.6 L of PEG 400 in addition to the 2.0 kg of PEG 4000.

Freeze-Drying

Monitoring of the cask hoop's solution continued until March 26th, 2020. Unfortunately, the treatment was disrupted by the COVID-19 pandemic, as student volunteers and interns were prohibited by ECU from traveling to the *QAR* Lab. Although the PEG treatment has been affected by these events, treatment of the cask hoop will continue until the target concentrations of 25% PEG 400 and 40% PEG 4000 have been reached. After these target concentrations are present in the solution, the drying process can begin.

The method of drying used at the *QAR* Lab is freeze-drying. This process helps to avoid the destructive surface tension strain and cellular collapse that result from simple air drying (Ambrose 1990: 237). Rather than allowing the remaining water in the treated wood to escape through evaporation, freeze-drying ensures that the water is removed with little to no impact on the physical integrity of the artifact. To accomplish this, the PEG-treated artifact is first placed into a domestic freezer. Freezing damage is avoided at this stage as the PEG within the object inhibits the formation of ice crystals, preventing the rupture and cracking that usually occurs when water alone is present in a wooden object (Ambrose 1970). Once this is complete, the artifact is transferred to a freeze-drying chamber (Figure 4). The temperature of the chamber is

maintained within the range of -32 to -40℃ (Hamilton 1999a: 28). Once the wood reaches the target temperature of -25℃, a vacuum is applied, greatly reducing the atmospheric pressure within the chamber (Hamilton 1999a: 28; Hoffmann 2013: 39). In this environment, the frozen water sublimates into water vapor, essentially skipping its liquid form, and is collected on the freeze-dryer's condenser coils, where it re-freezes (Hamilton 1999a: 28). This is arguably the most important portion of the drying process as it avoids the surface tension forces of liquid evaporation, and therefore, prevents further cellular damage (Hoffmann 2013: 39). Freeze-drying continues until all excess water in the artifact is removed. Determining the remaining water content is accomplished by weighing the object during drying to gauge weight-loss as water is removed. When this measurement is stable, no excess water remains in the object and the drying phase of the treatment is complete (Hamilton 1999a: 28).

Figure 4. The freeze-drying chamber used at the *QAR* Lab. Courtesy of NCDNCR.

While the process of freeze-drying has been criticized in some cases for its potential to cause extreme desiccation and structural damage when the wood is not pre-treated with PEG (Ambrose 1990), it is currently recognized as the preferred treatment method for smaller wooden artifacts (Hoffmann 2013: 39). After freeze-drying is completed, the artifact is ready for further study and display. The storage or display environment used for the treated artifact should target a relative humidity of 45 to 60% to prevent further swelling or desiccation (Hamilton 1999a: 28).

Although the treatment of the Brunswick Town cask hoop was cut short by extraordinary circumstances, the performance of the treatment and the recognition of its importance to the stabilization and conservation of archaeological waterlogged wood were central components of the internship. Furthermore, using the *QAR* Lab's facilities and methods to treat the hoop plainly illustrated the utility of such treatments in conserving an artifact from a terrestrial context. It is my intention to see the remainder of the process through to its conclusion when it is again possible to return to the lab.

In the next and final chapter, the applicability of laboratory conservation methods to terrestrial archaeology will be discussed. Central to this discussion is the development of a general conservation protocol to be used in ECU summer field schools at Brunswick Town. This first-aid treatment guide is sourced from the experiences and methods encountered during the internship at the *QAR* Conservation Lab.

Chapter 6—Brunswick Town Conservation Protocol and Conclusion

Although the internship was mainly focused on the methods and procedures in use at the *Queen Anne's Revenge* Conservation Lab, the experience is highly applicable to artifact conservation in the field. While working at the lab, former *QAR* head conservator and current North Carolina Office of State Archaeology Special Projects Coordinator, Dr. Sarah Watkins-Kenney suggested that a segment of my report be dedicated to terrestrial conservation. Having worked at the Brunswick Town/Fort Anderson State Historic Site in the past, I decided to use the experience I gained from working at the *QAR* Lab to create a brief conservation guide for the recovery of iron artifacts at the site.

While conservation may be most closely associated with laboratory work, its implementation in the field is central to the practice of ethical archaeology. The archaeological record is a finite resource that is highly valuable in efforts to understand and interpret the human past. Archaeologists rely on the study of curated artifact collections to provide a more complete picture of historical events, groups, and individuals. Therefore, it is in the best interest of all archaeologists to act as stewards of the archaeological record. Stewardship of this resource not only includes the preservation of archaeological sites, but also the active and careful conservation of the artifacts themselves, whether *in situ* or after their removal from their original archaeological context (Beaudry 2009: 19).

According to principles 2 and 4 of the *Ethical Principles of the Society for Historical Archaeology*, the long-term preservation of artifacts recovered during an excavation and the curation of the data sets they generate are vital duties expected of historical archaeologists. While these principles focus on professional obligations, it is important that amateur, avocational and student archaeologists also adhere to these standards. The annual East Carolina University

archaeology field school at Brunswick Town/Fort Anderson presents a unique opportunity to apply these conservation practices in an educational field setting. The result would not only be better on-site stabilization of artifacts, but also the fostering of appreciation for the importance of conservation among the field school students.

Brunswick Town Background

Since 2015, East Carolina University has conducted its archaeological field school at the former British-colonial settlement and Confederate fort site of Brunswick Town/Fort Anderson in the coastal region of North Carolina (Harrup and Byrd 2015) (Figure 1). While the past two summer field seasons have taken place in the same area of the historic site, previous field schools have excavated at different locations throughout the property. Before the material culture recovered during these recent field seasons can be discussed, it is first important to explore the site's history and the prior ECU excavation.

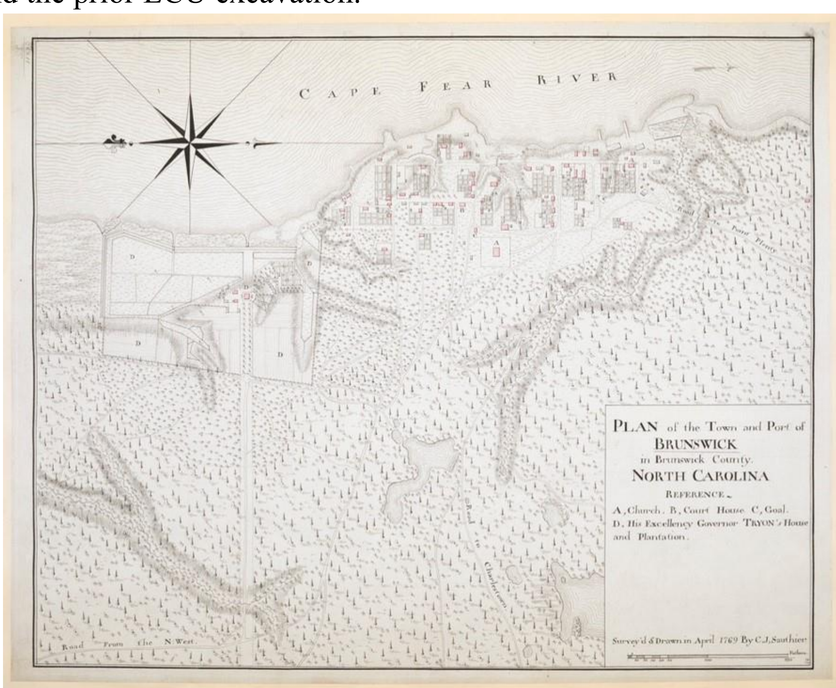

Figure 1. 1769 map of Brunswick Town and the surrounding area created by French cartographer, Claude Joseph Sauthier.

