UNDERSTANDING “THE FOG OF WAR”: ARCHAEOLOGICAL, HISTORICAL, AND GEOSPATIAL MODELING OF NORTH CAROLINA’S TORPEDO JUNCTION

By

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This thesis studies the German U-boat attacks on Allied merchant ships off the coast of North Carolina as part of the Battle of the Atlantic in the spring of 1942. Position fixing methods were not precise during the mid-20th century, and confusion during the attacks often led to misreported locations. This study seeks to reconstruct successful attacks by utilizing personal accounts, weather reports, merchant and U-boat routing information, U-boat and Allied attack and counter-attack methods, as well as the location of the wrecked vessel. By reconstructing and plotting the attack from beginning to end, imprecise and false coordinates can be interpreted in comparison to a vessel’s true location, and a pattern may appear between the attacks. Once this pattern is understood, the “fog of war,” or the uncertainty of battle, may be lifted, and the true sequence of events will be understood for vessels in this study and potentially for those that have yet to be found elsewhere

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Introduction

The Battle of the Atlantic was the longest engagement of the Second World War. The battle began on 3 September 1939 when the United Kingdom (UK) and France declared war on Germany two days after Germany’s invasion of Poland. That day, the order was sent out to Germany’s U-boats, which were already at sea, to begin targeting British vessels. The battle lasted until the day of Germany’s surrender on 7 May 1945 (Hessler 1989:6-9; Milner 1990:45; Elphick 1999:11). Germany’s U-boat force was under the direction of Karl Doenitz, promoted to Vizeadmeral on 19 September 1939, and who led Germany’s U-boats for the rest of the war (Hessler 1989:9; Hickam 1989:1).

The Battle of the Atlantic was not a typical Mahanian-style naval battle, but rather a *guerre de course* (a war on seaborne commerce) for control of the shipping lanes supplying Europe. This struggle resulted in naval actions that encompassed an enormous battlespace spanning the entirety of the northern and central Atlantic Ocean (Figure 1). The strategy of the German Navy, as in the First World War, was not to engage in open battle, but to destroy cargo ships, tankers, and troop transports that were sent to aid the Allied war effort, in particular those sent to assist the UK (Milner 1990:47; Elphick 1999:19). The UK were islands that lacked the supplies to carry out a prolonged engagement against Hitler’s war machine and relied on shipments from Canada and the United States of America (USA) for wartime necessities such as aircraft fuel, munitions, and food.

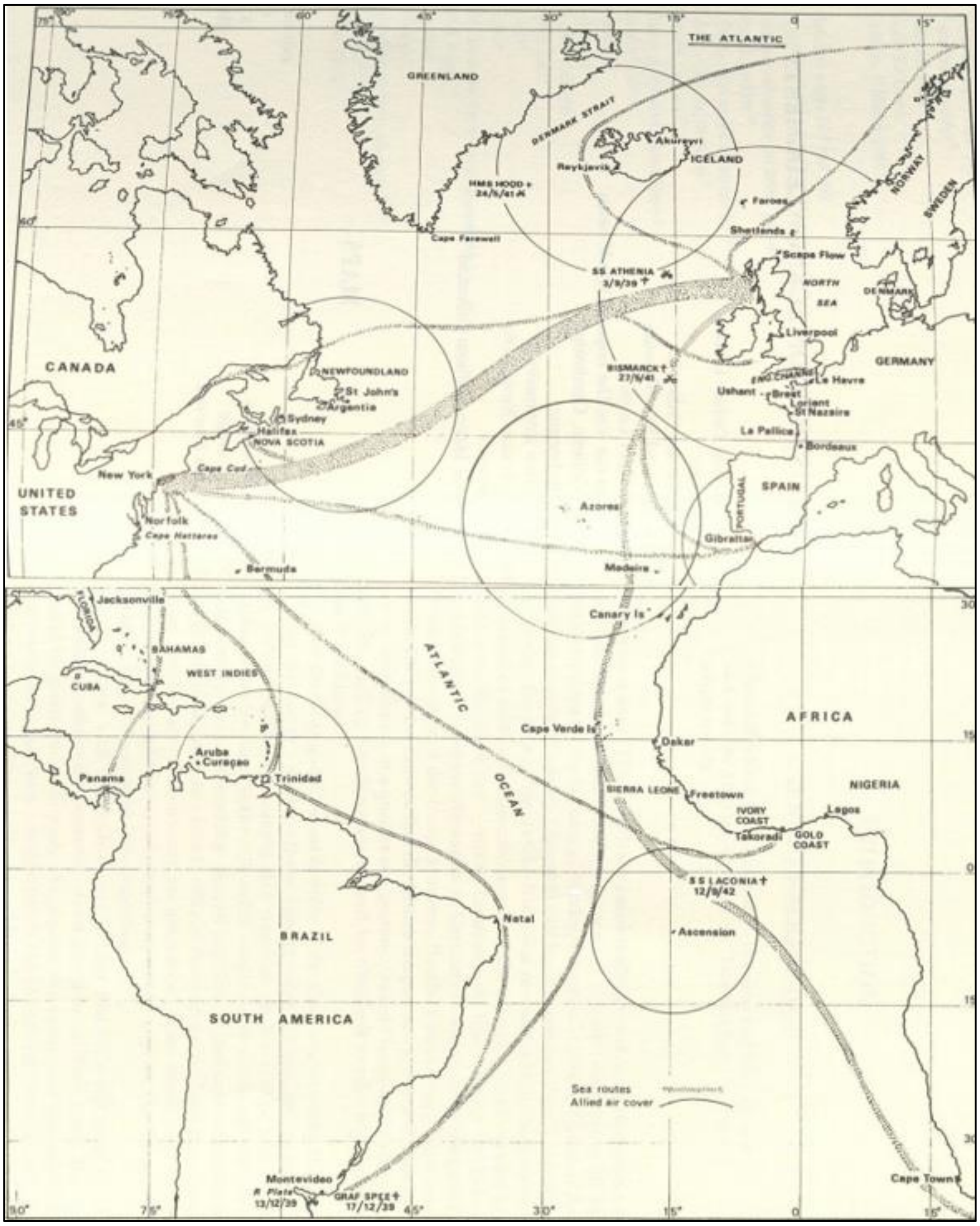


Figure 1: Map of the Battle of the Atlantic displaying sea routes and Allied air cover (Van der Vat 1988:xviii-xix).

U-boats were very effective weapons against merchant cargo vessels because they could hide underwater before launching an ambush, however, they are vulnerable when engaged in surface attack. To exploit this weakness, the British reintroduced the use of convoys.

The convoy system was used successfully against U-boats during the First World War, though not without some trial and error. The initial tactic used against U-boats was to send naval vessels to hunt them. This tactic failed because the ocean is vast, and U-boats can submerge and disappear to avoid detection (Van der Vat 1988:8). Allied commanders then realized that the best tactic against U-boats was to utilize armed vessels in a convoy. To attack the convoy, the U-boat had to expose itself, which allowed the escorting warships to sink it. At the start of the Second World War, however, there were few ships that were able to serve as escorts, and the U-boats experienced initial successes. These did not last long, as British warships began to utilize radar, learned to attack at night, coordinated with aircraft, and provided additional convoy protection. Further, despite Doenitz's persistent appeal to build more U-boats, a general lack in numbers hindered their potential (Hickam 1989:3). War materials continued to arrive in British shipyards from its allies, such as the USA.

Adolf Hitler wanted to keep the USA neutral and was very strict on his policies regarding U.S. vessels. The Japanese attack on Pearl Harbor on 7 December 1941 and the subsequent declaration of war on Japan forced Hitler's hand, and on 11 December 1941, Germany declared war on the USA. This was a relief to Doenitz and his U-boat command as it lifted the restrictions placed on U-boats when attacking (Offley 2014:49-50). After the declaration of war, Doenitz planned for an attack on the unprotected shipping lanes along the U.S. Atlantic coastline that supplied the British war effort.

The operation to the U.S. east coast was called *Paukenschlag* or "Drumbeat" (it should be noted that Homer Hickam refers to *Paukenschlag* as "Drumroll" in his book *Torpedo Junction: 1942*, thus, two translations can be seen in the historical sources). Doenitz called for 12 U-boats for this operation, and the first departed on 18 December 1941 for U.S. waters. (Hickam 1989:1-

2; Offley 2014:44-58). The attacks on U.S. shipping in January proved effective, but even Doenitz could not have predicted the amount of success during the ensuing months (Offley 2014:126-127).

U-boats were particularly successful when patrolling along the U.S. east coast between Cape Hatteras and Cape Lookout. Here, the continental shelf is closer to shore, which offered deep water where U-boats could hide. Additionally, the collision of the warm waters of the Gulf Stream with colder northern waters created a water column that varied in temperature and salinity, which interfered with sonar detection from pursuing destroyers (Bright 2012:128). The high number of unescorted ships and the inefficiency of antisubmarine measures in these waters created a U-boat haven, and attacks were so successful that this section of ocean became known as “Torpedo Junction” (Hickam 1989:22). Further, the U.S. government denied the threat posed by the U-boat in the first half of 1942 and refused to issue blackout orders for cities on the eastern seaboard. The city lights along the coast illuminated the ships travelling parallel to shore at night when U-boats preferred to hunt (Hickam 1989:8-9). As a result, U-boats decimated Allied shipping during the first half of 1942. It was not until an increase in antisubmarine forces from both ships and radar-equipped aircraft, as well as the gradual adoption of the convoy system by the United States (U.S.) Navy in the late spring of 1942 that U-boat success in U.S. waters decreased. This caused Doenitz to redeploy them elsewhere (Offley 2014:240-241).

The Battle of the Atlantic spanned a vast territory and took place over the entire course of the war. Due to the enormity of the battle, the entire battlespace would be too large to examine in a single project. This study will focus on the region off the coast of North Carolina during the first half of 1942. The reason for the selected time and location is due to the wealth of data from that time and region. Much of the data was already gathered by a team of researchers led by the

National Oceanic and Atmospheric Administration (NOAA) Monitor National Marine Sanctuary (MNMS) and forms the basis for this project. The coordinates of shipwrecks identified by NOAA often vary from the coordinates given in historical documents, such as eyewitness accounts or records from vessel logs. As of January 1942, U.S. ships were not equipped with efficient radar systems (Blair 1996:476). Also, many merchant vessels contracted from outside the USA relied on dead reckoning. Thus, while the error in position may be due in large part to position-fixing limitations of the time, these deviations are possible clues to the chaos and uncertainty that represent the concept of the fog of war, or confusion of battle. This has been noted in other studies (McCartney 2015, 2016, 2017).

Innes McCartney has published on the Battle of Jutland (McCartney 2016, 2017) along with an analysis of U-boats from both World Wars (McCartney 2015), which provides a foundation for this research. His work on locating HMS *Indefatigable* in 2001 is of particular interest to this study (McCartney 2016, 2017). During the battle, *Indefatigabl*e was at the tail end of a column of warships before succumbing to fire when poor charge handling caused the vessel to violently explode. *Indefatigable*'s location was not accurately recorded because it was rapidly destroyed, and key witnesses did not have good visibility. McCartney used the most reliable witness testimonies and historical research, such as the vessel's speed and distance behind the column, as well as the location of the German attack, to better determine the probable location of the wreck.

McCartney's (2015) work on German U-boat wrecks in the English Channel is another example of comparing wreck locations to the historical sources. First, a study area was developed that contained known historical records, reasonable diving depths, and "well covered hydrophonic data" (McCartney 2015:1-2). The known U-boat wrecks were then compared to the historical databases from both World Wars, while unknown wrecks were identified in person. McCartney's final analysis mentions the potential for furthering this research into other study areas. The study area presented here is the expanse of the Atlantic Ocean off North Carolina's Outer Banks during the Second World War.

The study area has already been examined as part of a graduate student thesis research project conducted at East Carolina University (ECU). This includes John Wagner's (2010) thesis "Waves of Carnage: A Historical, Archaeological and Geographical Study of the Battle of the Atlantic in North Carolina Waters" and John Bright's (2012) thesis "The Last Ambush: An Adapted Battlefield Analysis of the U-576 Attack upon Allied Convoy KS-520 off Cape Hatteras During the Second World War." Both studies examined the significance of the Battle of the Atlantic off North Carolina while utilizing cartographic tools and historical records. Wagner's thesis accessed recorded attacks to define a geographic area representing the Battle of the Atlantic in North Carolina waters, while Bright's study examined primary accounts, routing instructions, and battlefield analysis methods in a search for the archaeological remains of U-576 and its target. This research relied heavily on both studies and builds on their foundations to deepen our understanding of the behavioral factors that most contribute to the fog of war.

Research Questions

NOAA has spearheaded the effort to document over 40 vessels lost during the Second World War in North Carolina waters. This research utilizes data from 27 vessels, listed in Table 1, that were sunk by U-boats and four U-boats that were sunk by Allied craft and have been studied by NOAA. The four U-boats analyzed in this study are U-85, U-701, U-352, and U-576.

All vessels within the study were sunk in North Carolina waters between 19 January and 15 July 1942. The other vessels assessed by NOAA were excluded due to their non-combatant loss status (e.g., collision, mine, etc.). Furthermore, this research examines patterns in the circumstances of loss and the accuracy of the reported positions.

Table 1: List of merchant vessels located by NOAA utilized in this study. Data regarding dates, U-boats, and U-boat captains was collected by Hickam (1989).

Vessel Name	**Sinking Date**	**U-Boat**	**U-Boat Commander**
Ario	3/15/1942	U-158	Rostin
Ashkhabad	4/30/1942	U-402	Forstner
Atlas	4/9/1942	U-552	Topp
Australia	3/16/1942	U-332	Liebe
Bedfordshire	5/12/1942	U-558	Krech
Bluefields	7/15/1942	U-576	Heinicke
British Splendour	4/7/1942	U-552	Topp
Buarque	4/5/1942	U-552	Topp
Byron T. Benson	2/15/1942	U-432	Schultze
Caribsea	3/11/1942	U-158	Rostin
City of Atlanta	1/19/1942	U-123	Hardegen
Dixie Arrow	3/26/1942	U-71	Flachsenberg
E.M. Clark	3/18/1942	U-124	Mohr
Empire Gem	1/24/1942	U-66	Zapp
Equipoise	3/27/1942	U160	Lassen
Esso Nashville	3/21/1942	U-124	Mohr
Kassandra Louloudis	3/18/1942	U-124	Mohr
Lancing	4/7/1942	U-552	Topp
Liberator	3/19/1942	U-332	Liebe
Malchace	4/9/1942	U-160	Lassen
Manuela	6/25/1942	U-404	Bulow
Marore	2/27/1942	U-432	Schultze
Norvana	1/19/1942	U-123	Hardegen
Papoose	3/18/1942	U-124	Mohr
San Delfino	4/10/1942	U-203	Mutzelburg
Tamaulipas	4/10/1942	U-552	Topp
W.E. Hutton	3/19/1942	U-124	Mohr

The goal of this research was to create several datasets within a Geographic Information System (GIS). Convex hulls represent the total area of ocean created by varying location reports, and centroids represent the averages of these reports to determine their accuracy. The error in this accuracy is represented by the distance between the centroid and the location of the actual wreck, and will be understood by analyzing various factors, including weather, time of the attack, duration of the attack, bathymetry, and vessels involved. The chaos of a naval battle resulted in mixed reports of coordinates and actions. The patterns in accuracy compared to the circumstances of loss create an explanatory model that can be applied to the targeted wrecks of the Battle of the Atlantic. Finally, the explanatory model has the potential to be utilized as a predictive model that can be applied to other naval engagements of the Second World War.

Primary Research Question:

- Given the uncertainty created during naval battles, what knowledge can be attained by reconstructing the battlefield circumstances from the known wrecks, reported wrecks, and the scene of battle from the Battle of the Atlantic off the shores of North Carolina? How can this knowledge assist us in reconstructing other Second World War naval battles or locating shipwrecks lost to similar methods of war from the period?

Secondary Research Questions:

- How does the time of day affect the accuracy of reported positions? How does weather, bathymetry, currents, distance from shore, or wave activity affect these positions?
- How does the number of vessels present at the time of the attack (such as those in a convoy) and proximity to shore-based military installations affect reported positions?

- What was the difference in position accuracy between U-boat captains, U-boat types, armed and unarmed merchant vessels, aircraft, convoy vessels, or naval/Coast Guard vessels?
- How does the duration of an attack affect the accuracy of reported positions?
- What similarities can be examined between reported attacks with accurate positions versus inaccurate positions?

This research culminates in a nuanced explanatory model of naval actions that occurred during the Battle of the Atlantic off North Carolina's coastline during the Second World War. There is also the potential that this knowledge may assist scholars when reconstructing other Second World War naval battles, or locating shipwrecks lost during naval actions of other periods.

Thesis Structure

This study is divided into five core chapters, aside from this introduction and a conclusion. Chapter 2, "Generals and Battles: Exploring Theoretical Applications of Generalist and Battlefield Archaeology," focuses on theory and defines the two primary theoretical paradigms this study follows: generalist and battlefield archaeology, with an emphasis on the latter. Battlefield archaeology is further broken down into several popular strategies that archaeologists use to examine battlefields, with examples of their applications as well as their limitations. Chapter 3, "Step by Step: Methodology in Historical/Archaeological Research and the Creation of a GIS Database," outlines the methods for researching the historical narrative, examining the sources used for this research, and processing the data into a GIS. In addition, the chapter describes the basic setup for the comparison of the historic coordinates to the true coordinates using convex hulls, centroids, and other GIS functions. The chapter concludes with the method of selecting the historical characteristics of each vessel that were used in the analysis.

Chapter 4, "The Shepherds, the Sheep, and the Wolves: Technological and Tactical Adaptations of Torpedo Junction's Combatants," is a historical review of North Carolina's Second World War combatants, their technology, tactics, and position-fixing capabilities. These are broken down into Allied warships, aircraft, and merchant vessels. The lighthouse fixtures of Torpedo Junction and Allied efforts to protect the merchant vessels are also described. Finally, the chapter details the history, technology, and tactics of U-boats. Chapter 5, "Distances and Directions: Geospatial Analysis of the Vessels of Torpedo Junction," displays the mapping process featured in Chapter 3 for all the vessels in this study which had multiple coordinates to be analyzed. These maps highlight the differences in distance and direction of the vessel wrecks and their respective historical positions.

Chapter 6, "Lifting the Fog of War: Geostatistical Analysis of the Vessels of Torpedo Junction," extracts statistical data from the geospatial analysis, quantifies qualitative data, and utilizes this data to examine the role of the fog of war in the North Carolina battlespace. Finally, the conclusion provides a summation of the results for this study and details the potential for future research, since there were several limitations that have potential to be mitigated moving forward. This thesis examines several vessels, poses several research questions, and spans a large geographical space over an extent of time spanning several months. To efficiently study these vessels, in particular the locations of the wrecks as they relate to one another as well as to the battlefield known as Torpedo Junction, this research used several theoretical paradigms, which are detailed in the subsequent chapter.

CHAPTER 2: GENERALS AND BATTLES: EXPLORING THE THEORETICAL APPLICATIONS OF GENERALIST AND BATTLEFIELD ARCHAEOLOGY

Introduction

The basis for this research stems from two perspectives in archaeological thought: generalist shipwreck archaeology and battlefield archaeology. This chapter will outline the basis of these two paradigms, including a description of the terminology and the way each concept was first utilized. Additionally, previous studies conducted in the scope of each theoretical approach are provided as these are important to understand their range and limitations in this study. For this research, elements of both theoretical frameworks are used to give a complete and accurate narrative of each vessel in its final hours in combination with the historical evidence, which will assist in answering the questions posed in the previous chapter.

Generalist archaeology is a processual approach, which views cultures as exerting influence on one another. This framework is defined by creating broad or generalized statements about human behavior through scientific methods, such as understanding societal traits by utilizing data from several archaeological sites (Murphy 1983:69-79; Trigger 2006:314). A generalist archaeological approach is important to understand battlefield archaeology, which can be considered generalist in many ways. Finally, a third concept, that of the use of GIS, will be explained. Although this is less of a theoretical construct, the reasoning behind its application to this study will be outlined, especially as it relates to battlefield archaeology.

Generalist Shipwreck Archaeology

At the School of American Research Advanced Seminars in 1981, Patty Jo Watson (1983:27) described two emphases of research in shipwreck archaeology:

> [A] particular wreck may be perceived as a unique phenomenon and of interest primarily for its intrinsic characteristics, including the information it may offer about more general issues, or a general problem may require seeking out one or more particular wrecks in specific places dating from specific periods. Here the concern is primarily with the information the wreck provides about the general problem.

With that, Watson outlined the concepts of generalist archaeology and historical particularism. Historical particularism views culture as its own unique product and as such does not examine an archaeological site's influence or similarities to other sites (Trigger 2006:219). This stands in opposition to processual approaches, which assert that cultures have influence on one another. Further, generalist archaeology prioritizes asking questions and forming hypotheses prior to site research, whereas historical particularists often do not form hypotheses and justify a site's research based on a cultural connection. Nevertheless, historical particularism is an approach that has led to many well-produced studies on shipwrecks. As Richard Gould (1983a:4) stated, "[Historical particularism] justifies much of the current work in shipwreck archaeology, since shipwrecks are undeniably part of the total body of material studied by historians and historical archaeologists." It should be noted that Gould is not advocating for historical particularism, but is remarking that the artifact catalogues, drawings, and site plans collected from previous works have laid the groundwork for many modern archaeological studies.

The second emphasis described by Watson during this conference was researching a general problem that may encompass multiple wrecks. This was in the early roots of generalist archaeological research, which has shifted towards a more scientific standard to, as Larry

Murphy (1983:69) described, develop “general laws of human behavior through a problem-oriented approach.” As such, generalized research is scientific in nature, and is in contrast to the historical particularistic approach because it attempts to, as Murphy (1983:69-79) argued, create “law-like generalizations of relationships” rather than “describing various elements in a historical event progression.” Murphy (1983:70) continued that “[s]hipwreck archaeologists need to develop and implement broadly conceived research designs asking significant questions of a general nature about human social behavior, or the contribution of shipwrecks to knowledge will only be the generation of knowledge itself.” Although generalists believe that research must be problem-oriented, they also agree that any data recovery must be justifiable prior to excavation, as the excavated portion of a site is permanently destroyed (Watson 1983:31). As such, site selection should be guided by broader, thematic questions that are asked of history and archaeology (Richards 2008:39).

Generalist shipwreck archaeologists also argue that shipwrecks represent a parent culture and can be viewed and studied as artifacts of that culture (Murphy 1983:70-71,83). Thus, general patterns analyzed on a shipwreck reflect the patterns in the parent culture. Processual theorists view culture, or cultural systems, as evolving from a social point of view in which systems interact with one another (Trigger 2006:314). Therefore, a shipwreck may be viewed as an artifact representing the ideals and norms of a culture and can be compared to other shipwrecks of that and other cultures in a spatial and temporal way to understand cultural changes. This perspective also stands in opposition to a historical particularistic viewpoint, which views that a shipwreck stands alone as a representation of a specific culture, described as an isolated time capsule (Richards 2008:44-45). Generalized research is more anthropologically seated, and questions can be asked from an anthropological standpoint, such as how humans reacted under stress while at sea (Lenihan 1983:52; Watson 1983:32).

While there may be elements of both historical particularism and generalism inherently present in all research designs, one may be more heavily relied upon within a study (Watson 1983:31). Gould (1983a:21-22) believed that future archaeological work should emphasize problem-based research designs and the ability to “extend the results from a particular case to the realm of general propositions.” Thus, the only limitations to the study of shipwrecks are the research questions developed by the investigators (Murphy 1983:67-70). The research questions posed for the present study encompass human behavior on vessels during war.

While the historic behavior of humans on a ship engaged in battle cannot be observed in real time, the wrecks and wreck sites display clues for that behavior (Gould 1983b:105). In his comparative survey of Spanish Armada wrecks and aircraft wreckage from the Second World War, Gould (1983b:140) also asserts that archaeologists should be able to produce a narrative that led to the wrecking event, stating, “archaeology, by adopting a circumstantial line of reasoning based upon the analysis of materials and material remains in relation to the logistics of war, can offer general statements about human behavior under the stresses of combat.” Further, Gould (1983b:142) remarks that “it is this search for general, circumstantial relationships between materials and human behavior as a means of predicting and explaining present as well as past events that should characterize archaeology’s anthropological approach to the wreckage of war.” Gould is noting that by studying the wreck assemblages, general statements can be made as to the conduct of human behavior during battle. The archaeological remains display a historical narrative that researchers can interpret in the present, which leads to an explanation for human behavior and action in the past. This study observes many wrecks covering a large span of water. Thus, this research uses a generalist perspective to describe a relationship between the pattern of wrecks and human behavior.