The site of Brunswick Town was founded by Maurice Moore, one of the sons of South Carolina governor James Moore (South 2010: 1). The Moore family was deeply familiar with the surrounding land even before the establishment of Brunswick Town. During the Tuscarora War in 1711, Maurice Moore accompanied the North Carolina militia in their campaign against the local Native Americans. Following his participation in the brief but bloody conflict, Moore purchased separate properties in both Bath and Beaufort, North Carolina by 1713 (South 2010: 1). On June 3, 1725, Moore was allowed 1,500 acres of land to the west of the Cape Fear River. 320 of these acres were delineated as an area for settlement, with at least half of the landmass being divided into 356 half-acre lots (South 2010: 2). According to surviving land records, each of these lots measured approximately 82.5 feet wide by 264 feet deep (South 2010: 2). While the town's official founding under Moore can be traced back to 1725, the first two residential lots (Lots 22 and 23) were sold to Cornelius Harnett Sr. on June 30, 1726 (South 2010: 5). In the decades after this initial sale of land, Brunswick Town became an important hub for the British Empire's naval stores industry, with the community producing significant quantities of tar, pitch, and turpentine from the processing of the area's plentiful supply of longleaf pine trees (South 2010: 77).

Much of the settlement's British-colonial history was defined by conflict and chaos. One of the earliest events to define Brunswick Town's occupation occurred in 1748, during King George's War. As hostilities between the contending empires of Great Britain and Spain intensified, both nations' New World colonies became embroiled in the fighting. Brunswick Town's involvement in the war was marked by the arrival of two Spanish privateering vessels on the settlement's banks, part of a larger campaign against British colonial holdings along the North American east coast. The two ships landed scores of men, who immediately began

plundering and ransacking the town (South 2010: 48). The residents of Brunswick responded swiftly as a sixty-seven-man militia under the command of William Dry and John Swann descended upon the Spanish raiders and handily defeated them three days after their arrival (South 2010: 48-49).

The excitement continued years later during the tumultuous War for American Independence. The town's initial involvement in the struggle against the Crown is highlighted by the residents' early protest of the Stamp Act of 1765 (South 2010: 96). The rebellious attitude of Brunswick Town persisted throughout much of the American Revolution, with the actions of the town's occupants proving to be a thorn in the side of the British and a threat to the King's interests in the coastal region. British forces, Tory loyalists and Patriots alike made use of the settlement's strategic location as both a meeting place and a port of embarkation (South 2010: 223). Brunswick Town's propensity for dissident activity soon drew the full attention of the region's British forces, who eventually burned many of the settlement's buildings in 1776 (*The Virginia Gazette*, January 13, 1776 and April 5, 1776; South 2010: 223). Unfortunately for the town's denizens, the burning at the hands of the British was just one of many hardships that occurred in the second half of the eighteenth century. Combined with the effects of a September 1761 hurricane (*Edinburgh Evening Courant*, December 21, 1761) and the general "unhealthiness" of the surrounding swampland environment (South 2010: 220), many of the town's resident's elected to abandon the vulnerable and battered Brunswick Town after the burning, just before the conclusion of the American Revolution.

Although the area saw reuse during the Civil War as the site of the Confederacy's Fort Anderson, Brunswick Town never again regained the residential population it once had during the eighteenth century. As a result, the ruins of the colonial town remained largely untouched for

close to two hundred years. In the period since the site's abandonment, several attempts were made to hire historical archaeologists to excavate the Brunswick Town ruins. Candidates for the task included notable figures in the field such as Charles Fairbanks, J.C. Harrington, and John Griffin (Joseph 2010: 134). Although the position was offered to several members of the archaeological community, Stanley South was eventually chosen to direct excavations. From 1958 until his departure from the site in 1968, South identified a total of sixty British-colonial architectural features and managed to excavate twenty-three (Ewen 2006). In the ten years that he presided over the site's archaeology, South developed several methods of analysis that later became highly influential in historical archaeology. These included the Mean Ceramic Dating method and formula, and the Brunswick artifact pattern (Ewen 2006: 283). Although South eventually left Brunswick Town in 1968, his research remains highly relevant to all excavations carried out at the site today.

ECU 2018 Field School Season

From May 15th to June 7th, 2018, principle investigator Dr. Charles Ewen and students with the East Carolina University archaeology field school excavated two separate spaces, Lots 71 and 29 on the Brunswick Town grounds. Lots 71 and 29 are located in the southern portion of the site, referred to as the "commercial district" by previous researchers. This area roughly corresponds to a demarcation made on a 1769 map created by Claude Sauthier for Governor William Tryon (Harrup 2018; Byrnes 2018) (Figure 2).

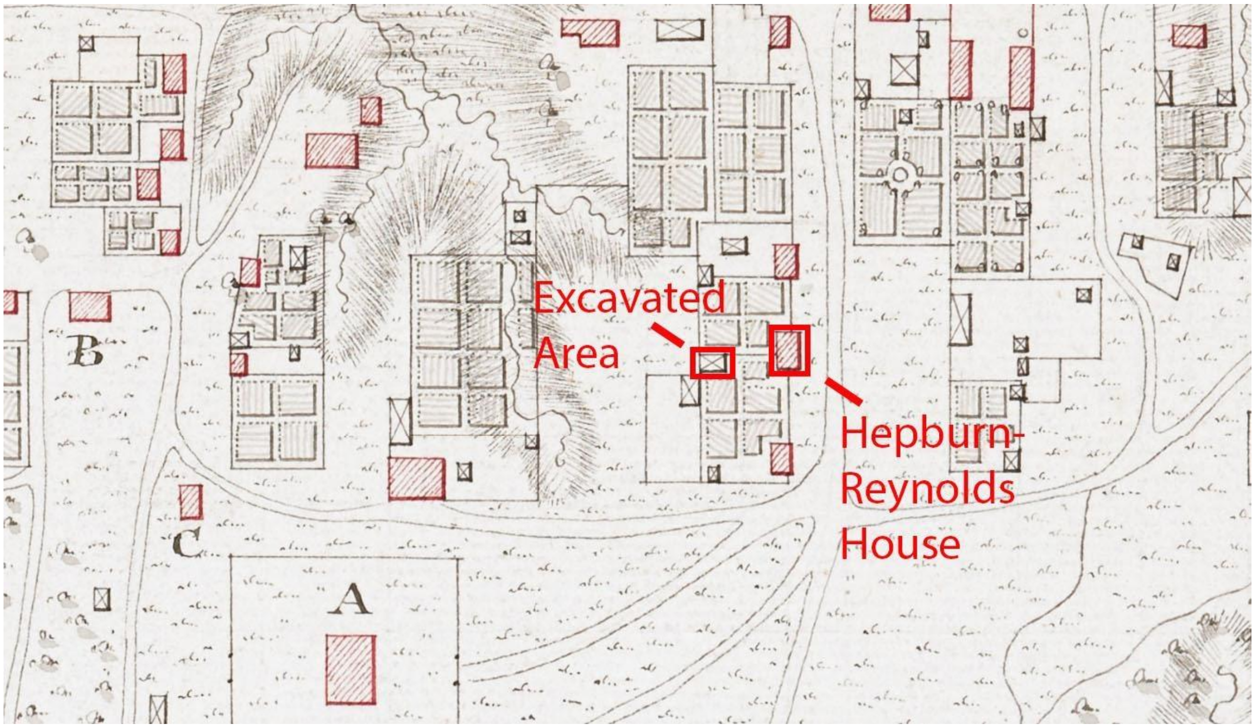

Figure 2. Section of Sauthier map showing the location of Lot 71. Taken from Byrnes (2018). Original image courtesy of the Boston Public Library Norman B. Leventhal Map and Education Center Digital Collections.

The excavations at Lot 71 focused on the investigation of a rubble pile located about 500 feet to the north of a structure known as the Hepburn-Reynolds house. The proximity of the rubble pile to the Hepburn-Reynolds house at Lot 71 aroused suspicion that the two structural features were related. To ascertain the function of this rubble and determine if any connection to the Hepburn-Reynolds house existed, 15 and a half 5X5 foot units were excavated in the area surrounding the rubble pile. Each of these units were excavated until reaching sterile subsoil at about one foot below surface. During the excavations, a foundation feature was uncovered consisting of two attached squares, with the southern square being larger than the northern square. Analysis of the two squares led to the conclusion that both features were hearths. 56% of the 3,648 recovered artifacts were associated with kitchen use. Viewed in conjunction with the identification of the features as hearths, the investigators at the 2018 Field School concluded that

the rubble was likely a detached kitchen associated with the Hepburn-Reynolds property (Byrnes 2018).

With the time remaining at the end of the 2018 field school, the students and supervisors turned their attention to lots adjacent to Lot 71 in an effort to identify the Lord-Wright house as labeled on the 1769 Sauthier map (Harrup 2018). Using ground-penetrating radar and sub-surface probing, doctoral student Matt Harrup managed to identify two parallel features extending to the north about two to four feet below the ground surface. Since these excavations occurred at the end of the 2018 field school, the investigation of this area was limited to three 5X5 foot units. The three units extended from east to west between the two planar features. The excavation managed to reveal that the eastern feature was an intact wall and that the parallel feature to the west was likely collapsed brick architecture. In total, 4,565 artifacts were recovered across the three units in Lot 29. The assemblage was dominated by tavern-related artifacts, leading to the conclusion that the brick features were once part of a tavern on the property (Harrup 2018).

ECU 2019 Field School Season

In May 2019, East Carolina University returned to the Brunswick Town/Fort Anderson State Historic Site to continue excavating where the previous field school left off at Lot 29. The field school began with the re-excavation of the three east-west units placed the previous year between the two brick features. After removing the previous year's backfill, the search for corners to each wall began. In order to accomplish this goal, new units were opened along the western brick fall, with excavations continuing in each new unit until a distinct corner was

identified. Using sub-surface probes, potential brick features were found along the walls and new units were dug.

Eventually, all four corners of the brick foundation were identified (Figure 3). The southwest, southeast, and northeast corners were found to be largely intact and articulated with the identified parallel walls to the west and east. The northwest corner was somewhat intact but was not visibly connected with any contiguous brick wall feature. From the identification of these corners, it was concluded that the building that once stood there measured approximately 15X25 feet.

After identification of the four corners, the field school participants focused on the excavation of the interior of the building. During this stage of the excavation, students recovered numerous artifacts that were consistent with the previous field season’s tavern-related assemblage. This included large amounts of bottle glass, intact and broken pipe stems and bowls, window glass, and other vessels related to drinking and food consumption. Preliminary analysis of the material recovered during the 2019 field school seems to indicate an occupation between 1735 and 1767.

Figure 3. Overhead view of the brick walls and corner features identified during the 2019 field school.

Material Culture from the 2018 and 2019 Field Schools

During the 2018 field season, excavations of Lot 71 yielded a total of 3,648 artifacts. Over half (56%) of these artifacts were representative of kitchen activity, leading to the conclusion that the foundation feature was likely a detached kitchen associated with the adjacent Hepburn-Reynolds property (Byrnes 2018: 18-19). According to Byrnes (2018), the assemblage is dominated by a large collection of colonial era ceramics, totaling to 1,372 sherds, or approximately 37% of the total artifact collection recovered from Lot 71.

The remainder of the assemblage includes numerous fragments of curved glass (possibly from drinking vessels), several clay pipe fragments, animal bones, and bottle glass. Accompanying these artifact types are numerous examples of archaeological metal. This segment of the assemblage is visibly represented by the high number of wrought iron architectural nails that were recovered during the excavation. Although the count is smaller, the metals recovered from Lot 71 also include individual iron tools, lead shot, a pewter button, iron pots, barrel bands, and furniture hardware (Byrnes 2018).

The excavations at the neighboring Lot 29 at the conclusion of the 2018 field school and the beginning of the 2019 field school yielded a somewhat similar artifact assemblage. The 2018 assemblage was largely dominated by ceramics, including several types of white salt-glazed stoneware, porcelain, delft, Staffordshire ware, and Creamware (Harrup 2018). Included in the artifact collection were numerous colonial-era wrought iron nails, glass fragments, and a high concentration of pipe stems and bowls. The 2019 field school recovered similar artifacts. These included a comparably large collection of pipe stems and bowls, similar ceramic types as the 2018 collection, numerous fragments of bottle glass, and several animal bones.

Current Conservation of Brunswick Town Artifacts

While no formal protocol for the immediate conservation of recovered artifacts is currently in place, great care is still taken to protect all recovered artifacts and avoid further deterioration. This includes carefully preventing all metal objects from getting wet after recovery and sorting excavated materials into different categories based on material type. Additionally, certain artifacts that are deemed important for interpretation are set aside for further conservation. This practice is exemplified by the treatment that the Brunswick Town cask hoop received following its recovery (see Chapter 5).

Current field storage involves the use of chemically inert, sealed, gallon-size polyethylene zip-lock bags to store and protect recovered artifacts. Artifacts remain in these bags from initial recovery until their eventual cleaning. After the artifacts are temporarily removed for cleaning, they are again placed into the polyethylene bags where they will remain until they are transported back to the Phelps Archaeology Laboratory at East Carolina University for cataloguing. The artifact assemblage remains at East Carolina University for a period of time before ultimately being transferred to the Office of State Archaeology's curated collection in Raleigh for long-term storage.