Innes McCartney produced one such generalist study. McCartney's work on German U-boats in waters around the UK attempted to determine how the archaeology of the wrecks can shed light on the sequence of events beyond the recorded historical text. McCartney showed that 78% of the shipwrecks within UK territorial waters are from the period 1914-1950, the time frame spanning both World Wars. These wrecks are linked to the broader battlefield in which the Allies fought two World Wars against the German U-boats. This represents a generalist approach, where these wrecks are all related to one another via larger cultural movements. Further, the archaeology of each wreck can be compared to the sinking reports, and conclusions can be drawn from a spatial sense (McCartney 2015:1-3).

Moving to waters closer to home, East Carolina University graduate student John Wagner conducted another generalist study within North Carolina waters in 2010. Wagner's study plotted the locations of wrecks associated with U-boat attacks during the Second World War (including events that did not necessarily result in a wreck) to define an area representing the extent of the battle in North Carolina (Figure 2) within the Eastern Sea Frontier (ESF). Similarly, the wrecks are viewed as artifacts that represent several parent cultures (ships of different nationalities) engaged in warfare and are therefore interacting with one another. The present study applies this perspective in a similar fashion to Wagner's (2010:8) approach whereby, "making broad observations about the battle and the events occurring during it, the underlying social and behavioral factors of the battle can be analyzed, providing far more information about the engagement in North Carolina waters than a site-specific survey of one wartime casualty ever could."

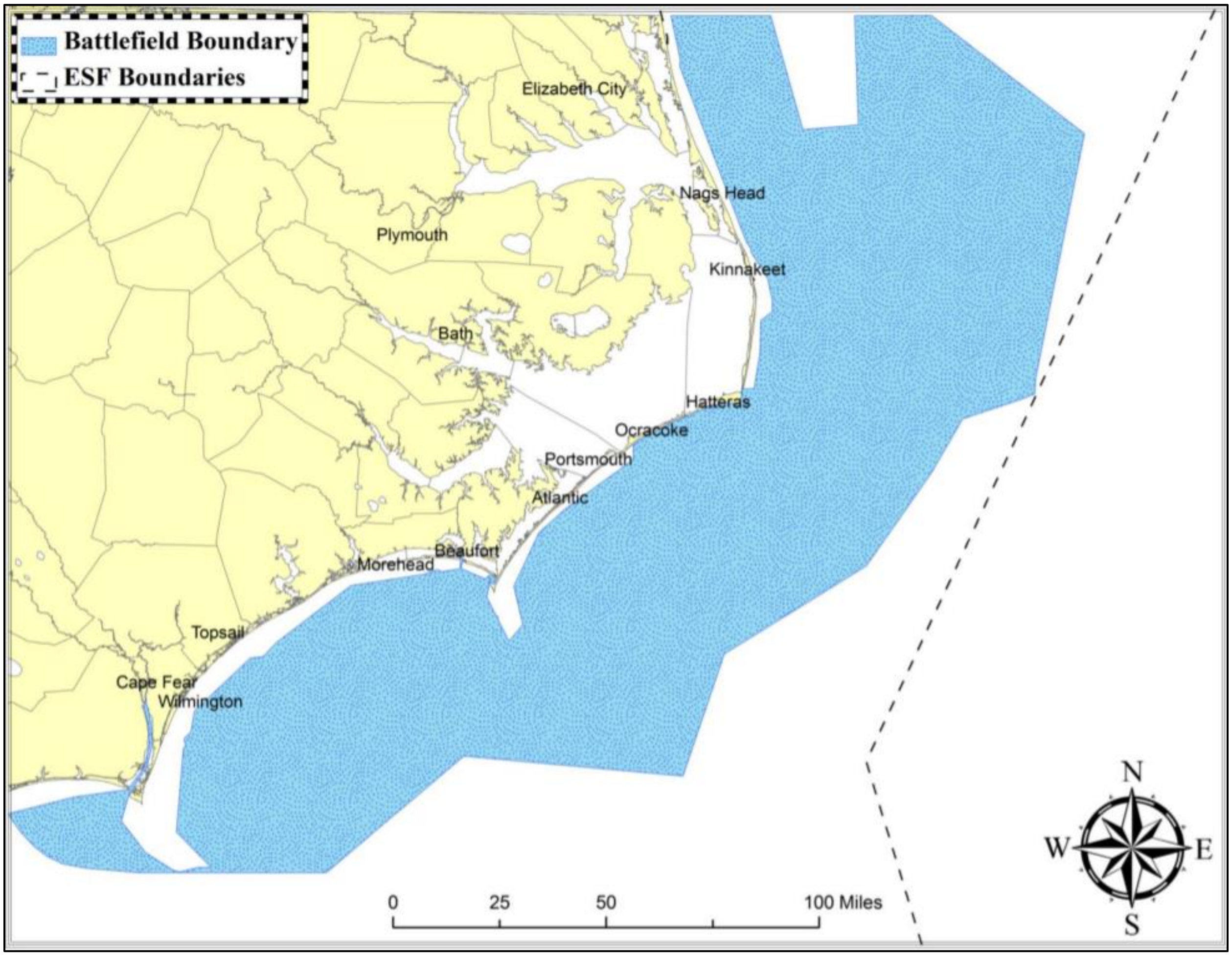


Figure 2: Representation of the extent of the Second World War's Battle of the Atlantic in North Carolina. Map created by John Wagner (Wagner 2010:187).

For this study, another aspect of cultural heritage in the generalist theoretical framework is that of intangible heritage including shipping routes and reported coordinates (Wagner 2010:9). Such research incorporates knowledge from shipping routes and reported coordinates into various attack events, as well as the location of the wrecks, and the parent culture of each wreck (i.e., nationality). To answer the proposed research questions, this data is compared, which holds true to the generalist form. The present research uses a generalist approach on a unique aspect of the human condition, that of warfare. As such, battlefield archeology often uses generalist ideas to understand the concept of battle across space and time. This led to the development of a theoretical paradigm for studying battlefields.

Battlefield Theory

Battlefield archaeology is a relatively new sub-discipline of archaeology that has evolved over the past four decades (Scott et al. 2007:429). Battlefield archaeologists study the site of a battlefield, ranging from ancient to modern periods. Artifacts found are often pieces of armaments, equipment, or fortifications. War is one of the most basic of human endeavors, and battlefields are the theaters in which humans engage in warfare (Conlin and Russell 2010:40). By observing the pattern of artifacts, or signatures, on a battlefield, researchers can make deductions concerning specific aspects of the battle, such as troop and individual movements. By tracing the movements of troops or individuals, these patterns reveal tactics utilized during the battle from opposing sides as well as the progression of battle (Fox 1993:5; Conlin and Russell 2010:40).

Archaeological data from battlefields can be used in tandem with the historical record. As Scott et al. (2007:429) described, "…the [battlefield] archaeological record is viewed as an independent dataset that can be compared to historical documents, participant accounts, maps, and other sources to build a more complete and accurate picture of an event or develop new views of strategy and tactics…" The historical documents and participant accounts are fused to trace events through the space and time of the battle. The narrative that the archaeological record produces can either support or contradict the written records. Further, archaeology can illuminate a battle poorly recorded by historical narratives (Freeman 2010:149).

Battles and the actions of the military units therein are not random; rather, they are planned and executed with the strategic aim and goal of the overall campaign in mind. Thus, battlefield archaeologists utilize a framework related to modern battle tactics to understand the layout of the battlefield. Further, by understanding the strategic aim of the battle's campaign, the battlefield's importance can be understood (Parker 2015:13). Strategy and tactics are two different concepts that are directly linked, as Lawrence Babits (2011:5) described: "[s]trategy is the overview and planning for campaigns and wars… Tactics is the term used for… the application of the plan, in conjunction with the available weapons and troops." The development of a strategy led to the tactics that would see the strategy through. To understand the development of the strategies and tactics that occupied a battlefield, archaeologists utilize several analytical tools. Many popular tools are well suited to the battlefields for which they were designed but fall short in encompassing all battlefields. These include the application of the military acronyms of METT-T and KOCOA. The latter, designated by the military as OCKOA, is used to analyze the landscape of the battle (Parker 2015:13-16). The American Battlefield Protection Program (ABPP) for years emphasized analysis of KOCOA, stating that "[t]he battlefield surveyor must also learn to view the terrain through the soldier's eyes" (Lowe 2016:7). Each tool should be analyzed fully with an understanding of how each is applied to a naval battle of the 20th century.

METT-T and KOCOA

Many battlefield archaeologists utilize METT-T as a method to analyze the archaeological record (Bright 2012; Simonds 2014; Babits 2015; Parker 2015; McKinnon and

Carrell 2020). The US military developed this tool for commanders to utilize for strategic planning, and it has been adapted by archaeologists for studying battlefields. The acronym represents Mission, Enemy, Troops, Terrain, which is further broken down into the acronym KOCOA, and finally Time. Table 2 gives a description of each.

Table 2: Definition of each component of METT-T, as described by Babits (2015:75-76).

Mission	**Enemy**	**Terrain**	**Troops**	**Time**
The plan, goal, or objective assigned to a military unit by command and the related tasks that must be accomplished.	The opposing military force, including their commanders, strength, equipment, and tactics.	Further broken down into KOCOA.	Friendly forces with combat power, including their commanders, strength, and equipment.	The amount of time available to complete the mission.

METT-T was later updated to METT-TC to include Civilian Considerations. Civilian considerations, or civil considerations, was a concept added to the METT-T acronym by the military in 2001 and included by battlefield archaeologists when examining battles that occurred in mostly urban settings (Fisher 2002:5; Brown 2007:20). This addresses the relationship between the civilian populations and military forces, such as collateral damage and evacuations (McKinnon et al. 2020:11). It should be noted that Babits does not include this in his analysis. The KOCOA acronym breaks down the concept of terrain into five major concepts to understand the way events play out during a battle and assist in the reconstruction of events. KOCOA stands for Key Terrain, Obstacles, Cover and Concealment, Observation and Fields of Fire, and Avenues of Approach. Table 3 gives a description of each. KOCOA works well for the terrestrial battlefields for which it was produced, however, this is not the case for naval battlefields and especially battles that occur over three dimensions: in the air, on the surface, and under water.

The theoretical application of KOCOA to naval battlefields is problematic. Babits' 2011 study of six battlefields from the Revolutionary War and the War of 1812 attempted to utilize both approaches (METT-T and KOCOA). The drawback to this study is that Babits' study emphasized the military history of the engagements rather than understanding the human factor, or the behaviors and the reasons for those behaviors during the battles (Simonds 2014:17-18; Parker 2015:20).

Table 3: Definition of each component of KOCOA, as described by Babits (2015:75-76).

Key Terrain	**Obstacles**	**Cover and Concealment**	**Observation and Fields of Fire**	**Avenues of Approach**
Terrain that is advantageous for one side to control.	Terrain that is restrictive or disruptive to troop movement.	Cover is used for protection from enemy fire, Concealment is used to evade enemy observation.	Observation is that which can be seen from a given position, Fields of Fire are areas that can be affected by weaponry from either side.	Routes that can be used to attack an opponent.

Battlefield studies have traditionally applied KOCOA in contexts from the American Revolutionary and Civil Wars, where engagements were brief and lasted from a few hours to a few days with large amounts of hand-to-hand fighting along with close-range artillery (Parker 2015:22). Thus, these previous studies have displayed that the theoretical applications of KOCOA are well suited to terrestrial warfare and can be applied to naval warfare up through the Civil War with some adaption. This is shown by Babits' (2015) study on the Battle of the Barges during the Revolutionary War, where surface naval battles often occurred within sight of shore. However, this is not true in all cases, and each concept of KOCOA needs to be heavily modified before it can be successfully applied to battles that include three-dimensional long-range factors such as aircraft and submarines (Parker 2015:22).

John Bright conducted a study in 2012 that involved modifying KOCOA while in search of the U-576 and the merchant vessel *Bluefields*, both of whom sank as a result of U-576's attack on convoy KS-520, which consisted of 19 merchant vessels and 5 escorting warships. U-576 ambushed the southbound convoy and successfully sank *Bluefields* and damaged two other vessels but was quickly sunk in turn by escort aircraft and an armed merchant freighter (Bright 2012:95-104). This attack, while utilizing 20th century technology, was nevertheless an isolated event, which happened in a matter of minutes at a specific location. This further highlights the problems with the theoretical concept, including its application to longer battles (spanning weeks or months) over a larger expanse of geographical space. McKinnon and Carrell's (2011) study of amphibious operations at the Battle of Saipan as well as Roth and McKinnon's (2018) analysis of aerial operations at the Battle of Midway during the Second World War noted limitations with KOCOA, adding that although it was successfully used to interpret terrain features encountered during amphibious landings or air raids (such as air defense batteries), KOCOA may be ill-suited in recording submerged battlefields. Additionally, both aerial and naval KOCOA attributes share similar parameters that are often situational, such as weather, time of day, and flight ceiling (Roth and McKinnon 2018:182-183; McKinnon et al. 2020:11). For these reasons, this study will not implement the KOCOA framework.

It is interesting to note that the location of the attack on KS-520 was lost for 70 years, as the coordinates that were recorded by two of the five escort vessels, the coordinates reported by the aircraft pilots, and the coordinates noted in the administrative correspondences after the attack, spanned an area of ocean nearly 230 square miles large. This may have been in part due to poor position-fixing methods of the mid-20th century, which resulted in large spatial inaccuracies (Broadwater 2010:179; Bright 2012:56). However, through critical evaluation of the reported coordinates and historical accounts, Bright created a grid pattern using a numerical system of probability to find the wrecks of *Bluefields* and U-576. According to Nathan Richards, both vessels were ultimately found in an area of high probability (Nathan Richards 2019, pers. comm.). Another reason for the lack of consistency in reported coordinates and the inconsistent accounts of many battles may be attributed to a concept known as the "fog of war," which should be analyzed to understand the reason that these inconsistencies are present.

Fog of War

The final concept described for this study and utilized by battlefield archaeologists, as well as military historians, is an effect known as the fog of war. The concept was first alluded to by Carl von Clausewitz's *On War*, although von Clausewitz does not use the term outright, he does imply this by writing, "[w]ar is the province of uncertainty; three-fourths of the things on which action in war is based lie hidden in the fog of greater or less uncertainty" (von Clausewitz 1943:32; Kiesling 2001:86). Clausewitz's original work was published in 1832, and the first translated version, published in 1873, used the term "cloud" in place of "fog" (von Clausewitz 1873:25). This may have been a mistranslation on the part of Colonel J.J. Graham, as Jolles' edition (1943) is considered to be closer to von Clausewitz's work. Lieutenant Colonel Sir Lonsdale Augustus Hale, military correspondent for *The Times*, first used the phrase in full at the end of the 19th century (Hale 1904:30-31; Foss 2018). Philip Freeman (2010:149) describes the phrase as "an axiom that explains the confusion that goes with a military engagement, where combat chaos frequently leads to confusing, if not contradictory, recollections." This confusion causes both soldiers and commanders to receive misinformation during battle which often leads to falsely recorded details (Hale 1904:30-31). Archaeological evidence has the potential to correct these falsehoods in both terrestrial and naval battles.

An example of naval data being recorded in error was the final speed and resting location of the warships HMS *Indefatigable* and HMS *Queen Mary* which were witnessed as being destroyed during the Battle of Jutland in 1916 (McCartney 2017:320). HMS *Indefatigable* (Figure 3) was not located until 2001, despite historical narratives recounting its final moments. The warship was the last vessel in a line of battlecruisers that engaged with an opposing German line. Its position as the rear vessel meant that its destruction had less witnesses that could contribute to the historical record. The most detailed account comes from the next vessel forward, as does a photograph of HMS *Indefatigable*'s final moments. Interestingly, the shipwreck was broken in two, the stern resting 500 meters from the rest of the vessel. This event was not directly witnessed by observers and thus not recorded in the historical account, although witnesses did mention the sound of a second explosion as the vessel sank. McCartney's historical analysis located several primary witnesses who recorded the events were not in optimal positions to fully observe the sinking (McCartney 2016:32-38, 2017:322).

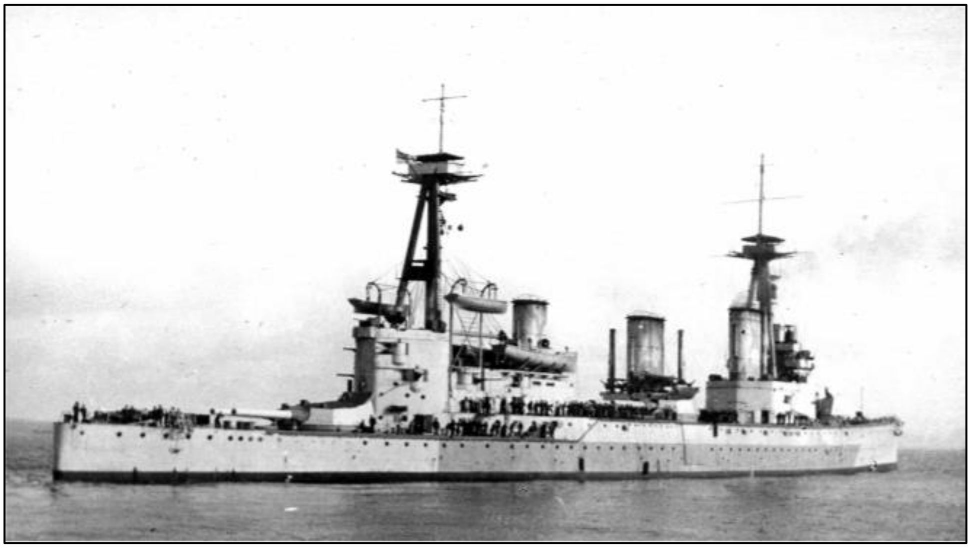


Figure 3: HMS *Indefatigable* (McCartney 2017:319).

Another issue is the speed of the vessel during the battle, as the recorded speed of HMS *Indefatigable* does not align with its located location (McCartney 2017:320). The reason for this has not yet been located, although it does pose further research questions and displays that the inaccurate recording of the vessel's speed during battle (potentially due to the fog of war) created discrepancies in locating the wreck (McCartney 2017:325). Additionally, despite more witnesses for the destruction of HMS *Queen Mary*, regarded as the German Navy's greatest single achievement during the First World War, differences in the narrative still occurred (McCartney 2016:49). These inaccuracies in the primary accounts demonstrate the effect that the fog of war can have on the historical record. Further, McCartney displayed how a careful analysis of the historical record with respect to the fog of war can be compared to the archaeological evidence to fully understand the narrative and progression of events of the battle. Figure 4 shows a corrected map that displays the wrecks where they are currently, compared to their historically recorded positions. This case further emphasizes the fog of war's effect on positional accuracy.

The discrepancies of the fog of war can be understood through a geospatial analysis on a historical map integrated into modern GIS software. Scott and McFeaters (2011:115) describe in their article "The Archaeology of Historic Battlefields: A History and Theoretical Development in Conflict Archaeology":

> [A]nalysis can be applied to via GIS in a variety of ways and through time and space, especially when historic maps or reconstructed landscapes are employed in the analysis. This is an inversion of the common archaeological approach to historical landscapes; instead of attempting to understand the meaning built into a landscape, it is an attempt to decipher the meaning given to a landscape and the events that transpired on that landscape.

Artifacts can then be plotted and incorporated into a GIS database along with other digital data such as aerial imagery and digitized historical maps. The final products can easily be manipulated to examine any relationships between the landscape, archaeological evidence, and historical text (Conlin and Russell 2006:24).

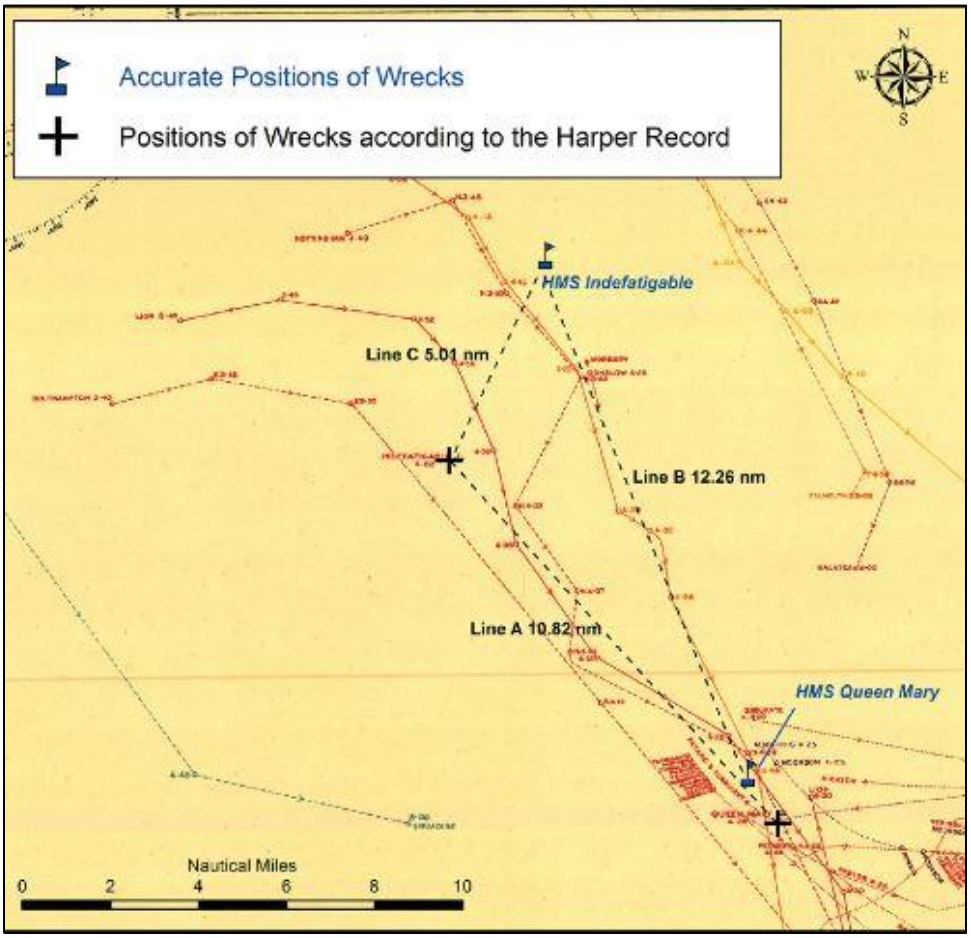


Figure 4: Corrected versions of HMS *Indefatigable* and HMS *Queen Mary* as compared to their historically recorded positions according to Captain Harper of the British Royal Navy's Navigational School, who compiled a record of the events (McCartney 2017:321).

GIS Application

In the past few decades, the introduction and improvement of geospatial technologies has given archaeologists new skills and tools to identify patterns in landscapes, archaeological sites, and even battlefields. GIS has a direct advantage over traditional mapping techniques because the software in GIS allows the user to create several thematic layers in the same map, which allows multiple elements to be edited and modified within a single dataset. Different layers can be combined to create new maps, while analytical functions can be accessed for greater insights into geospatial relationships. It is this level of visualization and spatial linking which allows for greater analytical potential that distinguishes the use of GIS from other related databases (Conolly and Lake 2006:17; Wagner 2010:16-18). GIS can also be used to create a predictive model with the knowledge collected from the archaeological site.

The use of GIS to produce a predictive model began in the western USA in the late 1970s. The theoretical implication is that the known archaeological sites in a region are examined for statistical associations with environmental factors. Once these are understood, various locations on a map are determined to have a higher or lower probability of having a site present based on the presence of those relevant environmental factors. Thus, patterns of various known archaeological sites can be analyzed and used to locate unknown sites that display similar patterns (Kvamme 1995:3). This process can be used on historical sites as well. Data collected from thorough historical research is entered into a GIS database, then the relevant environmental and site information is compared to the positions collected from the historical narratives for the observation of patterns, as is described in the following chapter.

Conclusion

As David Conlin and Matthew Russell (2010:39) state, "[b]attlefield archaeology is fundamentally about looking beyond individual sites and small-scale activity areas to larger contexts.” This statement has a generalist aspect to it. Thus, generalist archaeology and battlefield archaeology easily complement one another, especially when looking at multiple individual attack events that span a large geographic area over several months that are all part of a larger battlefield context. The study utilizes approaches like those displayed by previous archaeologists, such as generalist approaches, which rely on a defined area and specified time frame (Gould 1983b; Wagner 2010; McCartney 2015), and battlefield approaches such as the analysis of the fog of war (McCartney 2017). Ultimately, this thesis did not utilize approaches such as METT-T and a reevaluated KOCOA because of the challenges posed by examining long term operations (McKinnon and Carrell 2011). Though in this case, the large number of combatants and the large (and three-dimensional) battlescape should also be noted as limitations of these frameworks. Nevertheless, McCartney’s notions regarding the fog of war, when examined through advanced GIS analyses, are sufficient to address the questions posed by this study.

CHAPTER 3: STEP BY STEP: METHODOLOGY IN HISTORICAL/ARCHAEOLOGICAL RESEARCH AND THE CREATION OF A GIS DATABASE

Introduction

This research occurred over several major phases. Each major step entailed either extensive research or GIS data entry and visualization. The first step was historical research. This study utilized both primary and secondary sources gathered from the Joyner Library at ECU and digitized government documents available online. The research structure followed a set of themes, which included the background and narrative of the Battle of the Atlantic before the U-boats entered the waters off North Carolina and a narrative of each of the major combatants including German U-boats, Allied anti-submarine aircraft, anti-submarine warships of the U.S. Coast Guard and Navy, armed private vessels, and merchant vessels. Research also entailed collating the various technological and tactical advantages and disadvantages possessed by each combatant, as well as their development (expanded further in Chapter 4).

Historical research was conducted in tandem with archaeological research, which consisted of examining results of previous studies on shipwrecks of the Second World War off North Carolina conducted by NOAA's MNMS, students at East Carolina University, and other researchers. These studies are important as they identify each wreck using the archaeological remains compared to the historical evidence. Several observations can be drawn about each attack from these studies, as the examples will detail. Further, the locations of these sites are then eligible for comparison with positions compiled through historical research, which were compiled into a GIS database.

The GIS database is the input and display of coordinates and other geographic data so that both vector (e.g., points) and raster (e.g., images) data can be projected geospatially. Vector points represent attack positions or base locations, while raster data can represent shipping lanes and bathymetry. By adding these vector points and raster data to the database, relationships and patterns between the shipwrecks, positions recorded by historical sources, and other features that were important to the Battle of the Atlantic at Torpedo Junction can be analyzed. Additionally, tools within GIS are used to determine and display distances and directions between each feature. The distances, directions, and other relationships are important to fully analyze the battlefield and to create models that predict unknown locations. By utilizing the data collected through historical research, the locations of current archaeological sites, and the geospatial relationships between these sites and the historically recorded positions, this research conducts a full analysis of the battlefield off North Carolina.

Initially, as stated in the research questions in Chapter 1, there were several factors hypothesized to have an impact on the positional accuracy of the wreck sites. During the research process, these factors were added to a Microsoft Access database and organized by the wreck they were associated with. This compilation of data allowed for a closer examination of which factors may have greater, lesser, or no impact. After this analysis, several factors were chosen for inclusion in the final data set while others were eliminated. Additionally, many factors were calculated based on quantified qualitative data. The next sections detail the process of conducting historical and archaeological research, building an ArcGIS database, and calculating, selecting, or eliminating factors for use in analysis.

Historical Research

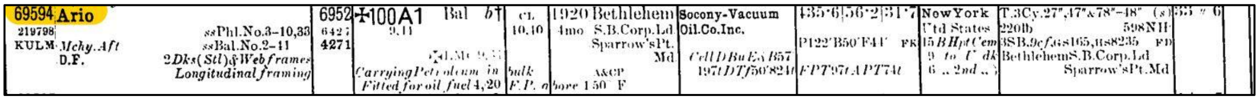
The first data collection step was to acquire historical and archaeological data. This was limited due to the temporary shutdown of many prominent archives such as the U.S. National Archives (primary sources from the U.S. Coast Guard and U.S. Navy). Nevertheless, various available primary and secondary sources were consulted. The most important secondary sources included Dan Van der Vat's (1988) *The Atlantic Campaign: World War II's Great Struggle at Sea,* Homer Hickam's (1989) *Torpedo Junction: U-boat War off America's East Coast, 1942,* Clay Blair's (1996) *Hitler's U-Boat War,* and Ed Offley's (2014) *The Burning Shore: How Hitler's U-Boats Brought World War II to America.* Many of these sources provided information for the historical background and narrative of the war against Hitler's *Kriegsmarine* in the years leading up to the U-boats entering North Carolina waters. The thesis presented here does not work to change the history of Torpedo Junction as told by other prominent historians, such as Hickam and Offley. Rather, it adds to their narratives by presenting factors that occurred during an attack (such as the time of day or proximity to the nearest shoreline) as possibly contributing to a vessel's crew misreporting their final position.

The history of the attacks at Torpedo Junction is further divided into three sections based on the combatants. These include the Allied anti-submarine forces, the merchant vessels, and the German U-boats, each having different sources important to their understanding. The historical research of the Allied anti-submarine forces relied heavily on the *War Diary: Eastern Sea Frontier, January to August 1942*, edited by Robert H. Freeman. The source details the forces made available to Rear Admiral Adolphus Andrews, Commander of the North Atlantic Naval Coastal Frontier, who was tasked with defending the east coast of the USA from Maine to

Florida (Freeman 1987). Additionally, much of the technological capabilities of the Allied Naval and Coast Guard vessels as well as Allied aircraft were found in Bright (2012), which was a major influence and source referenced by this study.

Data on tactics utilized for attacking U-boats were gathered from publications of the Office of Naval Intelligence by Captain Roger Welles, a destroyer captain of the First World War and veteran in anti-submarine warfare. The history of the development of position-recording equipment was well documented by the 1921 study "Radio Direction Finder and its Application to Navigation," printed in the *Scientific Papers of the Bureau of Standards* as well as Captain L.S. Howeth's (1963) *History of Communications-Electronics in the United States Navy.* Some of these technological advancements were also utilized to track merchant vessels along the coast.

The most important source regarding the technical information for each merchant vessel in this study was collected from *Lloyd's Register of Shipping* (1931, 1938, 1939, 1940, 1941, 1942, 1943). This data included a spreadsheet of vessel dimensions including superstructures, engines, modifications, bulkheads, national and company registries, and other relevant information (shown for *Ario* in *Lloyd's Register of Shipping*, 1943; Figure 5). While the most recent data regarding each vessel was found in the later volumes of Lloyd's, other vessel information was dropped or lost in these editions. As such, prior editions were sought to acquire this data, and were accessed at the Hampton Roads Naval Museum in Norfolk, VA.



69594 **Ario** 219798 KULM *Mchy.Aft* D.F.	ssPhl.No.3-10,33 ssBal.No.2-11 *2Dks(Stl)&Webframes* *Longitudinal framing*	6952 6427 4271	✠100A1 Bal *b*† 9.11 ✠LMC 9,33 *Carrying Petroleum in* *Fitted for oil fuel* 4,20	Cl. 10,40 *bulk* *F.P. a*	1920 Bethlehem 4mo S.B.Corp.Ld Sparrow'sPt. Md A&CP *bove* 150° F	**Socony-Vacuum** **Oil.Co.Inc.** *CellDBuEs B57* 197*t DTf*50'824*t*	435·6|56·2|31·7 P122' B50' F44' FK *FPT97t APT74t*	**NewYork** Utd States 15 *BHpt Cem* 9 *to U dk* 6 .. *2nd* ..	T.3Cy.27",47"&78"-48" (*s*) 220lb 598NH 3SB.9*cf*.GS165,HS8235 FD BethlehemS.B.Corp.Ld Sparrow'sPt.Md	33 [illegible] 6	

Figure 5: Entry of *Ario* in *Lloyd's Register of Shipping*, 1943.

Additional data on the make-up, identification, and defensive capabilities of the merchant vessels was acquired through publications by the Office of Naval Intelligence. This data was then added to an Access database along with any other relevant information, including the ports of departure and destination of each vessel, its cargo, final speed, draft, and master, although not all this information was deemed necessary for the final analysis. The methodology for determining which data were used in the final analysis is described later in this chapter. In addition to merchant ship data, information regarding the German U-boats was also collected in a separate spreadsheet.

Historical information regarding the German perspective included the names, types, and commanders of the U-boats that attacked the merchant vessels in this study (as well as those the Allies successfully attacked). Other evidence included each U-boat's type, commander, speed, guns, number of torpedoes carried, and specific missions carried out by individual U-boats prior to their moving into U.S. waters. This information was compiled from Gunter Hessler's (1989) *The U-boat War in the Atlantic* Volume I: *1939-1941*. Operational information regarding strategy and tactics was collected from the primary accounts of both Admiral Karl Doenitz's (1990) *Memoirs: Ten Years and Twenty Days* and the translated version of the 1942 *U-Boat Commander's Handbook* (Oberkommando der Kriegsmarine [OKM]), edited by Bob Carruthers (2012) in *The Official U-Boat Commander's Handbook: The Illustrated Edition.*

It should be noted that many secondary sources use the spelling "Donitz," but this thesis uses "Doenitz," as this was the version used in his autobiography. The technological information for each U-boat and vessel in this study is important as they are characteristics used to identify each wrecked vessel and are used in this study as potential factors that led to a greater or lesser degree of positional accuracy. The identification of each vessel based on its technological specifications was conducted by archaeological examination of the wrecks.

Archaeological Research

It is important to note that the shipwrecks presented in this study had previously been located and documented by NOAA's MNMS and its affiliated partners, and that, due to the nature of this study, these wrecks were not visited by the author in any capacity while writing this thesis. Nevertheless, the wrecks today serve as archaeological features, their identities represent the distribution of sites along the battlefield, and their current positions are instrumental for building an understanding regarding the level of positional accuracy achieved by captains and commanders in the spring of 1942 (determined by comparing them to the coordinates gathered from the historical record). For this thesis, the identity and position of each wreck, provided by NOAA's MNMS, are considered definitive.

Additionally, another important detail that the archaeological evidence of the wreck can give is the location of the torpedo's impact. Many vessels in this study have historical data indicating the location of the torpedo hit. However, this information was not recorded for some, such as *Caribsea* (Figure 6). These vessels required the archaeological record to determine the location of the hit. *Caribsea* was a freighter of 2,609 gross tons sailing north, unescorted, with a load of 3,600 tons of manganese ore from Cuba to Norfolk, Virginia, when it was torpedoed and sunk by U-158 shortly after 0200 hours on 11 March 1942 (NOAA 2020b). According to a study conducted by Kara Davis in 2015 on the historical and archaeological record of the vessel, the captain recalled that his second mate motioned at something on the starboard bridge and asked, "Does that look like a ship to you?" The torpedo struck immediately after with a 48 second run time, or the time that it takes for the torpedo to exit the torpedo tube of the U-boat and hit its intended target (Fox [Davis] 2015:57-58). A torpedo wake was not reported; thus, it may have been a G7e torpedo that struck the ship (the importance of the lack of a visible wake in the identification of the torpedo is discussed in Chapter 4). The G7e's speed is 30 knots (Helgason 2021). The distance of the U-boat can then be calculated to roughly 740 meters from the vessel.

To show the location of the torpedo strike, Davis created a digital 3D model of the wreck (Figure 7) that displays "the fragmentation of starboard hull framing and plating" (Fox [Davis] 2015:125). Further, the historical record and the archaeological evidence displayed by both the wreck and the 3D model indicate that *Caribsea* was struck in the starboard bow cargo hold (Figure 8). According to the U-boat Commander's Handbook, a shot at shorter distances (under 1,000 meters) is best made at a 90-degree angle (Carruthers 2012:45). The location of the U-boat relative to the vessel can therefore be estimated at 740 meters, 90 degrees off the starboard bow.

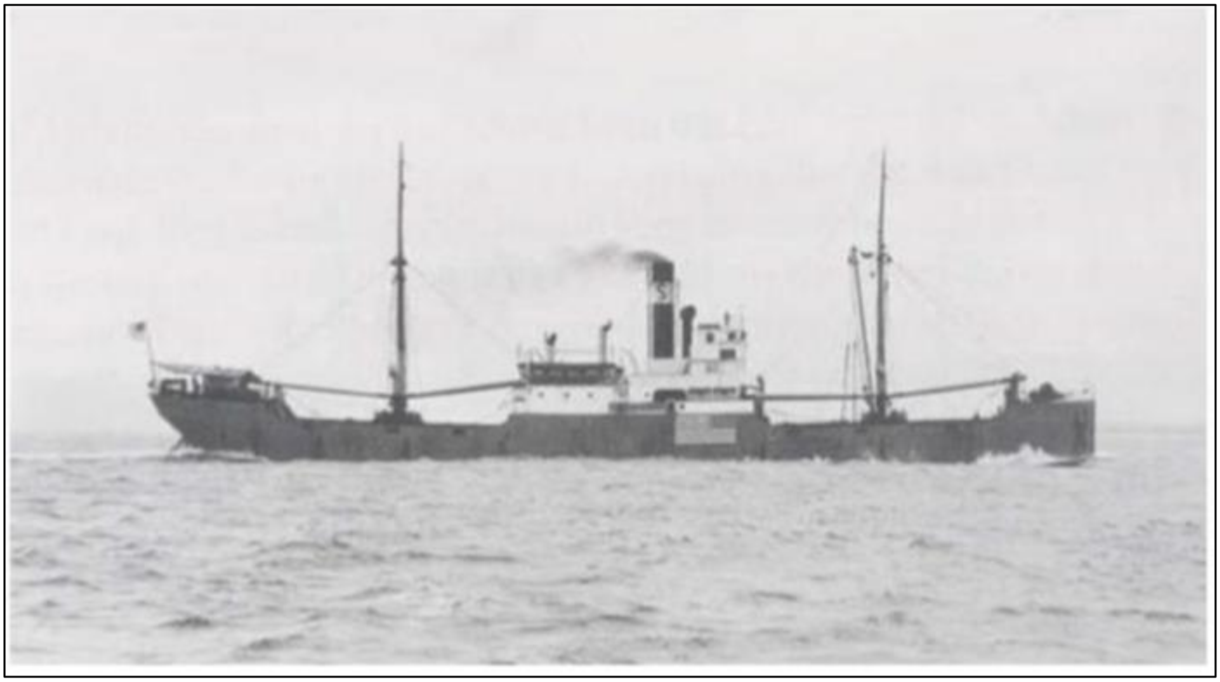


Figure 6: *Caribsea* prior to the Second World War. Photo courtesy of the University of Washington Digital Collections, Great Lakes Maritime History Project, October 2013 (Fox [Davis] 2015:37).

Archaeological information used in conjunction with the historical record creates a spatial relationship between the attacked vessel and the U-boat. Archaeological evidence was further analyzed using each wreck site as a separate feature within a larger battlefield site, that of Torpedo Junction, which was then plotted using GIS.

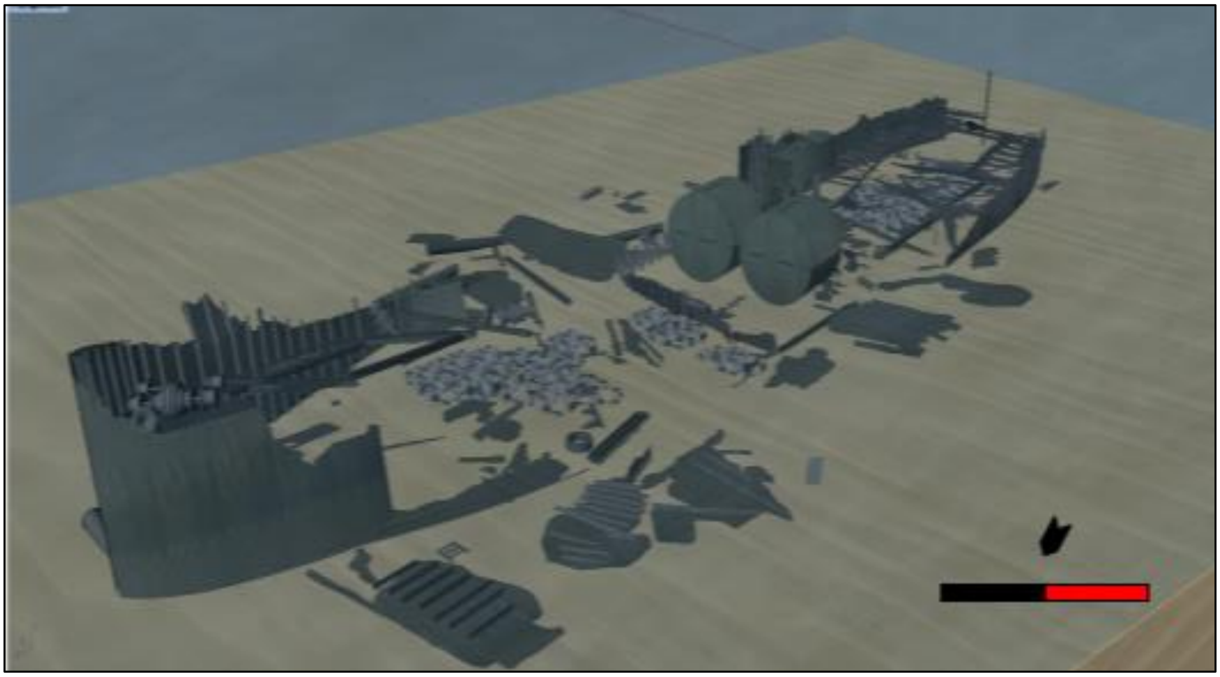


Figure 7: 3D digital model of *Caribsea* wreck (Fox [Davis] 2015:91).

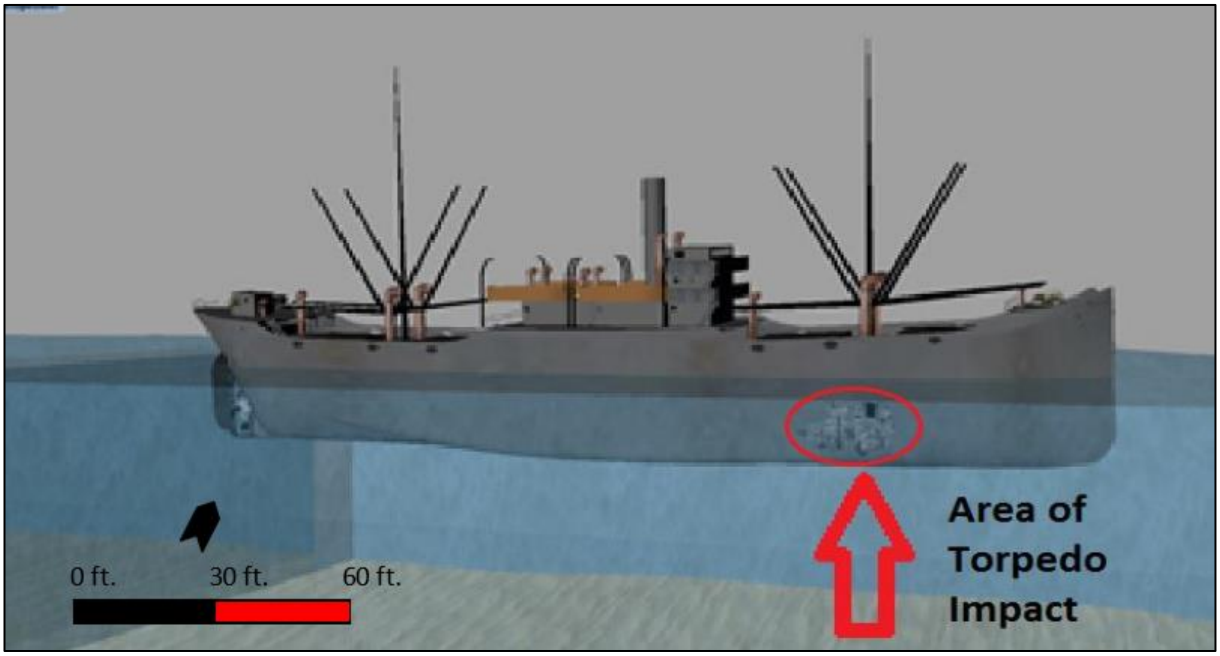


Figure 8: 3D digital model representing the area of torpedo impact on *Caribsea* (Fox [Davis] 2015:128).

As John Wagner described, “each vessel and the events it contributed to the battle [can be viewed] as individual archaeological features that, when added to a GIS, can compose an entire site plan or battleground for the waters of NC” (Wagner 2010:2). These features are then analyzed within a spatial context of one another, and when compared to the circumstances that caused the wreck, as will be demonstrated, patterns will appear.

GIS Database/Geospatial Methodology

To understand the level of error in locational accuracy, the coordinates of the wrecks, the historically reported positions, the German grid zone positions, and other important locations such as major bases, routes, ocean depths, and features to navigation such as lighthouses and lightships were added into a GIS database. ArcGIS Pro was the program chosen as opposed to other mapping software due to its ability to control and manipulate different data layers easily. Points and features were placed into groups that could be turned on and off so that the desired features were displayed when producing maps. Further, ArcGIS has several tools that were utilized to both calculate data and to display the relationship of the data geospatially. These tools included the measure tool, military tools that enabled the display of distance rings around a central point, and heat mapping used to display areas along the coast of higher and lower accuracy. Before these tools were utilized, however, necessary data was collected through historical sources, previous studies such as John Wagner’s study, and from NOAA’s MNMS, and input to the database.

Collecting GIS Data

In this study, coordinates were found in various historical sources such as *Merchant Vessels of the United States, 1943* (published 1 January 1943 and includes information on vessels lost the previous year), *Report of Wrecks Surveyed and Equipment Tested by USCG Gentian in Fifth Naval District 24 June-19 September 1943*, prepared by the Woods Hole Oceanographic Institution and the Fifth Naval District Intelligence Office (published 31 January 1944), *Lloyd's War Losses: The Second World War, Volume I, British, Allied and Neutral Merchant Vessels Sunk or Destroyed by War Causes* (1989), Robert Browning's (1996) *U.S. Merchant Marine Casualties of World War II*, and Jurgen Rohwer's (1999) *Axis Submarine Successes of World War Two: German, Italian, and Japanese Submarine Successes, 1939-1945*. The coordinates within the secondary sources (Browning, Rohwer, and *Lloyd's War Losses*) were found, "throughout the archives of various government agencies" (Browning 1996:xxi) and "the data of the Allied authorities" (Rohwer 1999:xiv).

Before these positions were entered, the coordinates provided by Rohwer and Browning had to be considered. The coordinates provided by Rohwer may be derived directly from the Office of Naval Intelligence, as the coordinates provided for the attack on the vessel *British Freedom* (not one of the vessels used in this analysis) on 27 June 1942 match with the coordinates provided by an Office of Naval Intelligence note attached to the Report of Interrogation of Survivors of U-701 (Op-16-Z 1942b:13; Rohwer 1999:106). Further, Browning notes that Rohwer "sometimes used the U.S. Navy's coordinates" (Browning 1996:xxii). As such, Browning makes references to Rohwer's coordinates in his work. The coordinates provided by Browning, however, are presented in what appears to be decimal degrees when in fact they were noted in degrees, minutes, seconds. This is confirmed by the numbers matching those presented by Rohwer. Further, Browning mentions that he often used Rohwer's data as a secondary source. Browning's coordinates, when viewed in the proper format, only differ from Rohwer's in the case of three vessels: *Ario* (Browning 1996:47-48; Rohwer 1999:85) *Dixie Arrow* (Browning 1996:55-56; Rohwer 1999:87), and *W.E. Hutton* (Browning 1996:51; Rohwer 1999:86). Thus, the coordinates provided by Rohwer, Lloyd's, and the USCG *Gentian* report are used most frequently as the recorded positions. Browning, however, was also utilized for information regarding the distance from which a torpedo attack took place, as well the speed and draft of the attacked vessel.