Although the procedures currently in use by the ECU field school are appropriate for most material recovered at Brunswick Town, there is an opportunity to expand field conservation practices further. Implementation of a more formal first-aid conservation guide for future field schools will provide students with the skills necessary to immediately tend to artifacts of any material type and also provide better context for the role of conservation in field archaeology. Furthermore, while it is unrealistic to apply these measures to all of the thousands of artifacts

recovered during a field school, the use of a general first-aid protocol will assist in the treatment and storage of artifacts that are potentially important in documentation, as mentioned above.

Artifact Material Types at Brunswick Town

To create a basic protocol for first-aid field conservation, it is first important to analyze the characteristics of the Brunswick Town artifact collection and the burial context of the material to determine which artifacts are most at-risk of severe deterioration upon excavation. As can be seen in the artifacts recovered during the 2018 (Harrup 2018; Byrnes 2018) and 2019 field schools, much of the Brunswick Town assemblage can be associated with three main artifact material types: ceramics, glass, and metals.

Of the three artifact types listed above, ceramics and glass survive the best, as evidenced by their frequency in the assemblages. Unlike metals, the breakage that sometimes occurs during deposition into the archaeological record is often "the most destructive event visited upon" artifacts in these two categories (Rodgers 2004: 141). While certain lower-fired ceramic types such as earthenware and prehistoric pottery can become fragile upon excavation due to their softer, more porous structure, higher-fired ceramics such as stoneware and porcelain are highly resistant to deterioration (Rodgers 2004: 141-142). The higher firing temperature during the manufacturing process of these ceramics ensures the formation of a hard body, impervious to most salt and water contamination (Rodgers 2004: 143).

Much like high-fired ceramics, archaeological glass is resilient and often survives in the burial environment. In fact, glass is regarded as one of the most stable archaeological materials (Hamilton 1999a: 20). In contrast to both ceramics and glass, archaeological metals are highly susceptible to corrosion and deterioration (Cronyn 1990). These metals are usually unstable and

vulnerable to significant chemical decay (Cronyn 1990: 165). While each of the artifact types found at Brunswick Town exhibit differing degrees of stability, all have the potential to deteriorate.

Glass Degradation

Although most glass survives well in the archaeological record, artifacts of this type are subject to degradation as a result of moisture in the burial environment (Cronyn 1990: 130). Central to glass deterioration are its main chemical components: silica (usually comprising about 70-74% of the glass), sodium carbonate or potassium (16-22%) and calcium oxide (5-10%) (Hamilton 1999a: 20). As moisture is absorbed into the surface of the glass artifact, the sodium carbonate or potassium components may leach out, leaving behind a “fragile, porous, hydrated silica network” (Hamilton 1999a: 20). This results in observable cracking, flaking, and pitting along the artifact’s surface. Glass possessing 20 to 30% sodium or potassium in its structure is at particular risk for moisture penetration (Hamilton 1999a: 20; Rodgers 2004). Often referred to as “glass disease”, this process is again characterized by the intrusion of positively charged hydrogen protons in the form of water into the structure of the glass, causing the alkali metal ions to leach out (Cronyn 1990: 131; Rodgers 2004: 147). This process contributes to a flaky, multihued appearance, ultimately culminating in the devitrification or crystallization of the glass structure. Once devitrification occurs, the glass becomes susceptible to salt intrusion. If salt has penetrated the glass and the artifact is left to dry, the salt contents will crystallize and destroy the outer layers of the object (Rodgers 2004: 148). In order to stabilize glass suffering from this degree of deterioration, the object must be stored in an environment with a relative humidity of about 40% (Cronyn 1990: 137).

Ceramic Degradation

Like glass, ceramics generally survive very well in the archaeological record (Hamilton 1999a: 17). However, certain types of ceramics, namely low-fired variants of earthenware and prehistoric pottery, are susceptible to extreme degradation and total loss in certain burial environments. This is especially evident in damp soils, where porous underfired ceramics will gradually rehydrate to clay, weakening the object significantly (Cronyn 1990: 145). High-fired ceramics such as porcelain and stoneware, however, remain robust in a variety of conditions. In addition to the weakening of the ceramic object's structural integrity, artifacts may also exhibit flaking of their surface glaze and grey or white encrustations as a result of the presence of soluble and insoluble salts (Cronyn 1990: 146). For ceramic artifacts recovered from terrestrial contexts, passive stabilization involves allowing the object to dry after cleaning soil from its surface (Cronyn 1990: 150). In the cases where a ceramic object has been recovered from a salty deposit, it is usually necessary for the artifact to be placed into desalination treatment upon its arrival to the laboratory (Cronyn 1990: 150-151; Hamilton 1999a: 17).

Iron Degradation

In contrast to both ceramics and glass, archaeological metals are highly vulnerable to corrosion and deterioration. Although the Lot 29 Brunswick Town assemblage does feature several metal types including copper and lead, the most abundant metal type is iron, mostly in the form of building materials. Iron is often regarded as the most common metal recovered from archaeological sites, and also the most difficult to manage due to the variety of environments where corrosion of iron can occur and the complexity of the corrosion products (Hamilton 1999a: 38). While the corrosion of iron is still a subject of conservation research, several important aspects are now understood.

Electrochemical corrosion begins after the artifact comes into contact with oxygen and water. While the iron object remains in the presence of both oxygen and water, its negatively charged electrons are gradually removed and positively charged cations are created (Cronyn 1990: 166-167). Since this system results in a flow of electrons within the object, it is often referred to as a corrosion cell (Cronyn 1990: 167). While this cell is active, metal from the surface of the artifact is steadily lost, with the corrosion proceeding further into the object until none of the original metal remains (Cronyn 1990: 182-183).

As corrosion takes hold of the iron object and the released cations react to the anions in the burial environment, a concreted, red-orange surface forms around the iron object (Cronyn 1990: 168). The iron artifacts recovered from Brunswick Town feature thick concreted shells, often containing a matrix of sand or small rocks (Rodgers 2004: 77). These corrosion products are generally comprised of iron oxides and carbonates, and, if solid enough, may stifle active corrosion cells and protect the artifact from further corrosion (Cronyn 1990: 168, 179).

Despite the passivating effect of the corrosion products, it must be emphasized that all iron artifacts are actively corroding upon excavation (Cronyn 1990: 195; Rodgers 2004: 83; Turgoose 1982). The most obvious signs of continued corrosion after excavation are orange "tears" that may appear on the surface of an object, and the cracking of the protective corrosion layer as a result of temperature fluctuations once the object has been removed from the soil matrix (Cronyn 1990: 195). In order to slow or prevent further corrosion, actions must immediately be taken to stabilize the artifact. Passive stabilization is often the best course of action when attempting to prevent further corrosion of artifacts in the field (Cronyn 1990: 196). This involves establishing a temporary controlled environment to protect the object from the moisture, oxygen and chloride content of the post-excavation environment.