Creation of the GIS Database

The different sets of coordinates were entered into a separate spreadsheet for each wreck, which was then entered into ArcGIS using the XY table to point function. Coordinates recorded by the historical sources during the Second World War used the North American Datum (NAD) 1927 projected coordinate system. All vessel coordinates were entered in NAD 1983, however, to keep positions uniform with the current positions. The difference in position between NAD 1983 and NAD 1927 for locations in the conterminous USA can vary between 10 and 100 meters (NOAA 2020b). This level of error is small enough for the purpose of this study to be disregarded, where the differences in positions can vary for several miles. An example of entered coordinates is shown for the vessel *Ario* (Figure 9). A convex hull was then created around the coordinates, forming a polygon (Figure 10). The area of this polygon represents the square mileage of ocean that the coordinates span. In the case of *Ario*, the area covers roughly 380 square miles of ocean.

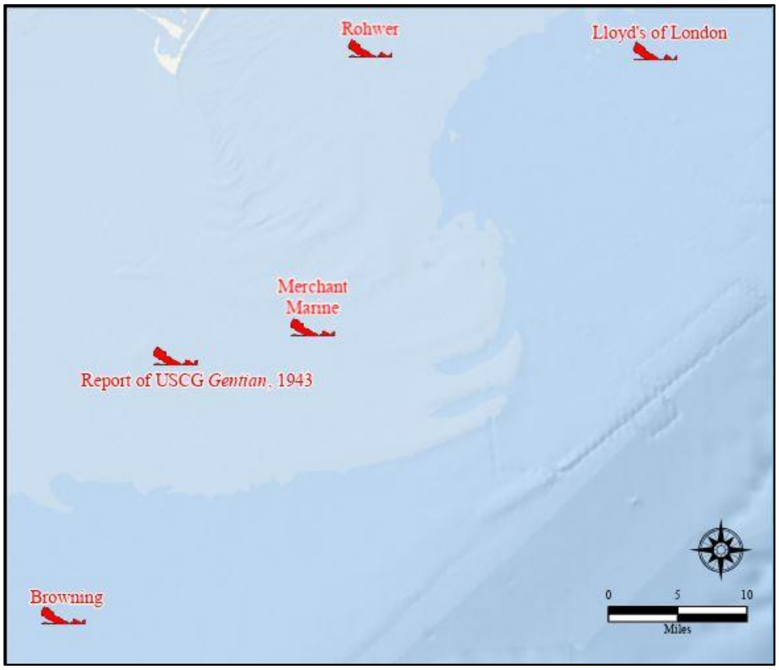


Figure 9: The coordinates of *Ario* as recorded in various sources are entered into ArcGIS. (Image by author, 2020.)

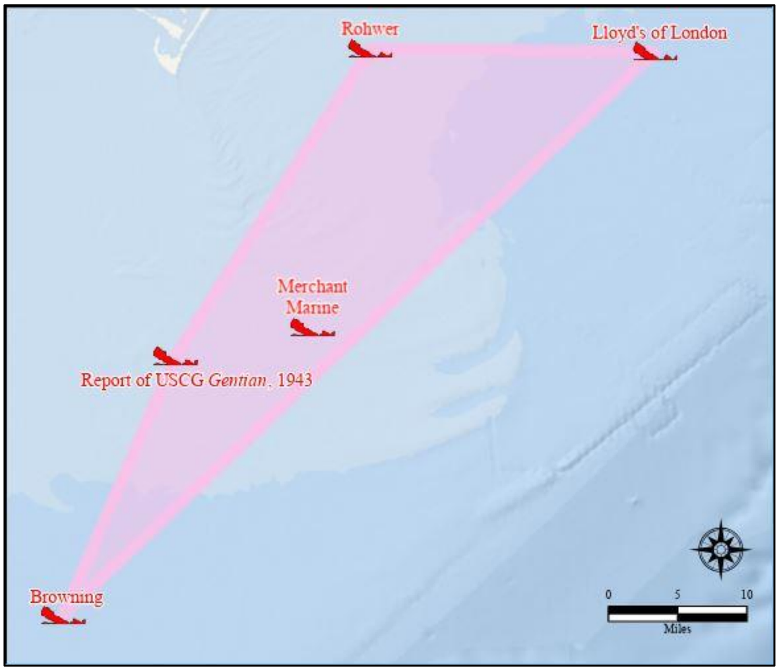


Figure 10: A convex hull created around the coordinates, denoting the area of ocean that the reported coordinates of *Ario* span. (Image by author, 2020.)

A centroid was then created for each vessel, which represents the center or average of the convex hull (Figure 11). The position of the centroid is then compared to the wreck's true position provided by NOAA.

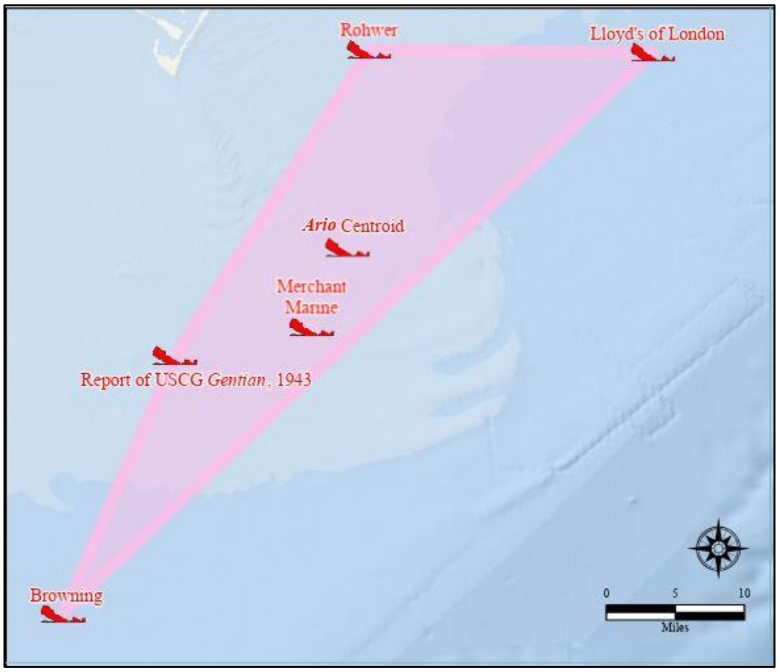


Figure 11: A centroid of *Ario* generated from the convex hull. (Image by author, 2020.)

The distance and heading to the true position was compared to the centroid using the measure tool (Figure 12). This projection, however, may be off, as the wreck of *Ario* has long been misidentified. Thus, the sources that provided attack positions may in fact provide the coordinates of another wreck, such as *W.E. Hutton*. Nevertheless, this projection displays the manner in which the convex hulls and centroids were generated.

Using positional information from the German U-boat commanders created another set of coordinates entered for comparison to both the centroid and the wreck. The Germans utilized a grid system to track the locations of their attacks.

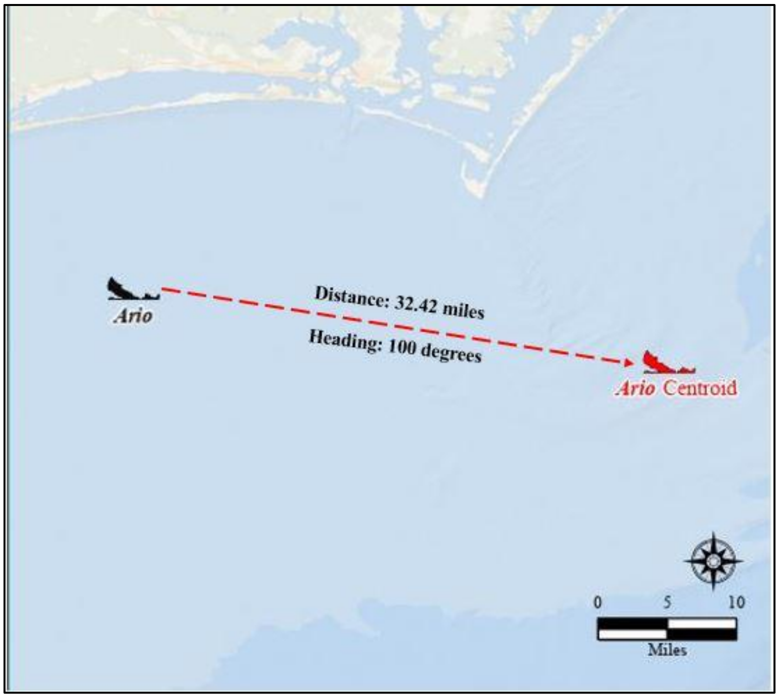
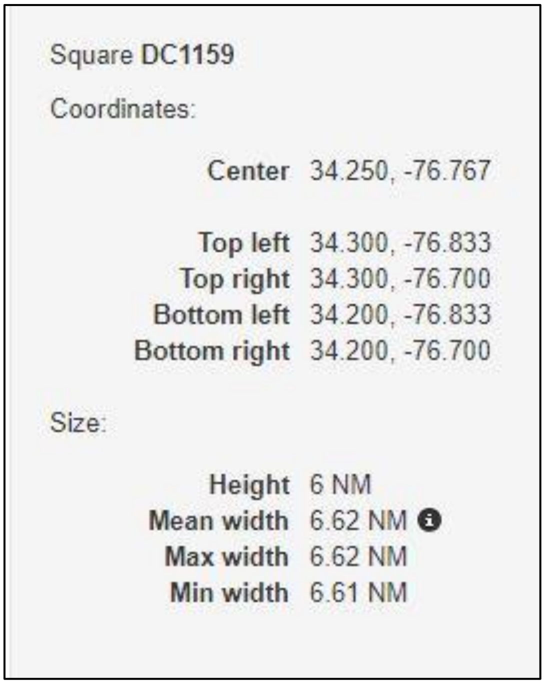


Figure 12: Distance and heading from the generated centroid to the true position of *Ario* given by NOAA. (Image by author, 2020.)

These grid positions are found in both Homer Hickam's (1989) *Torpedo Junction: U-boat War off America's East Coast* and Jurgen Rohwer's (1999) *Axis Submarine Successes of World War Two: German, Italian, and Japanese Successes, 1939-1945*. To generate these coordinates, the Naval Grid Calculator at navalgrid.com was instrumental. The grid square number for the vessel *Ario* is displayed in Figure 13 after being entered into the calculator. The calculator locates the grid zone and produces the coordinates of all four corners of the square grid, the center, as well as its size. Most grid squares are produced as six nautical miles north-south and an average of six and a half miles east-west.

The coordinates for the center of the grid square are the coordinates that are utilized for analysis and represent the level of German commander accuracy. These coordinates are entered into the GIS database and, using the measure tool, the distance and heading of these coordinates are compared to the true position of the wreck as well as the centroid. The visual comparison of the German point to the wreck is displayed in Figure 14.

It should be noted here that the datum used by the Germans during the Second World War to create this grid zone was not found, despite historical research. Thus, while the center of the grid zone was gathered from the calculator, the coordinates were entered into the database using NAD 1983, as were the Allied points. This is a factor that may need adjustment in future studies, however, the methodology can be repeated using NAD 1983 for the calculated center of grid zones for other vessels in North American waters, as the error presented in the results of this study would be consistent. An additional note is that the calculated grid squares, while on average being six nautical miles by six nautical miles, did vary in each square by up to half a mile in either direction (minimal error).



Square **DC1159**

Coordinates:

Center	34.250, -76.767
Top left	34.300, -76.833
Top right	34.300, -76.700
Bottom left	34.200, -76.833
Bottom right	34.200, -76.700

Size:

Height	6 NM
Mean width	6.62 NM ℹ
Max width	6.62 NM
Min width	6.61 NM

Figure 13: Results of the Naval Grid Calculator for the vessel *Ario*. (Image by author, data from navalgrid.com, 2020.)

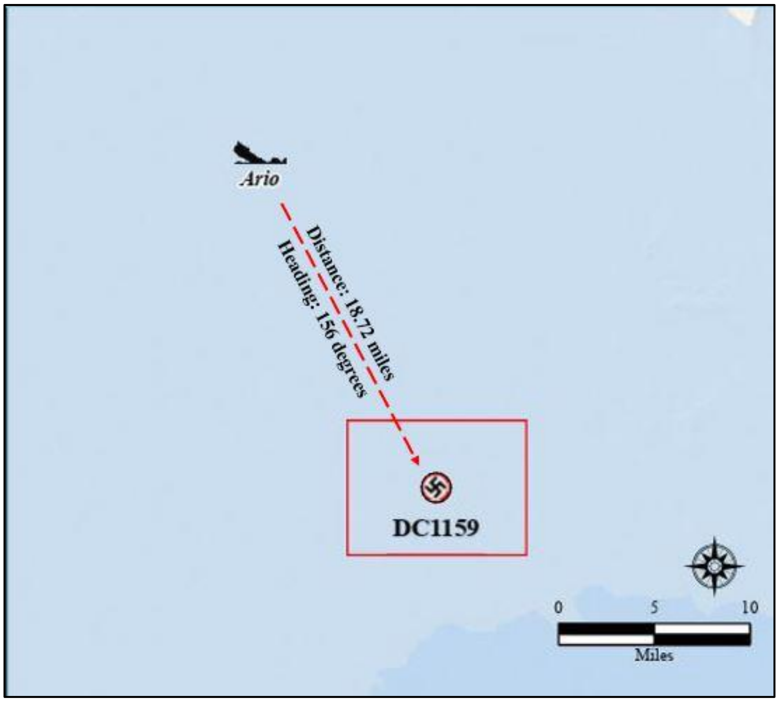


Figure 14: Distance and heading from the wreck to the created German point for *Ario*. (Image by author, 2020.)

To complete the geospatial analysis, the location of important military features such as the Cape Hatteras and Cape Lookout lighthouses, military bases such as Elizabeth City and Cherry Point, shipping routes of 1942, the bathymetry of the continental shelf, and NOAA navigational maps for the waters surrounding both Cape Hatteras and Cape Lookout were entered into a GIS database by John Wagner and provided by Nathan Richards. Similarly, the measure tool was used to calculate the distance and heading to the military and naval bases, which can provide aid to a vessel in distress, as well as to the nearest shoreline. The distances/directions of each wreck to the nearest lighthouse/lightship were also calculated with the measure tool, as these were navigational aids around the shallow waters of the capes. The relationships between these features are analyzed in a series of maps. The data examined through these maps, however, did not contain all the information from the Access database, but rather were carefully selected from the historical/archaeological data collected through research.

Choosing Factors for Analysis

The distances between the wrecks and military features such as the lighthouses and bases and the wrecks' distances from shore were determined to influence the locational accuracy of the merchant vessels. Additionally, the historical and archaeological research as well as the data collected by measuring the distances between vessels, centroids, and other features were all recorded in the Access database, much of it being used for analysis. Not all data used for this analysis was found in the historical sources or calculated through the GIS database, as several factors were more abstract and difficult to quantify. These factors include the speed of the attack and the level of violence. Upon conducting research and creating the GIS database, spatial factors for each vessel were entered into the Access database including distances and directions. Once this database was completed, different factors were chosen for their potential to cause discrepancies in positional accuracy as detailed below.

Calculated Factors

When examining several factors, choices had to be made regarding which parts of the database were considered. One such choice involved the way to determine the duration of each attack and includes a *level of violence*, which was considered to potentially affect geospatial accuracy through the fog of war. Different levels of violence may result in a different density of fog, such as a highly violent attack resulting in a greater level of confusion. The duration and level of violence had to be determined by examining several factors in each attack case and designating each case in one of two factors in two different categories: slow or quick and calm or violent. An attack was defined as slow if the vessel remained afloat for longer than two hours after the attack began, even if the crew had abandoned ship (described in Chapter 6). Vessels at times remained afloat and drifted long after the strike, often within sight of the crew. An attack was considered quick if the vessel sunk within an hour; often a quick attack occurred within minutes. These two categories are easier to define. The lines between a violent and calm attack, however, are much finer. While there are no "calm" attacks when a U-boat attacked merchant vessels, attacks that were placed in this category had several factors in common. One major factor that calm attacks had in common is the lack of a distinguished explosion or fire that cannot be extinguished. A calm attack is in opposition to one that was determined violent, such as *Dixie Arrow*: engulfed in flames from the ignition of the flammable cargo (as is the case with many tankers). A violent attack was also characterized by the accurate use of the U-boat's deck gun.

Deck guns were used in the attacks on *Ario*, *Ashkhabad*, and *Marore*. *Ario* was shelled by U-158's deck gun for half an hour, and an hour after the U-boat departed, the crew attempted to board and salvage the vessel, which quickly sank afterwards. This event is designated as a slow and violent sinking. Hickam (1989:188) notes that a deck gun was mentioned to have been used against Soviet *Ashkhabad*; however, the gun crew was wide of their mark, and because the vessel sank quickly, it was given the designation of quick and calm. *Marore*, although fatally hit and quickly sinking, was also shelled from U-432, thus a designation of quick and violent. Another vessel, *E.M. Clark*, is given the designation as violent due to the severity of the storm during which it was attacked and sunk. Out of 27 merchant vessels (including HMT *Bedfordshire*), five vessels received designations of slow and violent, ten received designations of quick and violent, eight received designations of quick and calm, and four received designations of slow and calm. The larger categories utilized for each attack are given in Table 4.

Table 4: Designations for the level of speed and violence for each of the vessels.

Vessel	U-Boat	Duration	Deck Gun	Explosion or Fire	Speed Prognosis	Violence Prognosis
Ario	U158	1.5 hours	Yes	No	Slow	Violent
Ashkhabad	U402	Minutes	Yes	No	Quick	Calm
Atlas	U552	Minutes	No	No	Quick	Calm
Australia	U332	2 hours	No	No	Slow	Calm
Bedfordshire	U558	Minutes	No	Yes	Quick	Violent
Bluefields	U576	Minutes	No	No	Quick	Calm
British Splendour	U552	2 hours	No	Yes	Slow	Violent
Buarque	U552	Minutes	No	No	Quick	Violent
Byron T. Benson	U432	Days	No	Yes	Slow	Violent
Caribsea	U158	Minutes	No	No	Quick	Violent
City of Atlanta	U123	Minutes	No	Yes	Quick	Violent
Dixie Arrow	U71	2 hours	No	Yes	Slow	Violent
E.M. Clark	U124	Minutes	No	No	Quick	Violent
Empire Gem	U66	3 hours (under own power)	No	Yes	Slow	Violent
Equipoise	U160	Minutes	No	Yes	Quick	Violent
Esso Nashville	U124	3+ hours (stern towed)	No	No	Slow	Calm[a]
Kassandra Louloudis	U124	Minutes	No	No	Quick	Calm
Lancing	U552	Minutes	No	No	Quick	Calm
Liberator	U332	Minutes	No	No	Quick	Calm
Malchace	U160	3 hours	No	No	Slow	Calm
Manuela	U404	Days (towed)	No	No	Quick	Calm
Marore	U432	Minutes	Yes	Yes	Quick	Violent
Norvana	U123	Minutes	No	Unknown	Quick	Violent
Papoose	U124	Days	No	No	Slow	Calm
San Delfino	U203	Minutes	No	Yes	Quick	Violent
Tamaulipas	U552	Minutes	No	Yes	Quick	Violent
W.E. Hutton	U124	Minutes	No	Yes	Quick	Violent

[a] Rohwer (1999:86) notes that U-124 mentioned using its gun against *Esso Nashville*, but this is not mentioned in any Allied sources that were researched, thus it was deemed a calm attack.

It should also be noted that each of these vessels further has a recounted narrative on NOAA's MNMS's Shipwrecks webpage (NOAA 2020b). The speed of the attack and the level of violence are two factors that were added to the Access database and used in the final analysis, however, many were added that were not later included as they were determined to have little or no possible effect on locational accuracy.

Researched Factors

When creating the Access database, different pieces of information, or data, were included for each of the 27 Allied vessels (26 merchant ships, 1 warship) and the 4 U-boats. The data collected was found to be included in most historical accounts for the vessels, thus each vessel had information for most of the factors added. When conducting the analysis to determine the geospatial accuracy of the study vessels, not all the data entered to the Access database was included. Some of the factors were not analyzed further due to their predicted lack of effect on accuracy. Each factor was weighed for their potential to inform positional accuracy as they were added.

The vessel's name was the first important characteristic that was added for identification. Its recorded sinking date was used to consider weather patterns throughout the months as well as changes over time as the war progressed. The time of attack was recorded for all sources (mostly Freeman [1987], Browning [1996], and Rowher [1999]) and an average was taken to designate a specific time of attack for the purpose of this study. This data was important to determine the time of day including the position (or lack thereof) of the sun for better viewing the events of the attack. To further understand the visual impact of the time of day or night and the amount of visibility, the amount of possible moonlight was also considered. Before this data was analyzed for its effect on geospatial accuracy, the qualitative data (name of the moon phase) was converted into quantitative data (percentage of moonlight). Each phase was given a percentage based on a rounded number of the amount of the moon visible (divided into quarters, or 25%) (Table 5).

Table 5: Moon phases and respective percent of moon visibility.

Moon Phase	New	New/First Quarter	First Quarter	First Quarter/Full	Full	Full/Third Quarter	Third Quarter	Third Quarter/New
Percent	0	25	50	75	100	75	50	25

The vessel's master was also recorded in the Access database. This was determined to have little effect on the locational accuracy because many of the merchant captains were quite stubborn and ignored orders to zigzag or dim lights. With masters remaining oblivious to the dangers of the capes, the attack would come as equal surprise to any master. Additionally, they would have relied on similar instruments of position taking: direction finders or gyrocompass navigation. It was therefore concluded that their years of service were not examined as contributing factors. Other factors recorded included the depth of the attack, due to its effect on the U-boat's ability to retreat after an attack. Further, many captains did not believe that a U-boat would come shallow, hence the depth was examined.

Data regarding the number and type of casualties were also added to the database. These vary from servicepersons on armed vessels, crew of the merchant vessel, and on one, *Buarque,* passengers. This was also not included for final analysis, except in the case of *Norvana*, where the lack of survivors in addition to conflicting U-boat reports makes an analysis of the vessel limited overall. The port of departure and the intended port of arrival were added to the Access database, which was recorded in *Lloyd's War Losses* (1989) as well as the vessel's cargo, which was recorded to determine its eligibility for ignition (i.e., flammable cargo).

Recording the side of the vessel that was hit allowed for a determination of the direction that the attack came from, as a vessel traveling from a port in the Caribbean to New York (north) being hit on the starboard side might indicate that the U-boat attacked from the east. Additionally, the distance of the torpedo's shot was used in conjunction with the U-boat's direction to place the U-boat's position in comparison to the vessel. The location of the vessel's engine (as well as its specifications, number of boilers, furnaces, etc., found in *Lloyd's Register*) were added to the Access database to consider the potential damage of a torpedo strike. Other data provided by NOAA (2020b), Hickam (1989), and Browning (1996) include the nationality of the vessels attacked. This was to determine whether the position-fixing techniques, the capabilities of merchant crews, or procedures in an emergency varied between nationalities.

The successful strike of a torpedo was often the difference between a slow or quick attack, calm or violent. Further, some vessels required a second shot. Doenitz's report on torpedo malfunctions using contact pistols for the first half of 1942 stated that 40% of vessels went down after a single hit, 38% required two or more, and 22% escaped after being hit by one to four torpedoes (Doenitz 1990:94). Within the study group, 25 vessels (excluding *Bluefields*, which was torpedoed after Doenitz had concluded his study, as well as *Norvana*, where reports are too inaccurate) have a recorded number of hits. Unfortunately for many vessels, the sources disagree on the exact number. The major sources used include Moore (1984), Hickam (1989), and NOAA (2020b). The sources agree that 8 of the 25 vessels required at least two hits (some are debatable on two or three), 15 are confirmed one-shot kills, and two vessels, *Buarque* and *Liberator*, are debated between one and two hits. This research, however, does not include vessels that were successfully hit but escaped.

In addition to the number of torpedoes utilized in the attack, the distance of attack (distance that the torpedo was required to travel before striking the target) was also recorded. This is a feature that Browning (1996) covers, but not for every vessel. Several, such as that of HMT *Bedfordshire*, were retrieved from other sources, while others were calculated using a torpedo's speed along with the recorded run time (*Caribsea*). Only 9 of the 27 vessels have a recorded distance between the U-boat and the vessel. The average range of the attacks is only 860 meters (940 yards), with all but one being recorded at 1,000 meters (1,094 yards) or less. The exception is *Atlas*, attacked and sunk by U-552 on 9 April 1942, was hit from 2,000 meters, or 2,187 yards (Browning 1996:73).