Soil and Site Context at Brunswick Town

The type of soil at an archaeological site is highly important in determining an artifact's degree of deterioration and also influences the planning for its conservation. According to Pedeli and Pulga (2013: 13), soil can be understood as a "physical, chemical, and biological system that interacts with the materials it contains". At Brunswick Town, the soil is characterized as Baymeade-Blanton-Norfolk series, featuring a loamy subsoil and fine sand (Byrnes 2018; Barnhill 2004). As a result of the sandy soil, the matrix is susceptible to permeation by atmospheric gases and water. Combined with the generally humid climate of the Cape Fear Region, this soil context creates harmful burial conditions for any artifacts at risk of corrosion through contact with oxygen and water (Pedeli and Pulga 2013: 13). Despite the negative effects of burial environments like this, the rate of chemical corrosion rapidly decreases in such deposits and stops completely in some cases. In these contexts, an equilibrium has been created (Bowens 2009: 148). Removal of the artifact from this equilibrium through excavation restarts or accelerates the corrosion process, endangering the object (Pedeli and Pulga 2013: 24).

On-Site Conservation Plan

In order to prevent severe degradation and the destruction of important archaeological information, it is crucial that "first-aid" procedures are prepared for the field (Bowens 2009: 148). These procedures primarily involve the proper packing and storage of archaeological materials immediately after excavation and before the artifacts can be transferred to a laboratory to undergo active conservation treatment (Bowens 2009). It is recommended that arrangements regarding the conservation of an assemblage are made at the earliest stage of an archaeological

project. This involves either having access to a professional archaeological conservator, or even having one present on-site during the project (Bowens 2009: 149). In the absence of a conservator, basic conservation plans can be developed to facilitate the care of artifacts by non-conservators. It is advisable for these plans to be cost effective and very simple to execute in the field, so that other excavation activities are not disrupted in the process (Pedeli and Pulga 2013: 8).

Currently, ECU's field school procedures manual includes an overview of the treatment of certain artifact types in both the field and in the laboratory. The manual includes instructions for the storage of delicate artifacts, steps for cleaning different material types, and recording practices during artifact recovery. It is the intention of the first-aid protocol introduced in this chapter to supplement the information already present in the procedures manual used annually by the ECU field school. This entails providing additional information regarding the identification of deteriorating materials and a more in-depth description of storage recommendations for specific material types. The brief conservation protocol detailed below encompasses the three major artifact groups at Brunswick Town: glass, ceramics, and iron. However, as iron is often the most difficult artifact to deal with upon recovery (Hamilton 1999a), it is a central focus of this basic guide.

It must be noted that the following information will not be applicable to all objects recovered during an excavation at Brunswick Town. As mentioned by Bowens (2009) and Pedeli and Pulga (2013), it is essential that none of these procedures disrupt the excavation. If all recovered artifacts receive such treatment, the process will unfortunately be very slow and will undoubtedly impact the project's timeline. Therefore, it is recommended that this conservation

protocol be applied primarily to artifacts with the highest potential to yield information relevant to site interpretation.

I. <u>Identifying Artifacts Requiring First Aid</u>

Before first-aid conservation takes place at the site, it is first important to identify the archaeological materials that are at the highest risk for further degradation after excavation, as not all materials will require immediate treatment. For each of the three main artifact material types encountered at Brunswick Town, signs of deterioration will likely be readily identifiable upon inspection of their surface and structure. The main indicators of deterioration for each type are listed below.

<u>Glass:</u>

Glass is one of the three most common artifact types recovered over the past two field seasons at Brunswick Town (Harrup 2018; Byrnes 2018). While it survives very well in an archaeological context, it is important to identify any glass artifacts that are exhibiting significant signs of deterioration.

Visible Signs of Glass Deterioration (Pedeli and Pulga 2013: 49; Cronyn 1990: 130-133):

- Clouded/loss of transparency on the surface
- "Sugary" appearance, indicating devitrification
- Discoloration or staining
- White encrustation deposit, indicating presence of insoluble salts

Ceramics:

Like glass, a multitude of ceramics are found in high frequencies during excavations at Brunswick Town. Despite the relative robusticity of ceramics in the archaeological record, significant deterioration may be apparent immediately after excavation.

Visible Signs of Ceramic Deterioration (Pedeli and Pulga 2013: 48-49; Cronyn 1990: 145-146):

- Soft or crumbling structure (low-fired wares are particularly vulnerable)
- Flaking surface, glaze, or paint
- Grey/white encrustations, indicating presence of insoluble salts
- Discoloration or staining

Iron:

The third major artifact group found at Brunswick Town, and arguably the most susceptible to harmful corrosion upon recovery (Cronyn 1990; Hamilton 1999a), is iron. Given the highly aerated, sandy soils of the Brunswick Town area, iron objects are continually exposed to water and oxygen. Upon exposure during excavation, the deterioration that began in the burial environment has the potential to accelerate.

Visible Signs of Iron Deterioration (Pedeli and Pulga 2013: 43-44; Cronyn 1990: 179-181):

- Somewhat saturated orange/brown surface color with incorporated soil
- Bulky red/brown mass (more common at damp aerated sites)
- Light orange protuberances or bumps

- Irregular and blistery details and edges

II. Documentation and Bagging of Artifact

After determining that an artifact is suitable for on-site first-aid conservation, that artifact will receive initial documentation and storage. This interim process will be the same for artifacts of all three types and includes photographing the artifact before it is placed into a plastic bag. It is essential that the materials used to store the artifacts are 1) chemically and mechanically stable to prevent breakage and protect their contents, 2) chemically inert so that no interactions occur between the storage container and the archaeological material, and 3) economical and readily available (Pedeli and Pulga 2013: 98). The Canadian Conservation Institute recommends the use of inert plastics such as polyethylene, polypropylene, polyester, and polystyrene (Tétreault and Williams 1992). For this purpose, the polyethylene plastic bags currently used for standard artifact storage at Brunswick Town are appropriate. The bag will be labeled with provenience information matching the unit and level that the artifact was excavated from. In cases where an artifact will be separated from the rest of the level's material for purposes of treatment, the new bag will retain the same Field Specimen (F.S.) number as the standard storage bag and receive the designation "Bag 2 of #".

III. On-site Storage of Artifact in a Controlled Environment

After the artifact is bagged and labeled, the object is ready to be stored in a container. Once again, these containers must fulfill certain requirements to be eligible for storage use. These include 1) mechanical integrity to withstand transportation and compression and 2) chemical integrity to protect its contents from environmental hazards and prevent interactions with the archaeological material (Pedeli and Pulga 2013: 98). Sealable, airtight polyethylene or

polypropylene plastic boxes prevent the influx of both oxygen and water and are ideal for creating a controllable storage environment (Pedeli and Pulga 2013: 98-99). It is important that recovered materials are packed separately depending on their material and whether they are wet, damp or dry (Pedeli and Pulga 2013: 102).