The exact speed and draft of all the merchant vessels at the time of this study were unavailable from primary sources. Browning (1996) does include both, but only for 15 of the 27 (although one, *Liberator*, did not have its final draft recorded). The recorded final drafts varied from 17.08 ft. to 34 ft. for all vessels. The recorded final speed was mostly consistent around ten knots, although both *Caribsea* and *Buarque* were going much slower at four and six knots, respectively. Browning also recorded the final speed of *Norvana* at nine knots, despite the vessel being sunk with all hands and with conflicting reports. This is not addressed in the text, and thus the recorded attack speed, listed as the "speed in knots when attacked" (Browning 1996:xi), may in fact be the average or maximum speed of the vessel.

Another substantial series of data that was collected involved the U-boats that conducted the attacks. The U-boat's name (designated as a number), commander, and type were important factors that were utilized. The type was particularly important as this also contained information about the U-boat's size, speed (both on the surface and submerged), range at different speeds, number of torpedoes carried (or combination of torpedoes and mines), maximum crew, and maximum diving depth. The most important source for this data was found in Appendix I of Hessler (1989). Additional information for engines, construction location and details, as well as modifications for Type VIIs was found in Marek Krzysztalowicz's (2012) *Type VII: Germany's Most Successful U-boats* and Robert W. Thew's (1991) "The Type IX U-boat" in *Warship International.*

Like the data collected for the merchant vessels, much of this data was not included in the final analysis due to perceived lack of effect on geospatial accuracy. This includes the number of torpedoes or mines carried by the U-boat, its construction history, total range (as each battle between a U-boat and vessel would have been quick and in a small area before the U-boat left the scene), or maximum crew. The name of the U-boat's commander was included as each individual may have better locational accuracy from one another. As such, less descriptive data regarding each attacking U-boat was designated for inclusion in this study's analysis. This decision-making process filtered out many previously hypothesized factors prior to analysis, including some of those posed by the secondary questions.

Conclusion

This chapter described the methodology of conducting both historical and archaeological research, including the use of data provided by NOAA as well as researched in a variety of primary and secondary sources. The historical and archaeological data was added to an Access database. Geospatial data that was calculated using ArcGIS software was also included in the

Access database, where coordinates were entered from gathered historical sources including Browning (1996) and Rohwer (1999) as well as the current wreck positions provided by NOAA. The positions of the historical sources created a series of convex hulls and centroids that represented the total area and average calculated point of the historically recorded coordinates, respectively. Additionally, the coordinates at the center of the German naval grid zones, created using the Naval Grid Calculator from grid zone positions provided by both Hickam (1989) and Rohwer (1999) were added to the GIS database. The distances and directions between the centroids, wreck positions, and German positions were calculated using the measure tool, as were the distances/directions of the wrecks to other features that were added to the database, such as lighthouses and military bases.

The results of these distances/directions were included in the Access database. Several of the qualitative factors in this database were simplified into data that could be quantified and used to create a finite number of circumstances, such as the level of violence of an attack. Finally, all these factors were reviewed and chosen for their potential relevance on geospatial accuracy. The following chapter presents a deeper examination of the historical research, including the technological and tactical capabilities of each of the combatants of Torpedo Junction. This is required to understand the results of the geospatial analysis in context.

CHAPTER 4: THE SHEPHERDS, THE SHEEP, AND THE WOLVES: TECHNOLOGICAL AND TACTICAL ADAPTATIONS OF TORPEDO JUNCTION'S COMBATANTS

Introduction

The technology and tactics of the combatants represent many of the human elements of naval battles. The deployment of a depth charge, the surfacing of a U-boat, or radar detection of an enemy (technology) will cause a human response to utilize a method (tactic) that results in success or failure of the tactic used. The Battle of the Atlantic off North Carolina's coast was fought between three major combatants, each with their own unique missions, technology, and tactics. The Allied antisubmarine forces worked to protect merchant shipping that traveled through the state's waters and to hunt U-boats. These forces included destroyers, Coast Guard cutters, aircraft, and other small vessels. Most of these vessels utilized weapons and technology designed to find and destroy enemy submarines, including sonar and depth charges for submerged U-boats and radar and deck guns for those at the surface. Upon finding a submerged U-boat, specialized tactics were developed for attack, as submarines were, in terms of large-scale naval warfare, a relatively new concept.

The primary task of merchant vessels was to transport war materials, oil, personnel, and other forms of cargo along the coast while avoiding U-boat attacks. These vessels were designed to survive long, and potentially hazardous ocean voyages and distinct features include updated engines and hazard detection such as echo sounders and double hulls. Direction-finding devices assisted in tracking their location along the coast. Deck guns were only installed on a few vessels, so their best defense was avoidance or seeking protection, either from air cover, minefields, or surface convoys. U-boats went to U.S. waters to sink merchant vessels, particularly tankers. They were armed with torpedoes and deck guns for defense against surface and air attacks, and they used a unique grid system to keep track of their locations. Their tactics for attack and defense were finely honed. Each of these elements should be analyzed individually to better understand their effect on the human element of Torpedo Junction.

Immediately upon the USA's declaration of war against Germany, Admiral Karl Doenitz, commander of Germany's U-boat fleet, proposed to send 12 large U-boats across the Atlantic to prey on the unprotected merchant ships along the U.S. coastline. His plans needed to be altered, however, as he did not have enough U-boats available. Nonetheless, between 16 and 25 December 1941, five U-boats left their dockyards in France for North American shores between Cape Hatteras and the St. Lawrence River. Despite his caution to keep this plan secret, the U.S. Navy was already preparing for the incoming threat, although the number of forces to defend the coastline was small (Hickam 1989:1-5). The first U-boat to reach the waters off Cape Hatteras was Fregattenkapitan Richard Zapp's U-66. On 18 January 1942, Zapp torpedoed the tanker *Allen Jackson*, the first of many victims in the waters that would later be known as Torpedo Junction (Hickam 1989:11,22). The U-boat war off North Carolina's shores was a battle of tactics and technology between the Allied antisubmarine forces, merchant vessels, and German U-boats.

Allied Efforts

The beginning of 1942 looked grim for the U.S. naval forces on the Atlantic coast. In fact, a few days before Christmas 1941, Rear Admiral Adolphus Andrews, Commander of the North Atlantic Coastal Frontier, wrote his concerns to the Chief of Naval Operations.

> There is not a vessel [in this command] that an enemy submarine could not out-distance when operating on the surface. In most cases, the guns of these vessels would be out ranged by those of the submarines. The limited capabilities of these vessels are apparent. It is submitted that should U-boats operate off this coast, this command has no forces to take adequate action against them, either offensive or defensive (Freeman 1987:13).

Admiral Ernest J. King was made Commander in Chief of the U.S. Fleet in the final days of 1941. Although King knew of the grave situation in the Atlantic, his priority was the Japanese Imperial Fleet threatening U.S. interests in the Pacific. King was also worried about the German surface ships, although they were bottled up by the British Royal Navy. That did not stop King from denying Andrews' request for a larger force to defend the coastline from South Carolina to Canada. A fleet consisting of 5 battleships, 2 aircraft carriers, 14 cruisers, and a group of submarines operated out of Hampton Roads, Virginia, but King wanted those ships in reserve for a surface battle against the Germans, or more likely, to be sent to the Pacific. Luckily, the U.S. Coast Guard was placed under the command of the U.S. Navy in November of 1941. Therefore, at the end of that year, Andrews had 20 vessels at his disposal: four personal yacht (PY) boats, four sub-chaser (SC) boats, one 165 ft. Coast Guard cutter, six 125 ft. Coast Guard cutters, two patrol gunboats (PG), and three Eagle boats. Additionally, Andrews had a total of 103 aircraft at his disposal, although only a quarter of these were suited for antisubmarine warfare (Freeman 1987:6; Hickam 1989:4-5; Bright 2012:172; Offley 2014:36-41).

Allied Antisubmarine Forces

In February 1942, King allotted Andrews the use of 11 destroyers on a temporary basis, many of which were old *Wickes*-class destroyers. These four-stack vessels were built for the U.S. Navy after the First World War. Ships of the *Wickes*-class were 314 feet long with a 31-foot beam and a 9-foot draft and displaced 1,090 tons. The ships could make 35 knots at maximum speed and had a range of 2,500 miles at 20 knots. When they were given over to antisubmarine detail in December 1941, their original armament was replaced with six 3-inch guns, four machine guns, the removal of their torpedo tubes, and additional depth charge equipment, such as Y-guns used to launch depth charges and depth charge racks. Additional fuel bunkers were also added. The common 3-inch gun on naval vessels was the Mark 21 which fired a 13-pound projectile to a range of 14,500 yards. Other destroyers included the *Clemson*-class, which had similar characteristics of the *Wickes*-class except for a 35% increase in fuel capacity (Hickam 1989:56; Bright 2012:169-175).

The Coast Guard cutters that made up the bulk of Andrews' initial fleet consisted of smaller vessels of different size, class, speed, and armament. In the Fifth Naval District off North Carolina, the primary cutters were of the *Active*-class and the *Argo*-class. The *Active*-class cutters were 125 feet long, displaced 210 tons, and could reach a speed of 13 knots. The *Argo*-class which included USCGC *Icarus* was 165 feet long, displaced 337 tons, and could reach 16 knots. Both classes had a primary armament of a 3-inch forward gun, commonly a Mark 2/1, which had a range of 7,000 yards and was also often installed on merchant vessels. Both classes were also armed with machine guns and depth charges. *Argo*-class vessels were equipped with Y-guns, which launched depth charges away from the vessel (Bright 2012:175; Helgason 2020). Another group of ships that made up Andrews' initial defenders were Personal Yachts. These vessels were crewed by volunteers and were later incorporated under the direction of the Coast Guard. Dubbed the "Hooligan Navy," these yachts were equipped with machine guns, four depth charges, and a radio, with orders to attack U-boats whenever possible (Freeman 1987:6; Hickam 1989:167; Thiesen 2016).

A final group of vessels that should be mentioned are the antisubmarine trawlers. These vessels were former fishing trawlers that were armed with three- or four-inch deck guns, .30-caliber machine guns, and depth charges. These vessels were around 170 feet long, and able to make a maximum of 12 knots. Andrews had several of these armed early in the war, and in February 1942 the British sent 24 trawlers with experienced crew and equipped with the British ASDIC apparatus, a sonar device developed to detect submerged U-boats, to aid their U.S. counterparts (Hickam 1989:210-211,285).

HMT *Bedfordshire*, the only Allied military vessel in the study group, was a deep-sea artic fishing trawler built in 1935 and converted for the purpose of anti-submarine patrol by the Royal Navy. The trawler operated around the southwest coast of England until the USA's entry into the war, after which it was transferred to the U.S. East Coast. Because of its small size, its destruction at the hands of a single torpedo from Kapitanleutnant Gunther Krech's U-558 was quick and violent, with all hands lost before a message was sent. Its sinking was thus not known for many days (Hickam 1989:217-218; NOAA 2020b).

In January 1942, the Eastern Sea Frontier was ill-equipped with aircraft. Throughout the entire frontier, stretching from the Canadian-U.S. boundary to the southern border of Onslow County, North Carolina, there were 103 aircraft, although only a quarter were suitable for antisubmarine defense (Freeman 1987:3-6). Many of the aircraft did not carry munitions and only carried enough fuel for a few hours of patrol. To obtain the greatest effect with the limited supply of aircraft, the Fifth Naval District off Cape Hatteras was divided into three sections of aerial coverage (Figure 15). These aircraft assisted the nine surface vessels that covered the 28,000 square miles of ocean within the district. January saw little increase in the number of aircraft available for patrol. By the end of March 1942, however, aircraft from both the Navy and

Army were stationed around the Fifth Naval District to defend Torpedo Junction. These included six PBYs at Norfolk, VA, four B-25s at Wilmington, NC, four B-25s at Charleston, SC, four B-17s, two B-18s, and four B-25s at Langley, VA, and three DB-7s at Savannah, GA. There were also 19 OS2U-3s stationed around North Carolina. These numbers continued to grow throughout the months, with Army aircrews adapting to depth charge use (Wagner 2010:110-116).

Figure 15: Sectors of Fifth Naval District divided for naval and aerial coverage in January 1942 (Wagner 2010:113).

The Mark 17 aerial depth charge was produced in large quantity by April 1942 and were used by aircraft in antisubmarine warfare. These charges weighed 325 pounds and carried a 234-pound TNT charge. The typical depth charge carried by antisubmarine vessels was either the Mark 6 (Figure 16) or the Mark 7. The Mark 6 weighed 420 pounds and had a 300-pound TNT charge, while the Mark 7 was larger, weighing 768 pounds with a 600-pound charge. This larger design was also made into a teardrop shape as opposed to the traditional cannister shape. Both charges had a maximum operating depth of 300 feet, until a modification came that increased the Mark 6's range to 600 feet (Hickam 1989:139; Bright 2012:177-181). The attack pattern employed by an antisubmarine vessel was based on where the U-boat submerged, and depth charges were deployed while following a curve pattern (Figures 17-19). Gunfire from antisubmarine vessels was applied as soon as a U-boat was sighted on the surface using pointed shells and continued until after the U-boat submerged (Welles 1917:1-5, 1918:11).

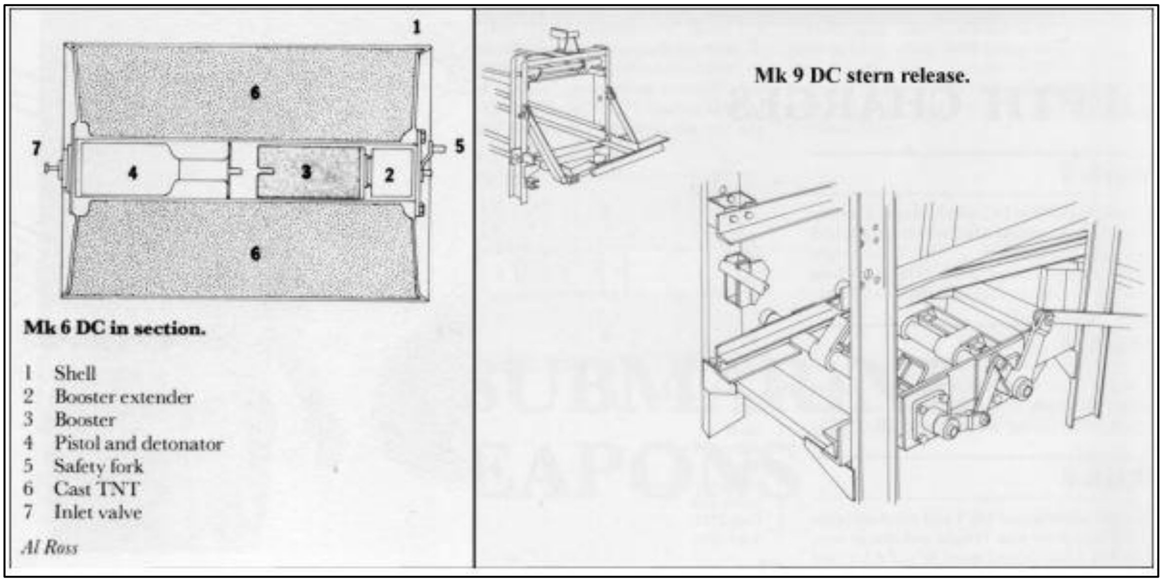


Figure 16: Schematic of Mark 6 depth charge and stern mounted Mark 9 depth charge release. The Mark 6 and Mark 9 were similar in design; thus the racks would be nearly identical as well (Campbell 1985:162-164).

Merchant Vessels

The merchant vessels that sank off Torpedo Junction range in size, nationality, and speed. Most vessels in this study, however, are U.S. vessels that averaged roughly 6,700 gross tons and 420 feet long.

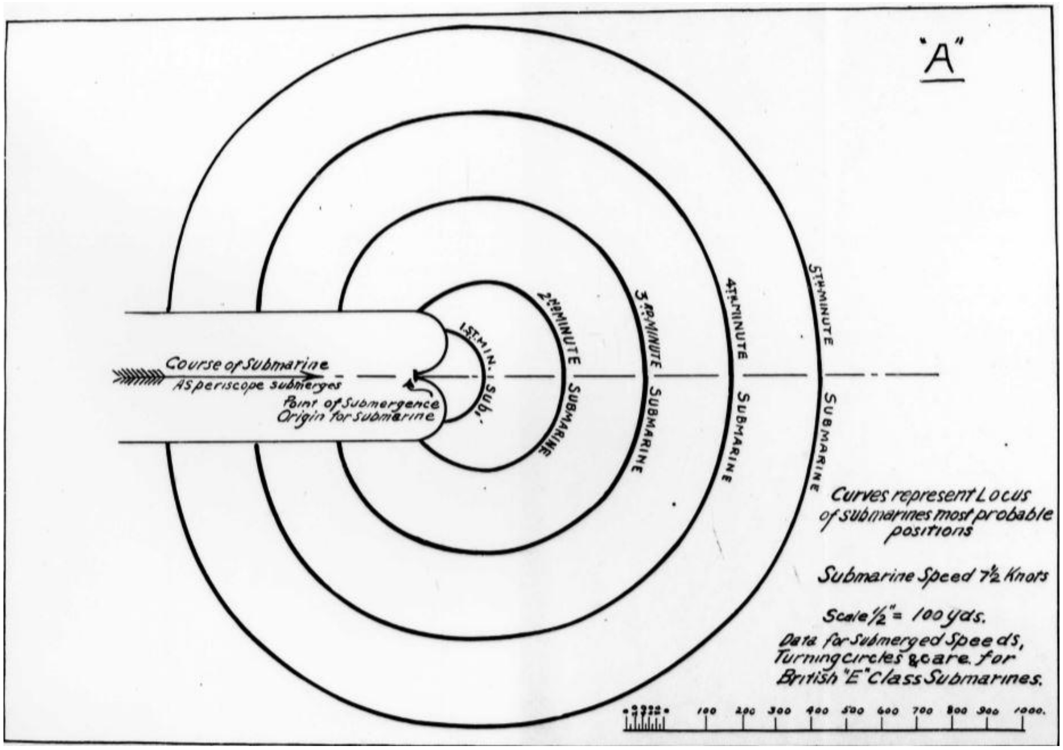


Figure 17: Display of U-boat's probable position after submerging (Welles 1918:3).

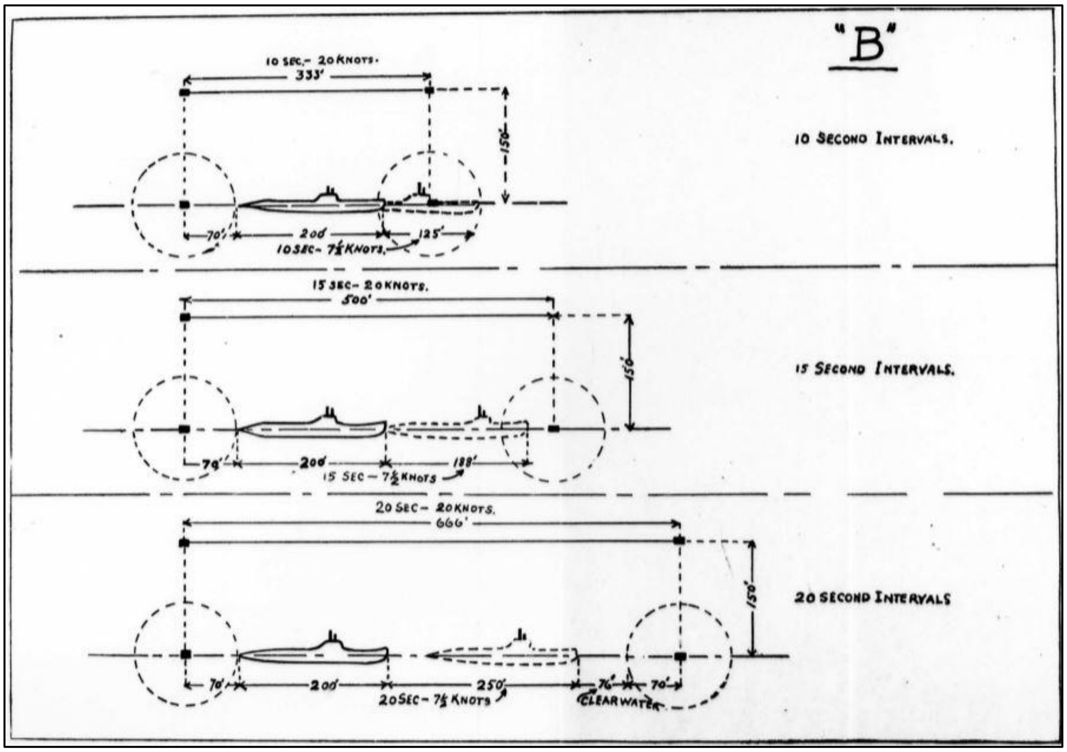


Figure 18: Depth charge intervals of antisubmarine vessel (Welles 1918:4).

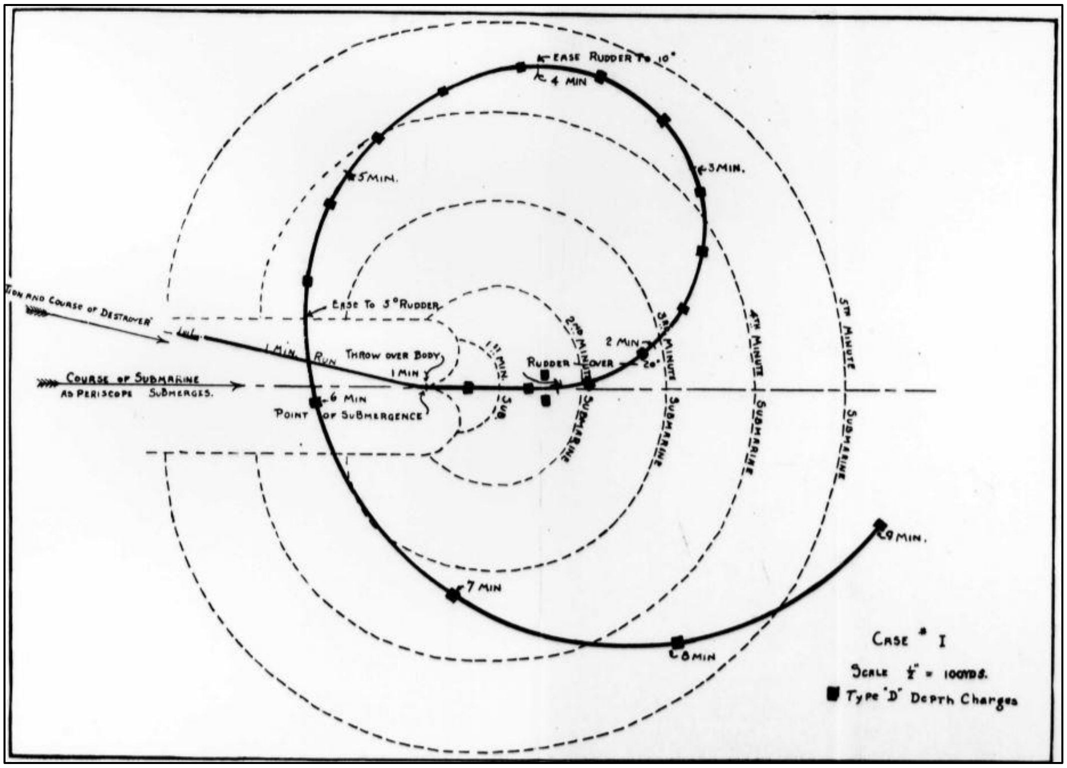


Figure 19: Depth charge curve pursuit using a one antisubmarine vessel (Welles 1918:4).

Many other countries contributed merchant ships, such as the UK, the Soviet Union, and Central and South American countries such as Brazil and Panama (*Lloyd's Register of Shipping* 1942, 1943). These vessels ranged in age and cargo, but all shared the same purpose of transporting goods while avoiding the U-boat menace. One method employed to avoid U-boats was to paint vessels in a dull grey or other neutral color to avoid standing out on the ocean. Another method was to paint the silhouette of a ship onto the side to cause confusion as to the vessel's size or range (Schuirmann 1944:15).