Glass:

When deteriorating glass is recovered from an archaeological deposit, it is recommended that the glass be kept damp, taking precautions to prevent any part of the glass from drying out (Cronyn 1990: 137). This can be accomplished by sealing the glass artifact in its polyethylene bag, and then sealing that bag in a larger plastic polyethylene or polypropylene container to prevent the evaporation of moisture (Pedeli and Pulga 2013: 104). This is especially useful for glass recovered from sites like Brunswick Town, with well-aerated and often damp soils. Long-term wet storage should be avoided as the pH of the solution will begin to rise, and any remaining glass structure will be leached out of the artifact. For glass that is exhibiting the "weeping" characteristics of glass disease, storage in a container with a relative humidity of about 40% is recommended (Cronyn 1990: 137). This can be monitored by attaching a relative humidity strip to the inside of the container to monitor the microenvironment (Cronyn 1990: 74). (Figure 4). As glass is one of the most frequent materials recovered at Brunswick Town, these measures will only be undertaken if a recovered glass artifact is deemed important for interpretation.

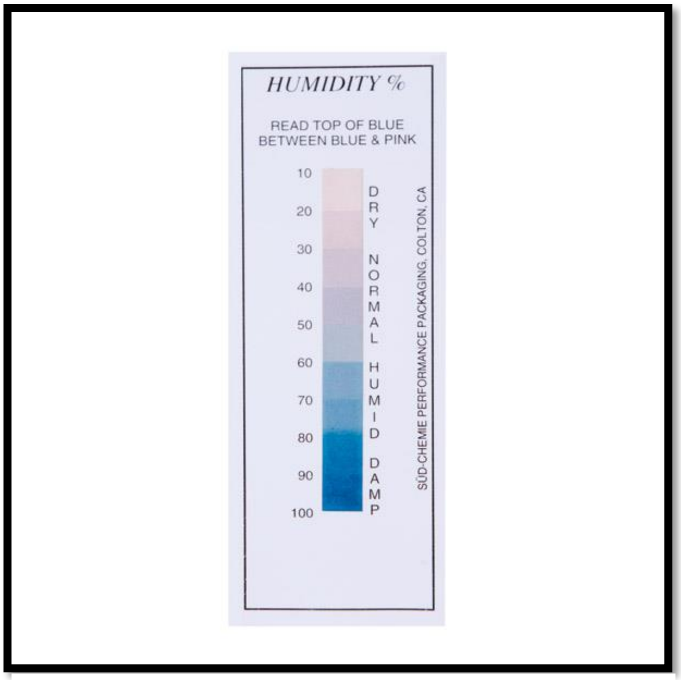

Figure 4. Relative humidity (RH) indicator strip.
Useful for monitoring storage environments.

Ceramics:

For most ceramic types recovered from land sites, passive treatment involves allowing the artifact to dry out (Cronyn 1990: 150). Crumbling and structurally weak ceramics must be packed with appropriate padding to prevent further breakage and abrasion damage during transport (Pedeli and Pulga 2013: 49; Cronyn 1990: 78, 157). Acceptable inert packing materials include polyethylene and polystyrene foam (Pedeli and Pulga 2013: 101). These materials must be packed delicately, but firm enough to prevent the movement of the objects within the container (Cronyn 1990: 78).

Iron:

Iron is the most complex material recovered at Brunswick Town and, therefore, requires a highly specific microenvironment for storage. The most common method of passive storage for iron artifacts in the field is desiccation. This process attempts to remove any water in the iron to

prevent further corrosion and ensure that the corrosion crusts do not break up and expose the surviving archaeological metal. The target storage environment for passivating iron is <20% relative humidity (Cronyn 1990: 196).

In order to accomplish desiccation and reduce relative humidity (RH) within the container, silica gel is employed. As with all materials used in first-aid conservation, silica gel is stable, inert, nontoxic, noncorrosive, and nondegradable. Three types of silica gel are available for use in artifact storage, with each type accommodating a specific RH range. Type I regulates RH from 0 to 40%, Type II from 30 to 60% and Type III from 65 to 90% (Pedeli and Pulga 2013: 135). For the purposes of iron storage, Type I will be chosen. The Canadian Conservation Institute recommends that 50 grams of silica gel be used per liter of a container's internal volume. For example, a container with an internal volume of 6 liters will require 300 grams of silica gel (Cook 2019). As with other containers requiring a controlled microenvironment, RH indicator strips are also stored in the container for monitoring. If the correct volume of silica gel is chosen for a given container, the storage environment can be maintained for months before the gel requires drying (Cook 2019). Once again, a controlled container will be reserved only for iron artifacts with the highest information potential as it is impractical to immediately treat all iron objects recovered at the site.

Additional Comments

Implementing these methods at the East Carolina University archaeology field school will help to supplement the measures already in place and ensure that the students gain an appreciation for field conservation and new knowledge of the proper storage of artifacts. Once fieldwork is completed, all artifacts are transferred back to the Phelps Archaeology Laboratory

on ECU's campus. While these artifacts may not receive immediate active conservation treatment, maintenance of the environmental conditions described above will prevent any further corrosion during storage.

Although the participation of a conservator for on-site conservation is recommended for most archaeological excavations, conservators are sometimes too expensive or not available for a project (Bowens 2009: 149). In the absence of a proper conservator, archaeologists following a basic conservation protocol will have the tools at their disposal to ensure the survival of at-risk artifacts. If significant deterioration is slowed or prevented after these objects are excavated, their informational potential survives as well.

Conclusion and Internship Assessment

Although the internship only took place from the Spring 2019 to Spring 2020 semester, its impact on me as a graduate student and archaeologist cannot be overstated. Participation in the procedures in use at the *Queen Anne's Revenge* Conservation Lab contributed to a better understanding of the methods and theory involved in archaeological conservation, and to an even greater appreciation for the significance of conservation in both terrestrial and marine projects. Working as a student intern resulted in exposure to nearly all aspects of the *Queen Anne's Revenge* Shipwreck Project, from the moment an artifact receives initial documentation, to the eventual artifact condition assessments that occur once an object has been transferred for curation and display at a museum.

Arguably one of the most important facets of this internship was the constant engagement in the five-stage conservation process regularly in use at the *QAR* Lab (See Chapter 3). This system encompasses all aspects of an artifact's treatment, beginning with its recovery in the

field, and ending with its inclusion in reports and eventual transfer for monitoring and display in a museum collection. The second stage, "Treatments in Process" and the third stage, "Final Documentation, Recording and Stable Storage", were focused on most heavily during my time at the lab. These stages include routine tasks performed on a weekly basis that are essential for the stabilization of archaeological material. These routine tasks, such as the chloride monitoring of passive desalination and the testing of PEG solutions, comprised the bulk of my responsibilities as an intern at the lab. Taking part in portions of each stage provided me with a foundational skillset required to be an effective conservation lab technician. It is very likely that many of these skills will remain applicable as I continue to work with artifact collections recovered from terrestrial sites.

As described in Chapter 4, working as an intern also provided an opportunity to engage in more specialized tasks and work on personal projects. Although these activities are not often considered routine, they are nevertheless integral to operations at the *QAR* Lab. Some of these specialized tasks included the chelation of organic artifacts to remove trace iron and sulfur concentration, cannon cleaning, monitoring of electrolytic reduction tank solutions, and participation in public outreach events. Once again, all of these tasks are relevant and applicable for any conservation-minded archaeologist. Public outreach in particular has become a central focus of archaeology in recent decades, as good practice of archaeology is increasingly reliant on the participation of members of the public to be successful (McGimsey 1972; Little 2012; Little 2007; Meighan 1986; Derry 1997; McManamon 1991; Milanich 1991).