While most of these merchant vessels were unarmed, several had defensive guns installed upon America's entry into the war. These guns varied from .30 caliber machine guns to 3-inch cannons to defend against surfaced U-boats, often the Mark 2/1 (Browning 1996; Bright 2012:175). While the guns were operated by trained military, the average crew was ill-suited to defend the ship with firepower. Merchant vessels were also double-bottomed which aided in stability in the case of attack or collision. The double-bottom design came about in the mid-1800s and deviated from single hull designs based on wooden ships. It proved that a vessel punctured in the outer hull by a submerged hazard could remain afloat if the inner hull remained intact (Smith 2013:109-110).

Many merchant vessels had engines that were retrofitted to use modern oil burning engines (*Lloyd's Register of Shipping* 1942, 1943). A merchant vessel's speed depended largely on its type and age. Its type can broadly be placed into three categories: passenger types, engine-amidships types, and engines-aft types. Important for this study are the engine-amidships types, or cargo carriers, which includes freighters, and the engines-aft types, which includes tankers. Cargo carriers have short superstructures that can either be composite or split and have a single small smokestack. Engine-aft types are considered "bulk carriers" that have a single large continuous cargo hold. The engines and funnel are situated aft, with the bridge situated on the poop, forecastle, or amidships (Schuirmann 1944:8-19). Thus, a torpedo striking the center of a freighter would damage the engines, whereas a similar strike on a tanker would be in the cargo hold, possibly carrying oil.

Merchant ships lacked the U-boat detection technology employed by the Navy, and thus had to rely on watching for periscopes and torpedo wakes. Binoculars used by a lookout positioned high in the ship proved the best visual for an unescorted merchant ship, although a lookout placed lower on the ship to view the surface to the horizon was also recommended for finding periscopes (Bureau of Naval Personnel 1943:8). This visual was limited to weather, sea state, and time of day. Manuals for posting watches were created for the Navy, however a lookout on a merchant ship undoubtedly had the same view as a naval ship. These manuals were based on the observation that a good lookout could view objects at a range of 6,000 yards with the naked eye and two or three times that while aided with binoculars (Bureau of Naval Personnel 1943:33).

Cape Hatteras was a natural choke point, as merchant vessels used the Gulf Stream to move to northern ports, while ships moving south hugged the shoreline to avoid the heavy current and also to avoid moving too far out to sea (Hickam 1989:11). Merchant captains initially ran at night and close to shore with the belief that darkness would camouflage their movements and U-boats would not operate in such shallow water. They were wrong on both accounts (Hickam 1989:58). Despite the carnage, merchant captains refused to heed Admiral Andrews' suggestions, which were to zig-zag both day and night, to only traverse the dangerous waters off Cape Hatteras by day, to keep their ships darkened at night, to consistently post lookouts, and to keep radio traffic to a minimum (Hickam 1989:169).

As another precaution, Andrews consolidated and moved the shipping routes so that they could be easily patrolled and protected. In addition, another defensive tactic was the placement of mines along the eastern coastline to deter U-boats. Admiral King ordered mines placed at the entrance of several important navy bases and harbors prior to America's entrance in the war. Throughout April 1942, plans were made to build safe anchorages using minefields in key locations along the coast where merchant vessels could wait through the night before traversing dangerous waters. One such location was the Cape Hatteras minefield (Figure 20), completed by the end of May 1942. The minefield and safe anchorage were laid with 2,500 mines. John Wagner (2010:89) described:

> In the end, the field consisted of two crescent shaped fields each 17 miles long and overlapping in the center for a distance of two miles and spaced approximately a mile and a half apart in the center. The easternmost leg consisted of three separate rows of mines, each spaced 500 yards apart, that begun south of Cape Hatteras Light and bent southwest towards Ocracoke Inlet. The westernmost

> leg consisted of four rows of mines, also spaced 500 yards apart, commencing just northeast of Ocracoke Inlet and curving northwest towards Cape Hatteras Light.

The minefield proved effective, but not against U-boats. Over the next few months, several Allied vessels were lost to the mines (Wagner 2010:79-90).

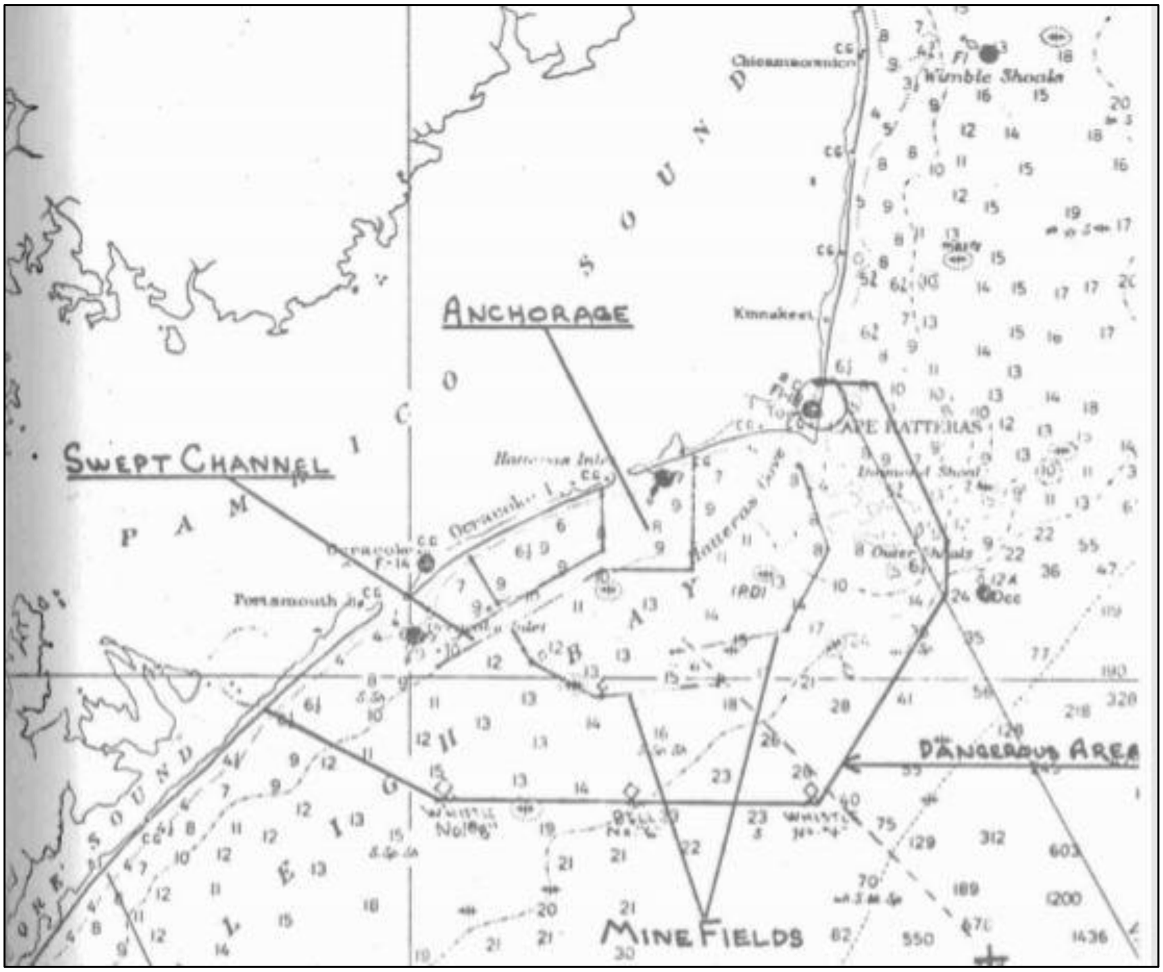


Figure 20: Cape Hatteras minefield and anchorage (Freeman 1987:421).

Throughout the spring of 1942, merchant vessels continued to fall prey to the U-boats. Andrews still did not have enough naval forces to create effective convoys. Until he could procure more warships, he devised a system that used the destroyers and Coast Guard vessels he had to serve as escorts for groups of merchant ships for a set distance, where another escort would be waiting. Groups of merchant ships then passed between different escorts. Andrews dubbed this system the “Bucket Brigades” (Hickam 1989:173-175). As the naval presence on the

East Coast increased, these became fully escorted convoys which included armed merchant ships, Coast Guard vessels, air cover, and destroyers.

Allied Sonar, Radar, and Position Fixing Methods

Three important concepts to consider when analyzing the inaccuracies of the reported locations of merchant shipwrecks and U-boat wrecks are sonar, radar, and the position-fixing methods of the Allied warships and merchant vessels leading up to and during the Second World War. Each were modernized as technology advanced during the early 20th century, and vessels moved from wooden hulls to steel. Further changes were the introduction of submarines and aircraft, which needed more sophisticated position-fixing methods as well as new technology to locate enemy combatants. The introduction of the submarine required modification to equipment and methods that used sound waves underwater for navigation. Some of the early work was for the purpose of avoiding hazards. Echo-sounding equipment was utilized for monitoring bathymetry, while sub-signaling technology utilized submerged microphones to detect submarine bells that were placed around dangerous points to navigation. Sub-signaling devices were installed in Navy ships as well as numerous merchant ships (Howeth 1963:300). From these sounding devices, the development of sonar devices continued into the First World War to assist in locating enemy submarines.

During the interwar years, the British developed the ASDIC apparatus, which used underwater sound waves to detect a submerged U-boat. The ASDIC equipment was like the sonar developments installed in U.S. naval vessels after the First World War, but with a streamlined housing and the ability to make a permanent recording of the range of detection.

U.S. companies quickly adopted the streamlined model, which increased the speed at which the apparatus could be used, from 3-4 knots to 15 knots. With similar sonar equipment at the start of the Second World War, the British and U.S. militaries were prepared to handle the U-boat threat on a technological front, as these machines could detect submerged U-boats up to 2,000 yards ahead of the vessel. U-boat commanders were well trained in evasive maneuvers, however, which allowed U-boats to escape destruction 95% of the time after detection (Howeth 1963:472-475; Doenitz 1990:12; Bright 2012:178).

The U.S. Navy received updated sonar equipment during the interwar period. Sonar schools were set up in Key West to train sonar operators in the use of these instruments. In the spring of 1942, the Antisubmarine Warfare Operations Research Group set up headquarters in Boston and later Washington, DC. This group was commanded by Captain Wilder D. Baker, an experienced destroyer captain and escort group commander. Their task was to, as historian Homer Hickam (1989:168) described it, “begin applying scientific methods to killing submarines.” Utilizing imported British models and given unique powers directly from Admiral King, the group worked to standardize antisubmarine tactics, weaponry, and training based largely on the results of the Royal Navy’s encounters with U-boats during the First World War (Hickam 1989:168; Blair 1996:479).

While sounding devices and sonar were used to assist in navigation and detection of underwater features, other devices were used on the surface. Throughout the 18th and 19th centuries, the primary method of position fixing was the sextant. The method developed by John Hadley in 1731 was the same method used into the mid-20th century by steel vessels, although the instruments were refined (Ifland 2000). To find direction, the magnetic compass had to be updated by using an electrical current to maintain the spin of the compass within a steel vessel.

This was the birth of the gyrocompass, first tested in a freighter off the east coast of the USA in 1911 (Huntley 1961:10). Both methods were used alongside a relevant navigational chart. For these methods to be accurate, however, the operator must have a clear visual of the sky and horizon. During the early 20th century, experimentation with the use of radio waves to determine direction and position was conducted by the U.S. Navy. The radio direction-finder is the product of several years of trial and error that began in 1906 and again in 1913. The first successful device was based on the design of Frederick A. Kolster in 1915, and adaptations were installed on battleships and cruisers until a smaller version was produced in 1917 for installation on destroyers. These allowed the commanders to identify and locate U-boats by following their radio traffic, which was highly effective in demoralizing Germany's U-boat crews.

In early 1918, the Chief of Naval Operations and his planning committee determined that shore-based systems in the USA, constructed around major harbors using a series of radio transmitters could assist in navigating vessels through bad weather and poor visibility. This was approved, and fast construction allowed them to assist the troopships returning with U.S. soldiers from Europe. The system was effective, and direction-finding stations were established around all major ports in the USA, in the Great Lakes, and around dangerous navigation points around the coast (Howeth 1963:262-265).

In the fall of 1919, further tests were conducted on the use of radio transmitters placed at different locations on shore to triangulate the position of a ship with a direction finder installed at sea. This idea was tested on the lighthouse tender *Arbutus* with radio transmitters positioned in three lighthouses. The results of these tests (Figure 21) were very optimistic.

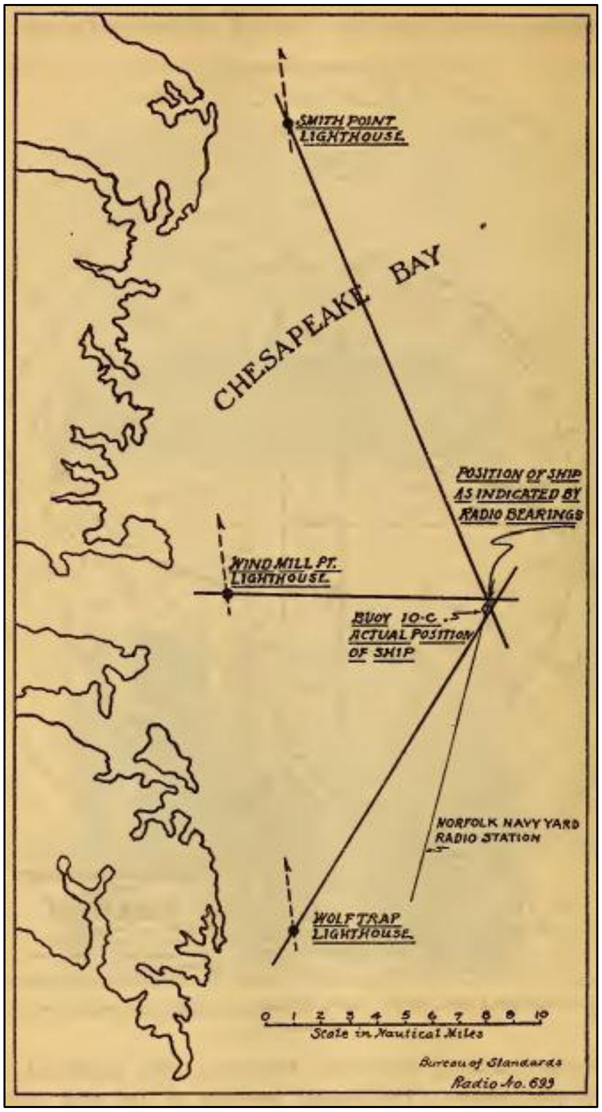


Figure 21: Direction finder triangulation of lighthouse tender *Arbutus* (Kolster and Dunmore 1921:554).

The following year, a similar test was conducted on the lighthouse tender *Tulip*, which traveled 45-miles along the shore and was tracked using radio signal triangulations with an exaggerated error of plus or minus 2 degrees. The transmitters were effective and easily installed at lighthouses or on lightships to accurately track vessels moving up and down the coastlines. Furthermore, a vessel in destress could accurately signal its location to shore or other vessels with direction finders, as shown in the rescue of the disabled Norwegian steamer *Onataneda* by the *Fanad Head*, which used its own radio direction finder to locate the vessel despite the SOS position being 90 miles in error. Coast Guard vessels adopted the use of the radio direction finder, or radio compass, to aid in rescue work (Kolster and Dunmore 1921:552-566; Tuska 1939:597-598).

The Navy's interest in radio waves continued beyond navigational purposes. Radar was developed based on the use of radio waves to detect enemy ships, submarines, and aircraft. Advancements in radar experimentation and production took place prior to the U.S. entry into the Second World War. In the late 1930s, the U.S. Navy worked on adding radar equipment to warships. In the spring of 1937, an experimental 200 mc radar was temporarily installed on the *Wickes*-class destroyer USS *Leary*. Due to low power in the antenna, the radar was only able to locate aircraft at a range of 18 miles. Nevertheless, the results were encouraging. The following year, the battleship USS *New York* was selected for the experimental installation of 200 mc radar given the designation XAF. Once again, the tests proved successful. A contract for six sets was awarded in October 1939, and the first production models, designated CXAM, were delivered in May 1940. Research was also conducted to design equipment like the CXAM for installation on smaller vessels. This design, designated as SC or SA (those produced by the Radio Corps of America), was produced in large quantity, and used extensively in all theaters of the war (Howeth 1963:447-460).

In June 1941, the Navy granted a contract for SG radars, a microwave surface search radar that was developed alongside the airborne microwave set, or ASV. Clay Blair (1996:476) notes the airborne model as the ASG, known as "George," was able to detect a coastline at a range of 100 miles, convoys at 85 miles, and a surfaced U-boat at nine miles. The radar was successfully tested on USS *Semmes*, an old *Clemson*-class destroyer, throughout the spring of that year (Howeth 1963:468). Radar devices installed on destroyers were later used to detect U-boats on the surface, such as the case of *Wickes*-class USS *Roper* against the Type VIIB U-85 in April 1942 (Hickam 1989:154-55,167). According to the recordings of *Lloyd's Register of Shipping* 1942 and 1943, all Allied merchant vessels in the study group save for *Ashkhabad* (which is unknown) are recorded as having direction finders; three were recorded as having an installed gyrocompass, four had sub-signaling devices, and five had echo-sounding devices.

By the time of the Second World War, the use of radio waves for navigation and position fixing had improved. Research was being conducted on high-frequency direction finders, known as "Huff Duff," which would enable warships to pinpoint the location of surfaced U-boats that attempted to communicate with German U-boat Command, which Doenitz insisted on at least once a day if possible. This system was first installed on a new destroyer in the spring of 1942. Another innovation in radio navigation was Long Range Aid to Navigation, or LORAN, a system developed in early 1941 that used radio pulses to provide nearly precise navigational fixes from shore out to 700 miles during the day and 1,400 miles at night. LORAN was first established in stations in Canada and Greenland to track the Atlantic convoys (Hickam 1989:168; Blair 1996:476-478). The effect that either LORAN or Huff Duff had on the merchant shipping off North Carolina in the spring of 1942, however, is unknown.

Other navigational features included lighthouses and lightships. Although these were not technological instruments within the ship, they were nevertheless used for assistance in position fixing for vessels near shore. There were several lighthouses along the Outer Banks. The Cape Hatteras lighthouse beacon was moved roughly a mile northwest from its former position in 1935. A new steel skeletal tower was built due to beach erosion impacting the structure and was leased to the U.S. Coast Guard as an observation tower during the Second World War. It was returned to the original brick tower after the beach erosion was stabilized in 1950. The light could be seen from approximately 16 miles offshore (National Park Service 2020). In 1898, the first lightship was stationed off Diamond Shoals to assist the Hatteras lighthouse. This was located roughly 15 miles southeast from the lighthouse's skeletal tower location and 14 miles southeast from its current location (Riemenschneider 2020a). As of 1943, the skeletal tower (located in Buxton, NC) also contained a radio direction finder. This, as well as the Cape Hatteras Lifeboat Station can be seen on the Cape Hatteras Location Map of the U.S. Coast Guard from January 1943 (Figure 22).

The Cape Lookout lighthouse received a radio beacon as well as four 250-watt T-14 electric bulbs in August 1933. That same year was the last year a lightship was stationed off Lookout Shoals until the outbreak of war (National Park Service 2017). The lightships were moored to the southern end of Cape Lookout Shoals to assist in navigation, roughly 20 miles south-southeast from the lighthouse. The lightships were also equipped with a radio beacon and a submarine bell (Riemenschneider 2020b). A third lighthouse, on Ocracoke, used a stationary light equal to 8,000 candlepower and could be seen 14 miles out to sea (National Park Service 2018).

German Efforts

In the fall of 1935, Doenitz was given command of the Weddigen Flotilla. Luckily, as Doenitz himself said, "as to the training of this first U-boat flotilla we had possessed since 1918, I had received neither orders, instructions nor guidance" (Doenitz 1990:13). Doenitz had his own plans for developing a formidable U-boat force. Doenitz drilled his U-boat crew day and night to deal with any situation that may have arisen in war and experimented with different tactics.

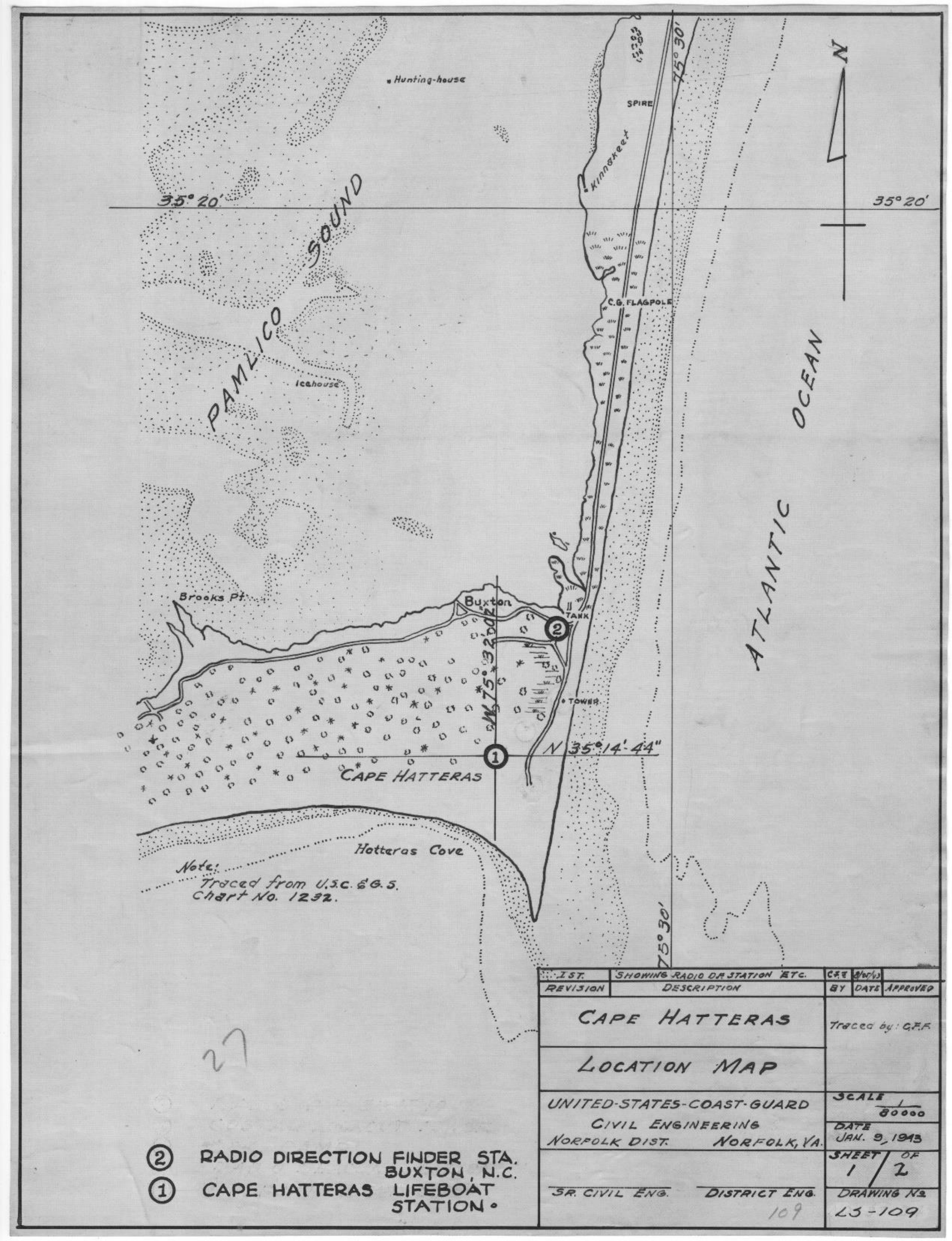


Figure 22: Location map of Cape Hatteras, NC, from January 1943. Note the location of the brick tower northeast of the lifeboat station (U.S. Lighthouse Society 2020).

One of these tactics involved a coordinated attack utilizing multiple U-boats on a single target. This was to combat the convoy system that destroyed the submarine campaign of the First World War. The tactic was to be later known as the wolf-pack. During the intense drilling, the crews became very confident in their branch of service as well as in their commander. The following year, Doenitz was appointed Officer Commanding U-boats (Doenitz 1990:13-19).

In the winter of 1938-1939, Doenitz concluded that to attack the convoys, he required at least 300 U-boats. Of these, at least 100 could be stationed in the Atlantic at any time (Doenitz 1990:33). His request, however, was denied and in January 1939 Hitler approved the Z Plan, which was Germany's naval strategy that sought a well-balanced fleet with heavy striking power in a campaign against British shipping. The plan called for the six-year construction of six battleships in addition to *Bismarck* and *Tirpitz*, light, and heavy cruisers, four aircraft carriers, and 233 U-boats. The U-boats were to serve in tandem with the surface forces in organized battle groups in the Atlantic. When the UK declared war in September 1939, however, the Z Plan was revisited as few of the surface ships were completed in time. Germany's navy was ill-prepared for war (Doenitz 1990:37-42).

German U-boats

In the summer of 1935, the German Navy had a total of 24 U-boats either completed or under construction. Of these, 12 were the 254-ton Type II U-boats, which due to their small size, were restricted to the North Sea, the east coast of England, and the Orkney and Shetland areas. Two were the larger Type I. These, however, were unsatisfactory due to their difficulty in handling and deep incline to the bow during a rapid dive. The Type I model later became the basis for the development of the Type IX. The final 10 were Type VII, which were highly effective. By the outbreak of war in September 1939, Germany had 56 U-boats in commission, but only 46 were ready for action. Of these, only 22 were suitable for service in the Atlantic. The remaining 22 were the small Type II (Doenitz 1990:46). More U-boats still were under construction as Doenitz pushed for a larger U-boat contingent which mostly consisted of the effective Type VII and the larger Type IX boats.

The Type VII was a 626-ton U-boat that held four torpedo tubes in the bow, one in the stern, and could carry 12-14 torpedoes. It reached 16 knots on the surface and handled smoothly. Its limited capacity for 67 tons of oil, however, kept its radius of action at only 6,200 miles. This problem was solved by repurposing the space available within the craft and increasing the total size to 753 tons. This raised the oil capacity to 108 tons and gave the U-boat an additional 2,500 miles of radius. The modified U-boat was designated the Type VIIB (Hessler 1989:4; Doenitz 1990:29-30,479). The Type VIIB was again modified by slightly lengthening the vessel by two feet to allow room for the installation of the new *Such Gerat* (seeking device) active sonar, which could detect both mines and targets.

In addition to these modifications, more space was added to the conning tower, and both the fuel and saddle tanks were lengthened. Finally, a modernized filtering system, new Junkers air compressor, and two quick-dive tanks were added. This new design became the Type VIIC (Figure 23) and served as the workhorse for Germany’s U-boat force. (Krzysztalowicz 2012). These new boats made up 94% of Type VII U-boats by the end of the war. The Type VIIC was 221 feet long, 769 tons, and could maintain 17 knots on the surface and a max speed of 7.6 knots when submerged. The range of the Type VIIC was comparable to the VIIB. Finally, both designs had a registered max depth of 309 feet and were complimented by a crew of 44 (Hessler 1989:114-115).

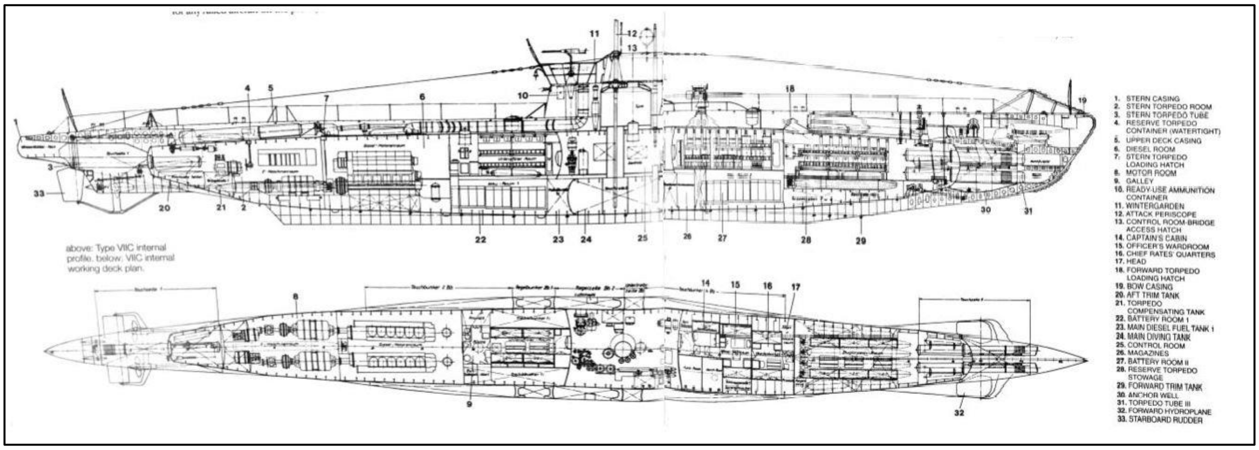


Figure 23: Schematic of Type VIIC U-boat (Kaplan and Currie 1997:72-72).

The contract for the first four Type IXs was given on 29 July 1936, and a contract for a second four was drafted shortly thereafter. The first three of these boats were completed in 1938, and the rest were completed in the following year. In December 1937, a design modification was given to increase the fuel capacity and move the deck gun farther aft. The new model was designated the Type IXB, and these were completed and launched shortly after the first Type IX. The Type IXB was again altered to allow an increase in fuel capacity, although at a slight cost in surface speed due to an increased displacement. This became the Type IXC. The Type IXB was 252 feet long, while the IXC was 237 feet long. Both models had a beam of 22 feet, a draught of 14 feet, carried a crew of 48 and had a maximum operating depth of 330 feet. Additionally, both models had a maximum speed of 18.2 knots on the surface and 7.3 knots submerged. Due to the increase in fuel capacity, the IXC had a greater range of 13,450 miles at cruising speed (10 knots) while the IXB could make 12,000 miles. Due to their large range, the first U-boats to enter U.S. waters were Type IXC (Hessler 1989:116-117; Doenitz 1990:197-198; Thew 1991:14-17).

U-boat Weapons and Technology

German U-boats were equipped with an assortment of technical features to wage war. For possible surface engagements, both Type VII models were armed with an SKC/35 88mm cannon mounted forward of the conning tower (Figure 24). The SKC/35 was developed after 1933 and was used on most early Type VII U-boats as well as some Type IX boats. It fired a 20-pound (9 kg) projectile roughly 7.5 miles (12 km). Type VII models were also equipped with an SKC/30U 37mm Flak gun (Figure 25), which had a range of 8,500 meters and an anti-aircraft ceiling of 6,800 meters, and two 20mm machine guns for anti-aircraft defense located on a platform abaft the bridge, which the Germans called the "Winter Garden." The Type IX was commonly fitted with an SKC/32 105mm cannon, which fired a 33-pound (15 kg) projectile to nine miles (15 km), to replace the 88mm on the Type VII. They maintained the 37mm Flak gun and two 20mm machine guns of the smaller model. U-432, which was recorded as having used its deck gun against *Marore*, was a Type VIIC, and thus likely had the SKC/35 88mm gun, while U-432, which used its gun against *Ario*, was a Type IXC, and was likely armed with the SKC/32 105mm cannon. Further, most Type IX models were fitted with a Metox R600 radar detector to assist in evading pursuing craft. Many were also fitted with crude 80cm wavelength GEMA radars projecting from the front of the conning towers. This could only scan forward of the bow, and the U-boat had to fully circle to get a 360-degree scan (Campbell 1985:248-251; Hessler 1989:114-115; Kaplan and Currie 1997:76; Mehl 2002:117-120; Bright 2012:160-162).

A final advantage to their larger size was that the Type IX was able to carry a maximum of 22 torpedoes, although 19 was the standard. The torpedo was a U-boat's primary weapon (Hessler 1989:117; Thew 1991:17).

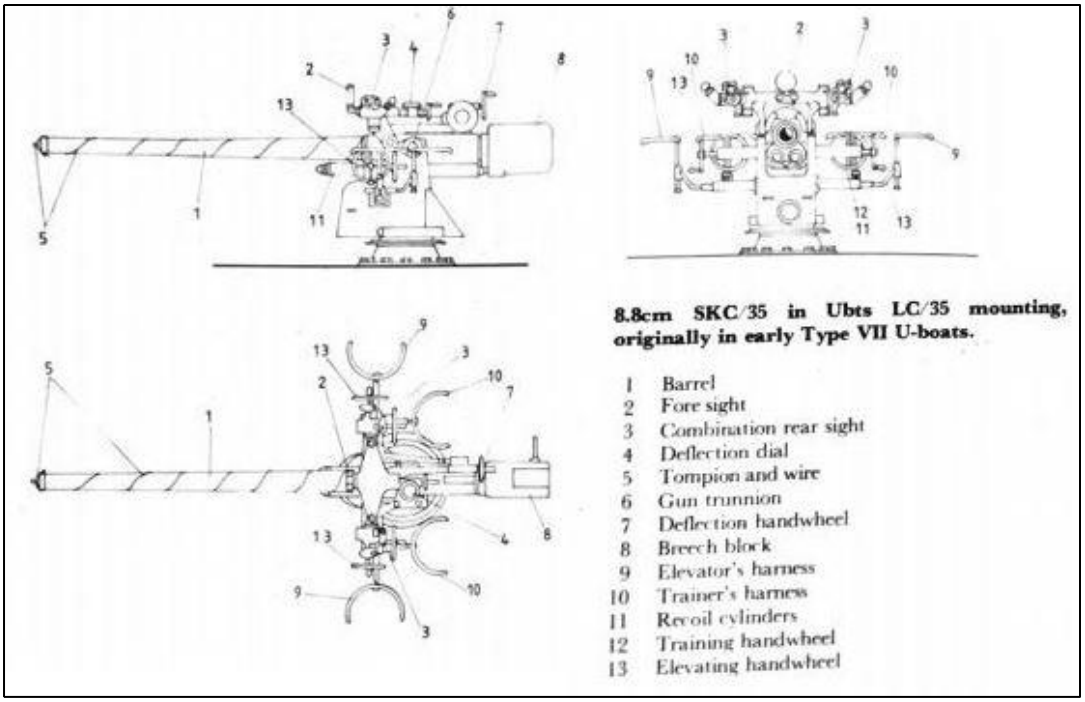


Figure 24: Schematic of SKC/35 88mm gun used on many U-boats (Campbell 1985:252).

During the first years of the war, German U-boats primarily used one of two types of torpedoes. The most common was the G7a, which utilized compressed air and had a range from 700 to 14,000 meters. The second was the G7e (Figure 26), which used an electric propulsion system. This system gave the G7e a shorter range, only 5,000 to 5,700 meters, but allowed the torpedo to travel without a visible wake. Both torpedoes used a 300-kilogram warhead that utilized a mixture of aluminum (which represented nearly one quarter of the total weight of each warhead) and a hexanitrophenylamine (HND) TNT mix developed during the First World War. The warhead was detonated by using either a magnetic pistol that was triggered by a magnetic disruption (such as being near the hull of a ship) or a contact pistol that was triggered upon impact. The G7a torpedo weighed a total of 1,528 kilograms, while the G7e weighed 1,603 kilograms (Bright 2012:159-160). Although the torpedo was a deadly weapon in theory, it proved to have flaws.

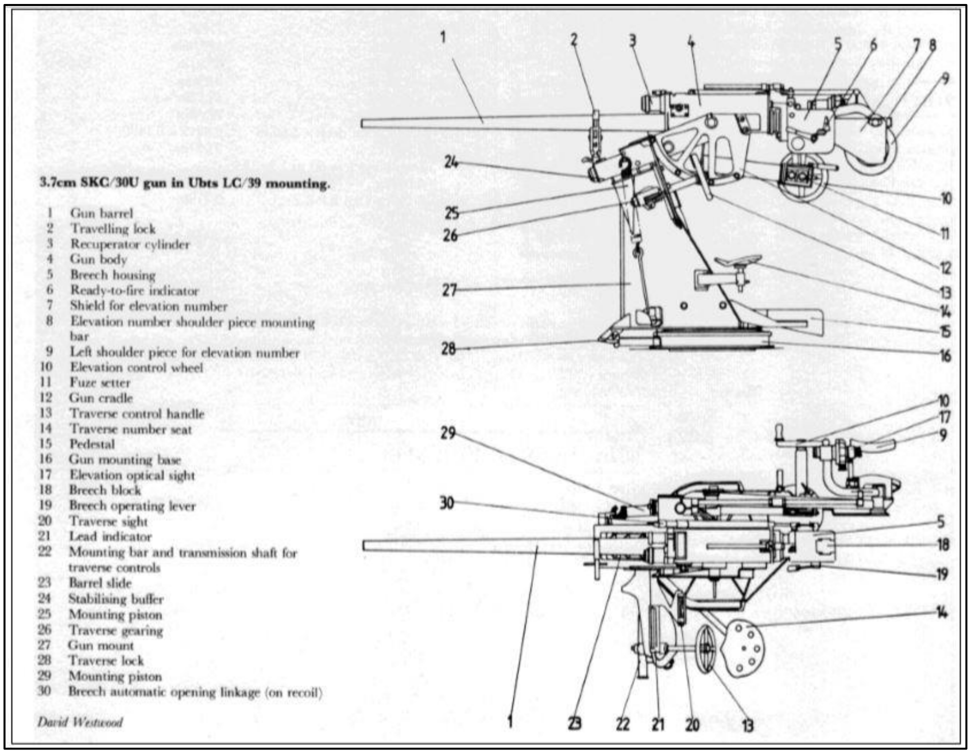


Figure 25: SKC/30U anti-aircraft machine gun (Campbell 1985:256).

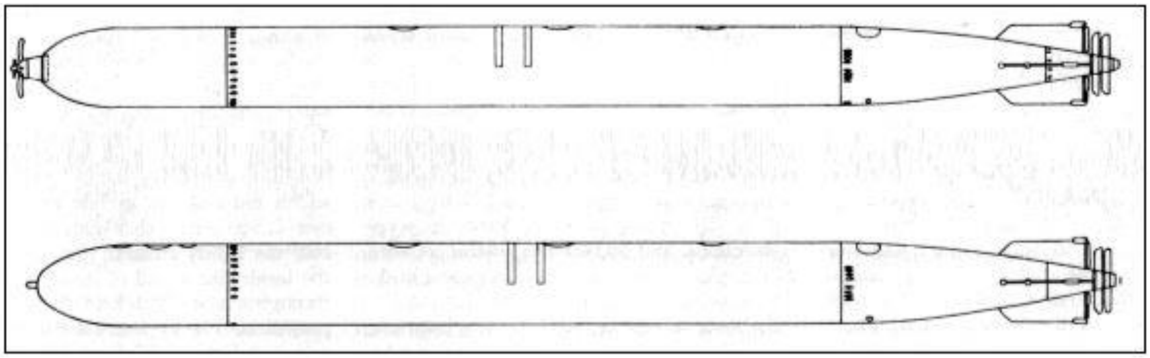


Figure 26: Schematic of G7e torpedo (Campbell 1985:263).

At the beginning of the war, many submariners believed that the torpedoes were defective. Unfortunately, neither the U-boat captains, officers of Doenitz’s staff or even Doenitz himself were able to solve this issue. Having no training as engineers or scientists (few had attended college), Doenitz’s staff had to rely on the technicians of the Torpedo Directorate for assistance (Blair 1996:104). At first, the Directorate maintained that the malfunctions were the result of poor torpedo handling and inaccuracy from the captains. Due to the testimonies of several reliable captains, including Gunther Prien of U-47 (having had torpedoes fail against the British battleship *Warspite*), Doenitz persuaded Grand Admiral Erich Raeder to order a full review of the malfunctions by the Directorate (Doenitz 1990:85; Blair 1996:105). The Directorate conceded that mechanical flaws may be interfering with the magnetic pistol, causing premature detonations. Doenitz also believed, along with many of his captains, that the torpedoes armed with magnetic pistols were running deeper than set, but this problem was not addressed by the Directorate (Blair 1996:105).

Due to problems in the magnetic pistol of the torpedoes, in June 1940, Doenitz ordered all torpedoes to be armed only with contact pistols. To fully test the overall effectiveness of the contact torpedoes, an analysis was made of 816 hits made by U-boats between January and June 1942. As Doenitz (1990:94) described, “40 per cent of the ships, we found, had been sunk with one torpedo, 38 per cent had required two or more before they sank, and 22 per cent escaped after being hit by anything from one to four torpedoes.” Many tankers and freighters were left alone because the U-boats had used all their torpedoes giving a *coup de grace* to ships that had already been hit (Doenitz 1990:95). It was not until December 1942 that the new Pi2 magnetic pistol was introduced. Therefore, it can be concluded that the U-boats in this study were armed with torpedoes that had only contact pistols and had to directly hit the ship to have an effect.

U-boat Tactics

Fundamentally, a U-boat’s attack relied on the element of surprise. Due to its size and light armament, it was ill suited for a surface engagement with a warship. Its ability to dive and move through the water column out of sight enabled it to attack without being seen until it was too late. Further, the ability to dive under water was also a U-boat's primary defense. This puts the U-boat out of range for surface gunnery action from warships or aircraft. This does not, however, deter an attack from depth charges. A direct hit from a depth charge while submerged would be catastrophic, while a near miss could cause a shock wave through the water that caused serious damage. Thus, while diving deep to escape attack from a ship's surface guns, the U-boat utilized its electric motors to evade depth charges. Sonar made a submerged U-boat a slightly easier target to track. Therefore, a U-boat's best chance of survival while under attack was to escape the attack area by speeding up when enemy activity on the surface increased and slowing down or stopping when enemy activity slowed (Carruthers 2012:101).

An advantage for the U-boats in the waters of North Carolina was the mixing of cold water from the north and the warmer Gulf Stream. This causes a stratified water column with mixed temperatures and salinity, which disrupts the sound waves of the sonar (Howeth 1963:474; Carruthers 2012; Bright 2012:128). The worst case for a U-boat was to be caught on the surface in daylight. As such, many U-boats traveled on the surface at night and retreated to the bottom during the day. Long hours in a cramped U-boat without fresh air was discomforting for the crews. Nonetheless, Admiral Doenitz instilled a level of comradery between himself, his captains, and their crew members (Hickam 1989:260; Kaplan and Currie 1997:7).

The U-boat's preferred attack was short-range, where the likeliness of a direct hit was higher. A short-range attack, however, was not to be carried out at a range under 300 meters for the safety of the U-boat. To carry out an attack at close range, the attack must be invisible, either by the cover of darkness or by attacking from underwater by judicious use of the periscope and utilizing the G7e torpedo, leaving no visible bubble trail. A close-range attack on a slowly moving ship should be made at 90 degrees, while a longer shot (over 1,000 meters) on a faster target should be made at a smaller angle, such as a 60-degree shot. Thus, the distance and speed of the target determined the angle of attack. To acquire the best estimates on speed and bearing, as well as to obtain the best possibility for a shot, a U-boat should position itself forward of the beam of the enemy vessel (Carruthers 2012:44-47). If the range was over 1,000 meters, several torpedoes should be fired at once in a fan pattern (Carruthers 2012:77).

It was best for a U-boat to attack with the sun behind, as a periscope would be lost in the reflection of the water, while the torpedo control officer had a clear view of the target’s outline. This also worked well for night attacks along the U.S. shores, as the liberal light policy of the eastern seaboard often outlined the ships, making them easier targets. An attack from the windward side of the target was preferred, as the periscope moved with the sea, making it more difficult to detect. A two to four wind state and two to three sea state were the most favorable, while rough or flat seas made carrying out an attack difficult or risky (Carruthers 2012:48). In the study area off Cape Hatteras, U-boats made special use of night attacks, since the cover of darkness allowed them to move undetected closer to shore and sink merchant ships hugging the coast using lighted buoys as navigation points. The lights of the East Coast further illuminated these ships, which Admiral Andrews had no control over (Hickam 1989:58). To assist one another in hunting merchant ships, as well as to avoid giving away their location, U-boat commanders adopted a unique position-fixing method.

The Germans developed a grid system prior to the Second World War to communicate the locations of ships and convoys to one another without the location being understood by the Allies. This grid system (Figure 27) consisted of 536 large grid squares worldwide, 465 of which were equal in size. Each square, called a Großquadrat, was divided into nine smaller square sections, and each of those divided again by nine, making a total of 81 small squares, known as

Kleinquadrats. Großquadrats were identified using two letters. Each sequential sub square was identified by its number in the grid arranged like the number pad on a telephone. Each reported attack consisted of the letter designation followed by four numbers indicating each sub square's location within the larger one (Figure 28). For distance, each Kleinquadrat was roughly six by six nautical miles, or 36 nautical miles in area (Kockrow 2012; Hessler 1989).

Conclusion

The technological advancements made in naval warfare throughout the early 20th century were many, but the introduction of the aircraft and submarine, as well as the weapons used by and against them, such as depth charges, torpedoes, and anti-aircraft guns, are perhaps the greatest stride from traditional naval doctrine, as the Second World War was the first time these technologies were used in a more strategic, less experimental role. These innovations brought the battlefield from mostly two-dimensional to three-dimensional, with combatants on the water, under the surface, and in the skies. The technology used to detect these combatants as well as to keep track of friendly forces also improved, such as radar, sonar, and direction-finding devices. The Allies developed special tactics to combat the German U-boat menace. Conversely, Doenitz and his team of commanders further adopted tactics to counter those of the Allies. Each force adapted and counter-adapted their technology and tactics against one another throughout the remainder of the war.

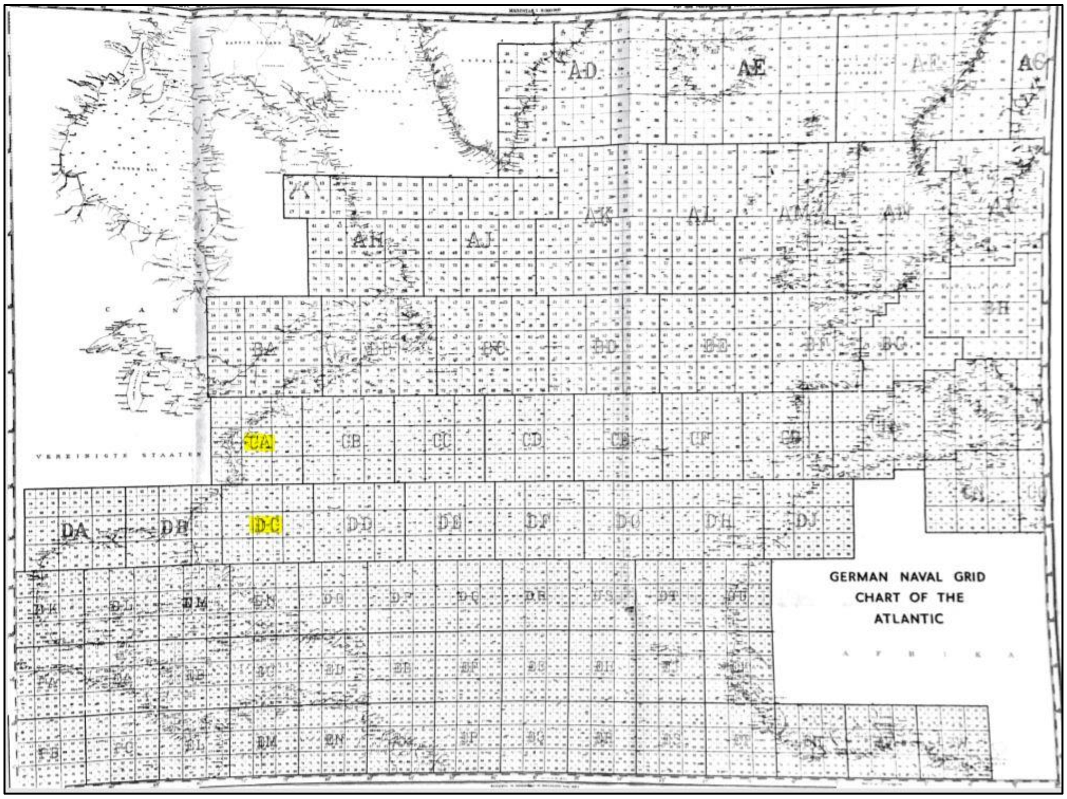


Figure 27: German naval grid of the Atlantic Ocean. Vessels in this study were recorded by Captain Jurgen Rohwer as being attacked in zones DC and CA, which are highlighted (Hessler 1989).