Perhaps the most tangible product of my time at the lab was the conservation of the Brunswick Town cask hoop, detailed in Chapter 5. The cask hoop's treatment process not only provided experience in the management of waterlogged wooden artifacts, but also clearly

demonstrated the significance of laboratory conservation in the stabilization of artifacts recovered from terrestrial contexts. This overlap between laboratory conservation and terrestrial archaeology also contributed to the later development of the basic Brunswick Town first-aid conservation guide described above. These transferable skills learned at the *QAR* Lab will no doubt be highly useful during future land-based projects. This experience provides a clear example of the importance of the *Queen Anne's Revenge* Conservation Lab and serves as a statement for the success of the internship option offered to anthropology graduate students at East Carolina University.

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Appendix A: Additional Documents

1.1 *QAR* Lab Conservation Activities Spreadsheet

Conservation Stage	Conservation Stage	Conservation Stage	Conservation Stage	Conservation Stage
1	**Recovery and Post-Recovery**			
	Field Recovery	KPK	EBC	
	Wet Storage (includes tanks set up and maintenance)	SWK		
	X-radiography	KPK	SWK	
	XRF and materials ID	SWK	KPK	
	Pre-Conservation Photography	EBC	KPK	
	DB records	KPK	EBC	
	Sediment processing	KPK	EBC	
2	**Treatments in Process**			
	Cleaning program for Large Artifacts: Cannon; Anchor; Stern Post	SWK	KPK	
	Cleaning: Concretion breakdown	KPK	EBC	
	Desalination: ER set up	KPK	SWK	
	Desalination: TDS set up	KPK	EBC	
	Desalination: NaOH	KPK	EBC	
	Alkaline sulphite solns.	KPK	EBC	
	Desalination monitoring: ER	KPK	SWK	
	Desalination monitoring: TDS	KPK	SWK	
	Consolidation: PEG set up	KPK	SWK	
	Consolidation: silicone oil	KPK	EBC	
	Consolidation: B72	KPK	SWK	
	Consolidation: PEG monitoring	KPK	SWK	

	Dehydration: solvent drying	KPK	SWK	
	Dehydration: air drying	EBC	KPK	
	Dehydration: freeze-drying	KPK	SWK	
	Surface Treatments:			
	Metals	SWK	KPK	
	(Tannic acid/B72/DS)			
Conservation Stage	**Conservation Task**	**Task Supervisor**	**Deputy**	
3	**Final Documentation, Recording, stable storage**			
	Dry Storage transfer to	EBC	SWK	
	Dry Storage maintenance	EBC		
	Post tmt Photography	EBC	KPK	
	Illustration program	SWK	KPK	
	Material Culture Analysis/Documentation	SWK	KPK	
	Reports and Publications	SWK	KPK	
4	**Preparation for Transfer**			
	Transfer liaison with NCMM	KPK	SWK	
	Object, documentation, records checking	EBC	KPK	
	Transfer paperwork/db records	KPK	EBC	
	Transfer packing and handling	KPK	EBC	
5	**Post-Transfer Artifacts at Museum**			
	Cannon checks	KPK	SWK	

	Artefact conditions assessments/surveys	SWK	KPK	
Other				
H&S	All Activities at QAR Lab	Chief Conservator (SWK)	Lab Manager (EBC)	
	Tank Days	SWK	EBC	

1.2 *QAR* Online "Adventures in History" Blog Text

URL: https://www.qaronline.org/blog/2020-04-15/my-story-brandon-eckert

Author: Brandon Eckert, QAR Lab Intern

My name is Brandon Eckert and I am an intern at the Queen Anne's Revenge Conservation Lab in Greenville, North Carolina. Currently, I am in my second year as a master's student in East Carolina University's Department of Anthropology. Since I was very young, I have been deeply interested in history. Much of this interest stems from the numerous times I accompanied my parents and younger siblings to historic sites and museums all along the east coast from western New York, where I'm originally from, to Florida. A few of these places included Revolutionary War battlefields, Spanish and English forts, southern plantations, and various historic buildings. While all of these sites were a great deal of fun to visit and tour, few had a bigger impact on me than Colonial Williamsburg in Virginia. Whether it was walking through the streets of a reconstructed British-colonial town or seeing the area populated with historical interpreters in full period dress, Colonial Williamsburg instilled in me a deep appreciation for our nation's comparatively recent British-colonial history.

After taking several history classes in high school, it was time to decide what to pursue in college. I researched history programs at universities all over the United States and in Canada. Lists were created, calls were made, and emails were sent. But, in the end, I still felt that something was missing in my search. I knew I loved history, but I wasn't sure what I wanted to do with it. Eventually, however, I came to the realization that pursuing archaeology was the perfect path to a career where I could interact with the tangible aspects of history on a regular basis.

This pursuit led me to the University of North Carolina at Wilmington. After four years of classes in all four sub-fields, I graduated with a degree in Anthropology in 2016. Immediately after graduating, I signed up for UNCW's archaeology field school. Although our excavations at Brunswick River Park near Wilmington did not yield much material, participation in the field school introduced me to the neighboring site of Brunswick Town. The other field school students and I eventually had the opportunity to visit the former British-colonial settlement, where we also met students from ECU's own field school. It was here that I met and briefly talked with Dr. Charles Ewen, who would later become my advisor at ECU.

When it came time to decide on my options for graduate school, ECU was at the top of my list. After being accepted into the program, I finally returned to Brunswick Town in the summer of 2018 to serve as a field school supervisor. In addition to my participation in excavations at Brunswick Town, I have also had the opportunity to work as an intern at the Queen Anne's Revenge Conservation Lab. While working at the lab, I have been able to participate in a range of treatment processes for the conservation of multiple artifact material types. In the time since I began working at the lab, I have also taken on a few personal projects. One of these is the treatment of a waterlogged wooden cask hoop recovered from Brunswick Town in 2015. While I am looking forward to graduating this Spring, I will miss the lab dearly. For a person that loves history as much as I do, this experience has been a nothing short of incredible.

1.3 *QAR* Online Brunswick Town Cask Hoop "Artifact of the Month" Blog Text

URL: https://www.qaronline.org/blog/2020-04-01/artifact-month-bt-hoop

Author: Brandon Eckert, QAR Lab Intern

While the *Queen Anne's Revenge* Conservation Lab is known for its treatment of artifacts recovered from Blackbeard's infamous flagship, conservators sometimes work with objects from other North Carolina sites. Recently, the lab received an intact wooden cask hoop from ECU's Department of Anthropology. This hoop was recovered from the waterfront at the British-colonial site of Brunswick Town in 2015 during the inaugural ECU Archaeology Field School, directed by Dr. Charles Ewen. Discovered in remarkably good condition on the muddy banks of the Cape Fear River, the wooden barrel band was waterlogged after centuries of rest in the river's waters. It remained stored in water until treatment could begin. In order to stabilize the cask hoop, it was brought to the QAR Lab in Spring 2019 to undergo conservation treatment.

The waterfront where the cask hoop was found was once the site of a wharf in the burgeoning colonial settlement of Brunswick Town. Founded by Maurice Moore in 1726, the settlement was known for the processing of long-leaf pine tree sap and resin for naval stores (tar, pitch, and turpentine). Aside from these economic ventures, the town also became embroiled in several important historical events, with the most notable being the American Revolution. Following the war, Brunswick Town was largely abandoned as the political and economic importance of neighboring Wilmington grew. Today, it is a popular state historic site!

Although the cask hoop is just a small piece of this history, it has the capacity to yield even more information about the town and its residents. However, before any new information can be learned from the hoop, it must be protected from any potential future deterioration. After centuries of burial on the shoreline of the Cape Fear River, much of the wood's original cellular structure has broken down. The cavities left in the wood after deterioration are filled with water. If left to dry without proper treatment, the water within the hoop will evaporate, leading to shrinkage and structural collapse.

In order to prevent this, PEG treatment is used. PEG, an acronym for Polyethylene Glycol, is a chemical compound that is used to strengthen the structure of waterlogged wooden

objects. During the process, PEG is gradually added to a tank holding the artifact in low salinity, reverse osmosis water. Over time, the liquid PEG replaces the water in the object, strengthening or “bulking” the artifact’s structure. Progress is monitored on a weekly basis until more PEG can be added. Additions are done in 5% intervals to slowly introduce more PEG into the artifact.

Once enough PEG has entered the artifact, it goes through the final stage of the process: freeze drying. At this point, the object is placed into a large, vacuum sealed freeze-dryer and kept at a temperature between -32 and -40°C. The remaining water in the wood freezes before transitioning into vapor. The amount of water removed during this process is determined by weighing the artifact after freeze-drying and comparing it to the weight before treatment. With the water finally removed and the PEG strengthening the remaining structure, the wooden artifact is finally ready to be stored in a climate-controlled environment.

While the Brunswick Town cask hoop is still a recent addition to the lab, it is well on its way to becoming stable through PEG treatment. Numerous other wooden artifacts from Queen Anne’s Revenge accompany the barrel hoop in this process. If you would like to know more about the cask hoops recovered from *Queen Anne’s Revenge* and how casks were constructed, check out our previous Artifact of the Month!

1.4 Brunswick Town Cask Hoop Treatment Record

Artifact Record				
Brunswick Town				
BT Wharf Crib 1				
Z1 L1 FS #14				
Wooden Barrel Hoop				
Date	**Step**	**Description**	**Loc.**	**Cons.**
5/2/2019	Handling	Transferred to VOA from ECU Anthro lab.	VOA 114	KPK BJE Charlie Ewen
5/2/2019	Bulking	Notes on artifact from 11/7/15 by S. Byrd stated that it was in 15% PEG 400 + 0.1% Proxel BD. Impregnation started at VOA in 15% PEG 400 in RO water (40 L of solution). Decided to forego the Proxel.	VOA 114	KPK BJE

9/19/2019	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.333 nD RO Temperature: 22.9°C Sample: 1.3554 nD Sample Temperature: 22.9°C	VOA 116	KPK BJE
9/19/2019	Desalination	Topped up with RO water	VOA 114	BJE
9/30/2019	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.333 nD RO Temperature: 24.5°C Sample: 1.3519 nD Sample Temperature: 24.6°C	VOA 116	BJE
10/3/2019	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.333 nD RO Temperature: 24.6°C Sample: 1.3515 nD Sample Temperature: 24.6°C	VOA 116	BJE
10/14/2019	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3329 nD RO Temperature: 23.3°C Sample: 1.3517 nD Sample Temperature: 23.3°C	VOA 116	BJE
10/22/2019	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3330 nD RO Temperature: 23.0°C Sample: 1.3524 nD Sample Temperature: 23.0°C	VOA 116	BJE
10/31/2019	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3331 nD RO Temperature: 23.3°C Sample: 1.3526 nD Sample Temperature: 23.4°C	VOA 116	BJE
11/4/2019	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3329 nD RO Temperature: 19.4°C Sample: 1.3529 nD Sample Temperature: 19.5°C	VOA 116	BJE
11/7/2019	Impregnation	Nominal PEG 400 Content: 20% v/v	VOA 114	KPK BJE

		Removed 2.4L of solution; added 2.4L of PEG 400		
11/12/2019	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3330 nD RO Temperature: 19.3°C Sample: 1.3591 nD Sample Temperature: 19.5°C	VOA 116	BJE
11/18/2019	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3330 nD RO Temperature: 22.9°C Sample: 1.3602 nD Sample Temperature: 22.9°C	VOA 116	BJE
11/18/2019	Desalination	Topped up with RO water	VOA 114	BJE
11/19/2019	Photographed	Pre-treatment photo both sides on a black background with a 10 cm scale and a 4 ft scale	VOA 110	EBC BJE
11/26/2019	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3329 nD RO Temperature: 23.2°C Sample: 1.3601 nD Sample Temperature: 23.3°C	VOA 116	BJE
12/3/2019	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3330 nD RO Temperature: 22.8°C Sample: 1.3601 nD Sample Temperature: 22.8°C	VOA 116	BJE
1/3/2020	Bulking	Nominal PEG 400 Content: 25% v/v Removed 2.5L of solution; added 2.5L of PEG 400	VOA 114	EBC
1/23/2020	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3330 nD RO Temperature: 23.3°C Sample: 1.3686 nD Sample Temperature: 23.2°C	VOA 116	BJE
1/30/2020	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3331 nD RO Temperature: 24.5°C	VOA 116	BJE

		Sample: 1.3691 nD Sample Temperature: 24.3°C		
2/10/2020	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3331 nD RO Temperature: 25.4°C Sample: 1.3687 nD Sample Temperature: 25.3°C	VOA 116	BJE
2/13/2020	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3331 nD RO Temperature: 26.8°C Sample: 1.3688 nD Sample Temperature: 26.6°C	VOA 116	BJE
2/20/2020	Bulking	Nominal PEG 400 Content: 25% v/v Nominal PEG 4000 Content: 5% v/v Removed 2.5L of solution; added 2.0kg of PEG 4000 and 0.6L of PEG 400	VOA 114	BJE
2/21/2020	Desalination	Topped up with RO water	VOA 114	BJE
2/27/2020	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3332 nD RO Temperature: 25.2°C Sample: 1.3753 nD Sample Temperature: 25.1°C	VOA 116	BJE
3/5/2020	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3330 nD RO Temperature: 24.6°C Sample: 1.3738 nD Sample Temperature: 24.5°C	VOA 116	BJE
3/19/2020	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3331 nD RO Temperature: 26.1°C Sample: 1.3742 nD Sample Temperature: 24.5°C	VOA 116	EBC

3/26/2020	Examination/Analysis	PEG monitoring using refractometer. RO Control: 1.3329 nD RO Temperature: 21.3°C Sample: 1.3728 nD Sample Temperature: 23.6°C	VOA 117	EBC