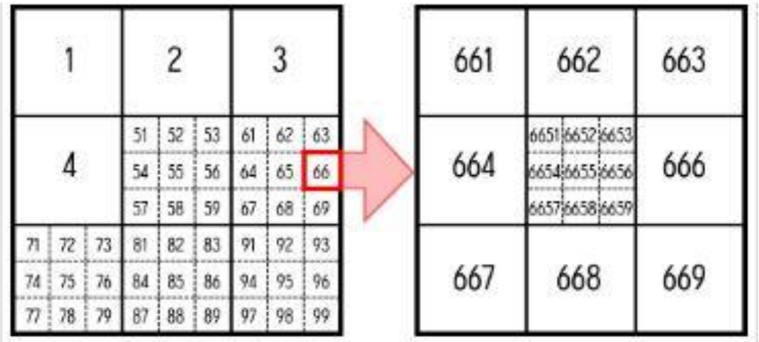


Figure 28: Method of reading German grid squares (Kockrow 2012).

CHAPTER 5: DISTANCES AND DIRECTIONS: GEOSPATIAL ANALYSIS OF THE VESSELS OF TORPEDO JUNCTION

Introduction

This chapter outlines a series of geospatial descriptions of North Carolina's Second World War naval battlefield. These descriptions display and manipulate geographic data and serve to outline the level of accuracy for reported vessel positions. The following chapter then outlines their usage as a foundation for geostatistical analyses (Chapter 6). Geographic data includes the position of the vessels, various recorded positions, the locations of military bases, merchant vessel routes, bathymetry, and German grid zones. These were all entered into a GIS database, which was then used to view selected positions and calculate distances and headings. These calculations permit the level of accuracy to be determined for both the Allies and the German U-boat commanders.

Geospatial analysis allows for the visual depiction of spatial accuracy levels (i.e., the distance between recorded positions and actual shipwreck locations). Further, this allows a measure of the distance as well as the heading from the wreck to the recorded points as well as any other features. Patterns begin to emerge by viewing the wrecks and recorded positions in relation to one another, geographical features (e.g., the Outer Banks and the Continental Shelf), and important features such as military and naval bases. This study examines the distances and headings from each of the wrecks as they sit today from their respective centroids created from the historically recorded points and the central point of the recorded German grid zones. Centroid analysis creates a set of standards by which to measure accuracy and precision.

Accuracy is measured by the distance from the historical records (centroids for Allied points and German points for U-boat accuracy) while precision is the distance between the centroid and the German points. For example, a centroid and German point being relatively close together while far from the wreck site designates a high level of precision, but low accuracy.

GIS Data Analysis of Merchant Vessels

To spatially understand the differences in accuracy, three different sets of points were calculated, input to a GIS database, and compared for analysis. The first set is the coordinates of the wreck as recorded and provided by NOAA's MNMS, (Figure 29). The second set is the calculated coordinates of the centroids, which is located at the center of a convex hull, the area created by all historically recorded coordinates. These historically recorded coordinates are displayed in comparison to NOAA's positions in Figure 30.

The convex hulls, described in Chapter 3, are displayed in Table 6. There are two features to note. The first is that only 23 of the 27 vessels were given convex hulls. This is because the other four vessels: HMT *Bedfordshire*, *Equipoise*, *Esso Nashville*, and *Norvana*, did not have more than one set of recorded coordinates. With only one set of points, a convex hull, which denotes the area spanning the recorded points, is not possible. The second feature to note is that many vessels do not have an area associated with them. These vessels only contain two recorded points.

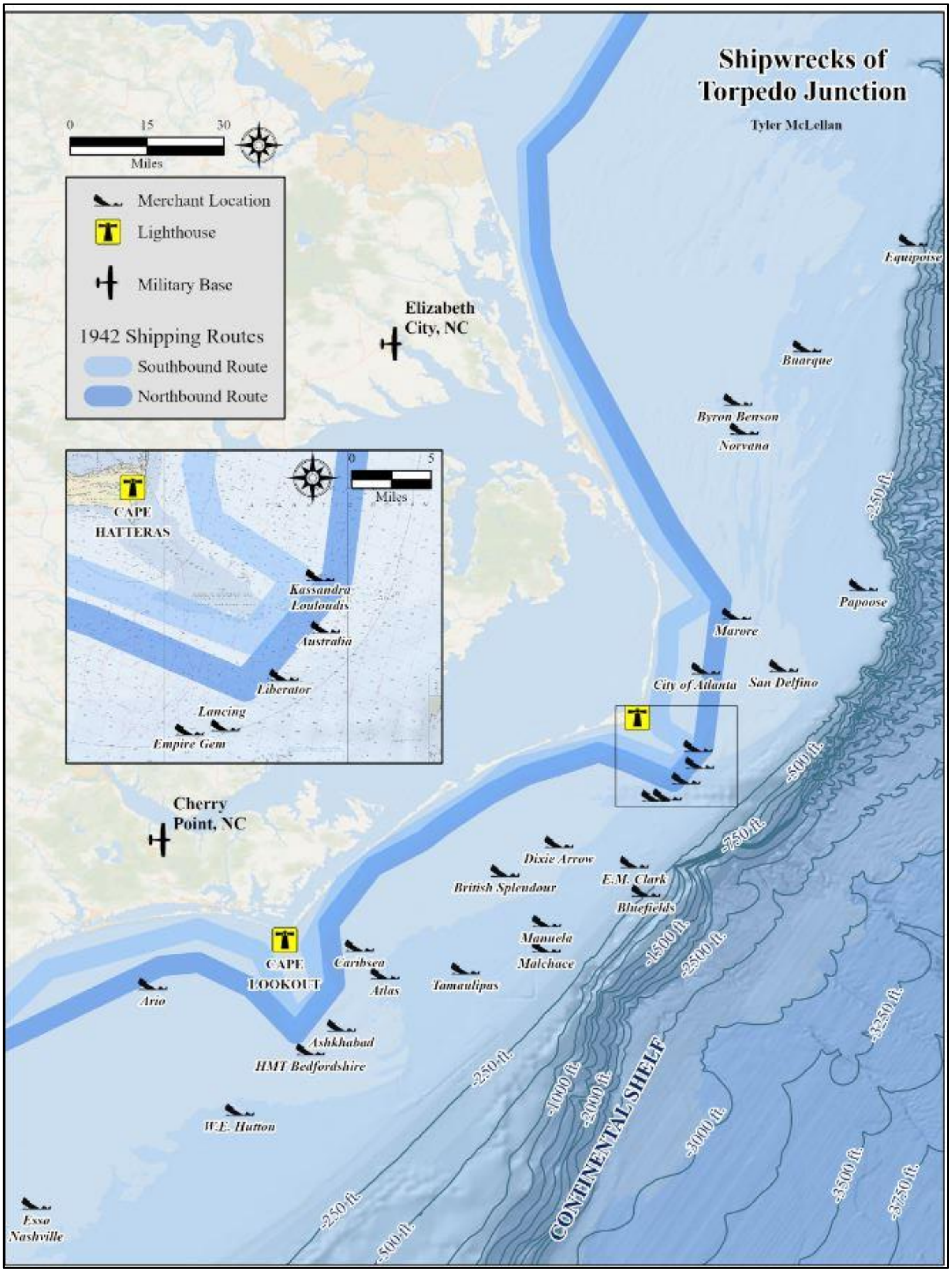


Figure 29: Wreck locations as provided by NOAA's MNMS. (Map by author, 2020.)

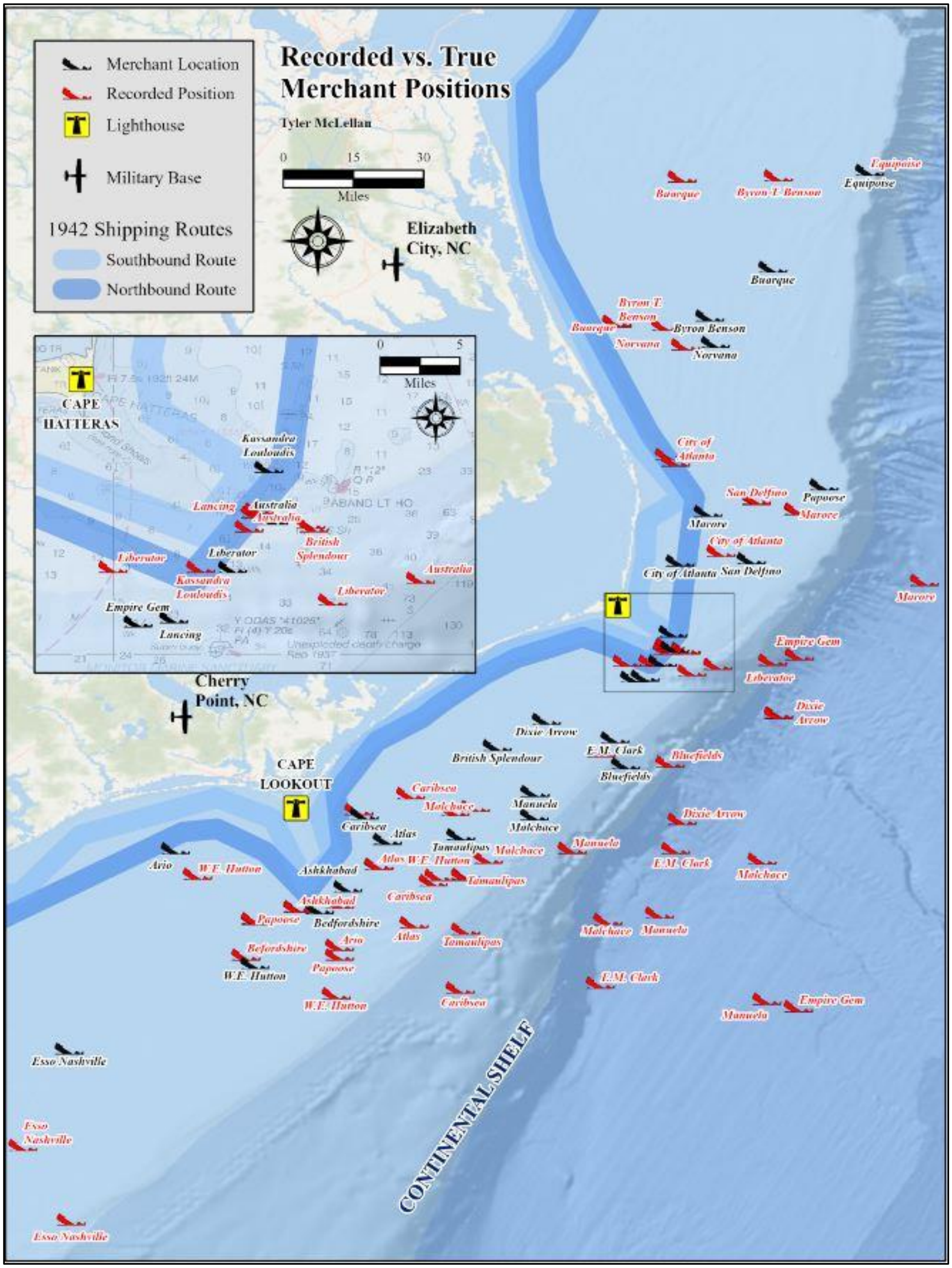


Figure 30: Recorded coordinates around the vessel’s true coordinates. (Map by author, 2020.)

The perimeter of these points represents the linear distance between the two points. The centroid is the representation of the center point, or average, within the convex hull, and thus serves as the historical point by which the level of accuracy for the merchant vessels is recorded. The centroids and convex hulls for each of these vessels are displayed in Figure 31.

Table 6: Area sizes of the convex hulls created from the historically recorded coordinates.

Ship	Number of Points	Area of Convex Hull (sq. mi)	Perimeter of Convex Hull (mi)
Ario	4	379.11	115.31
Ashkhabad	2	0	0.35
Atlas	2	0	0.54
Australia	2	0	83.14
Bluefields	3	190.74	190.03
British Splendour	4	6.52	13.65
Buarque	4	495.83	103.35
Byron T Benson	2	0	83.52
Caribsea	2	0	84.95
City of Atlanta	3	107.20	68.02
Dixie Arrow	4	31.46	60.27
EM Clark	2	0	98.04
Empire Gem	4	1391.85	185.23
Kassandra Louloudis	2	0	0.62
Lancing	2	0	0.54
Liberator	3	1.25	51.01
Malchace	3	266.65	111.44
Manuela	3	336.78	129.60
Marore	2	0	0.034
Papoose	3	.59	23.06
San Delfino	2	0	0.42
Tamaulipas	2	0	0.42
W.E. Hutton	3	499.61	108.68

The third set of positions utilized in this study is the calculated coordinates of the German point created by entering the historically recorded German grid square number (Table 7), detailed in Chapter 3.

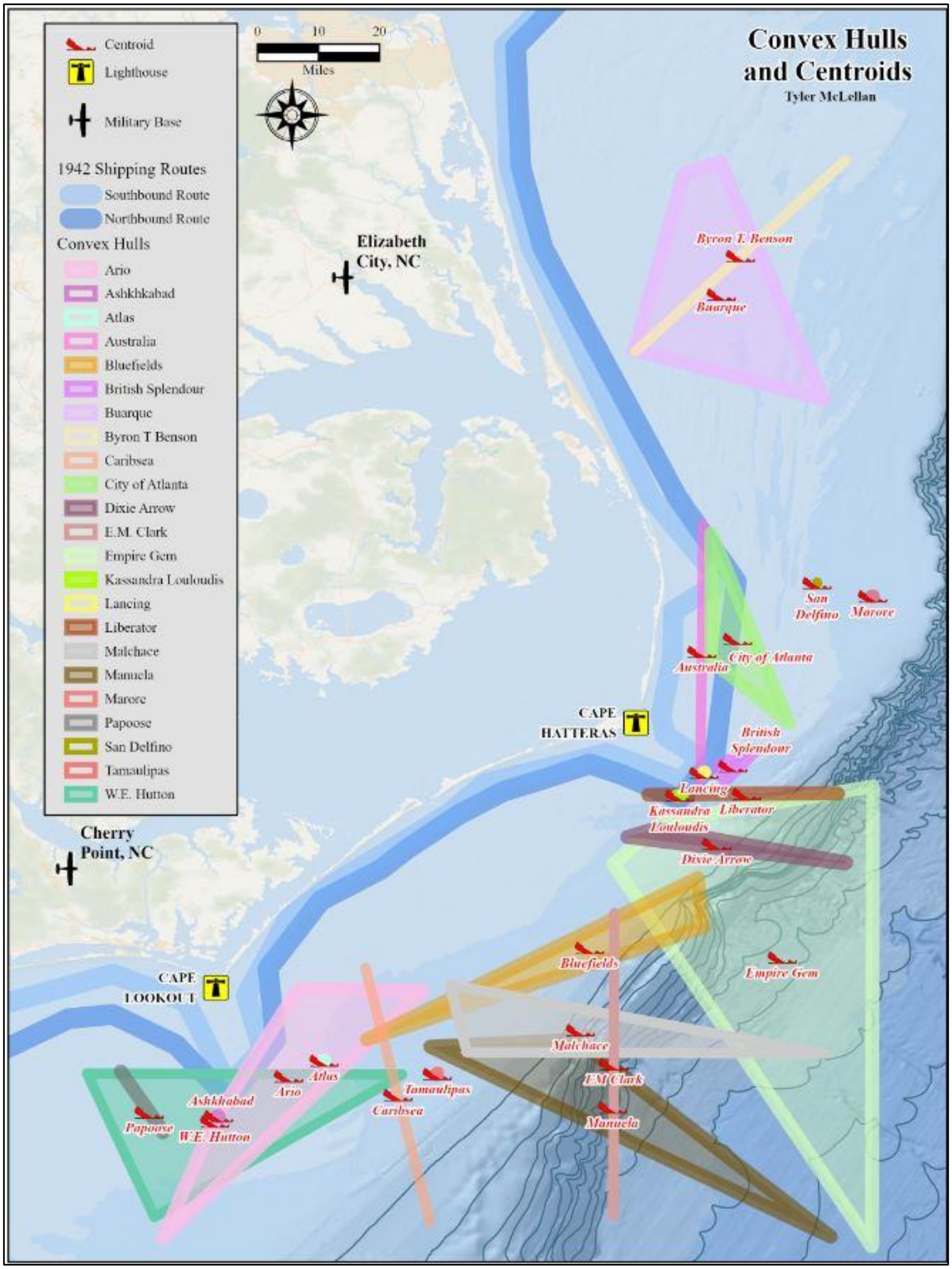


Figure 31: Convex hulls for each vessel with recorded positions. (Map by author, 2020.)

Table 7: Recorded German grid square numbers for the merchant vessels of this study. Note: the exact grid number of both *Bluefields* and *Equipoise* is unknown. Additionally, *Esso Nashville* contains a grid square that is outside of the boundaries of the map in Figure 32.

Vessel	U-Boat	Commander	Grid Zone
Ario	U-158	Rostin	DC1159
Ashkhabad	U-402	Forstner	DC1221
Atlas	U-552	Topp	DC1163
Australia	U-332	Liebe	CA7959
Bedfordshire	U-558	Krech	DC1183
British Splendour	U-552	Topp	CA7969
Byron T. Benson	U-552	Topp	CA7652
Buarque	U-432	Schultze	CA8448
Caribsea	U-158	Rostin	DC1136
City of Atlanta	U-123	Hardegen	CA7962
Dixie Arrow	U-71	Flachsenberg	CA7995
E.M. Clark	U-124	Mohr	CA7997
Empire Gem	U-66	Zapp	CA7968
Esso Nashville	U-124	Mohr	DC1418
Kassandra Louloudis	U-124	Mohr	CA7993
Lancing	U-552	Topp	CA7991
Liberator	U-332	Liebe	CA7959
Malchace	U-160	Lassen	DC1227
Manuela	U-404	Bulow	DC1228
Marore	U-432	Schultze	CA7936
Norvana	U-123	Hardegen	CA7668
Papoose	U-124	Mohr	DC1167
San Delfino	U-203	Mutzelburg	CA7965
Tamaulipas	U-552	Topp	DC1246
W.E. Hutton	U-124	Mohr	DC1183

The geospatial comparison for the various recorded grid zones for each vessel, the center of the grid squares, and the distance between these points is displayed in Figure 32. The distance and heading between the wreck and the centroid, the wreck and the German point, and the centroid and the German point were recorded for 19 of the 27 merchant vessels in this study. This is because these 19 sank quickly after being attacked and thus were not towed or drifted away from the attack site.

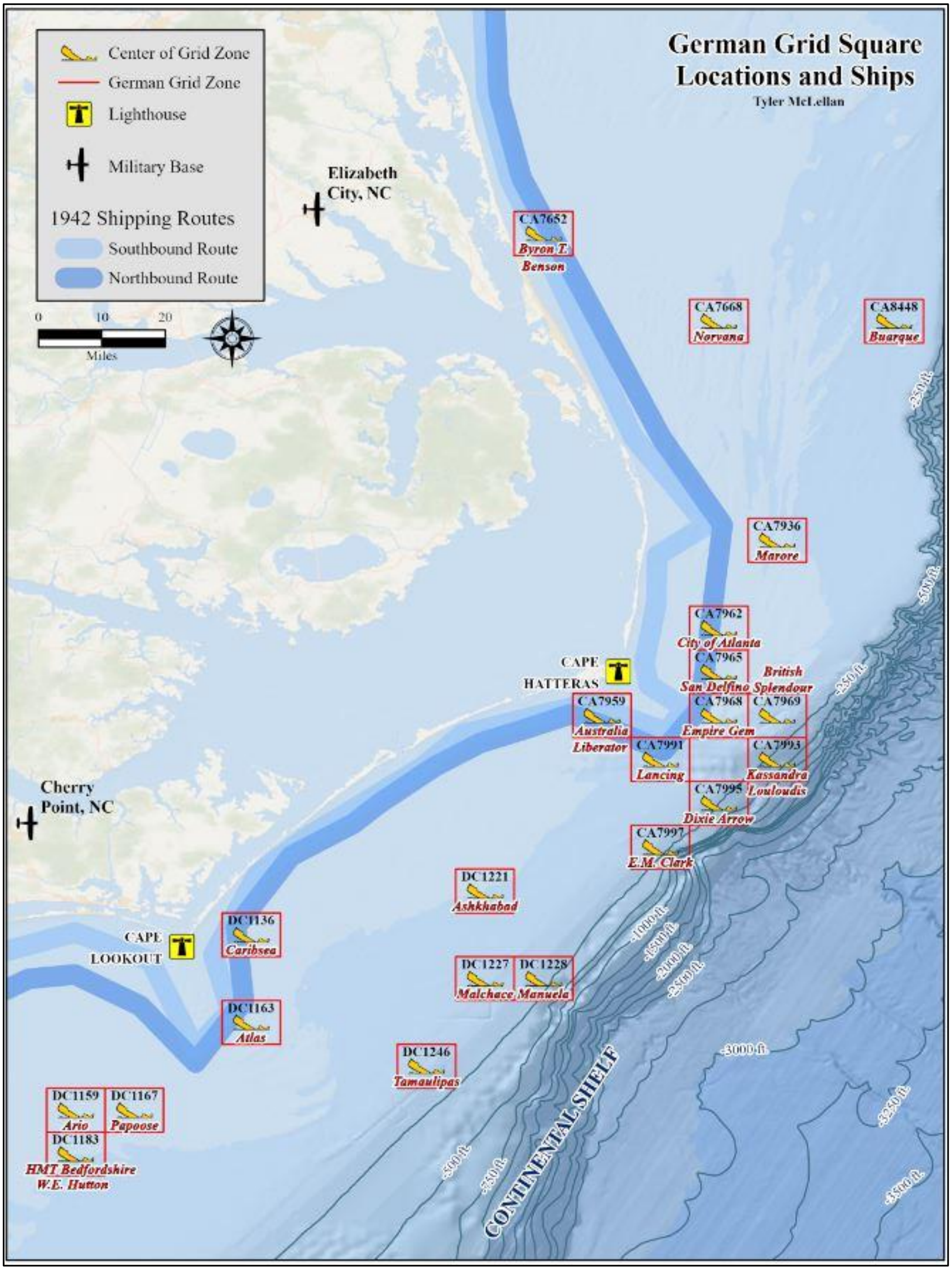


Figure 32: Creation of the center of each German grid square. (Map by author, 2020.)

Further, all 19 vessels had a German point and a centroid that could be used for comparison. Figure 33 geospatially displays the distance between each wreck and its respective centroid. This is further broken down numerically in Figure 34. Of the 19 vessels, 8 were located within 10 miles of the centroid, while 13 were located within 20 miles. The distance between the wreck and its respective centroid is used to determine the level of accuracy of the Allied vessels. As such, this graph displays a medium level of accuracy among the Allies. Figure 35 displays the compass headings from the wrecks to the centroids. This data shows that many centroids (11 of 19) were located to the east of their respective wrecks (heading between 0 and 180 degrees), with 7 of these 11 and over a third of the total 19 located in a southeasterly direction (heading of 90 to 180 degrees). Thus, an unlocated wreck that did not drift is 37% more likely to be found with a northwest heading from a generated centroid than any other direction, and 58% likely that the wreck would be in a western direction (north or south).

Figure 36 geospatially displays the distance between the wreck and the point generated by the German grid square and the Naval Grid Calculator. This data is displayed numerically in Figure 37 and shows that the German U-boat commanders were more accurate than the Allied sources (although the differences in datums may affect this in future studies), with 15 of the 19 wrecks being within 20 miles of the calculated point. As displayed in Figure 38, while the Germans displayed a consistent level of distance, the heading from their recorded point to the wreck is much more uniform, with no direct pattern observed. Overall, the Germans displayed a greater level accuracy with regards to distance than the Allies. It should be noted that because the grid zone is roughly six by six miles, the center point has a minor level of error of up to three miles.

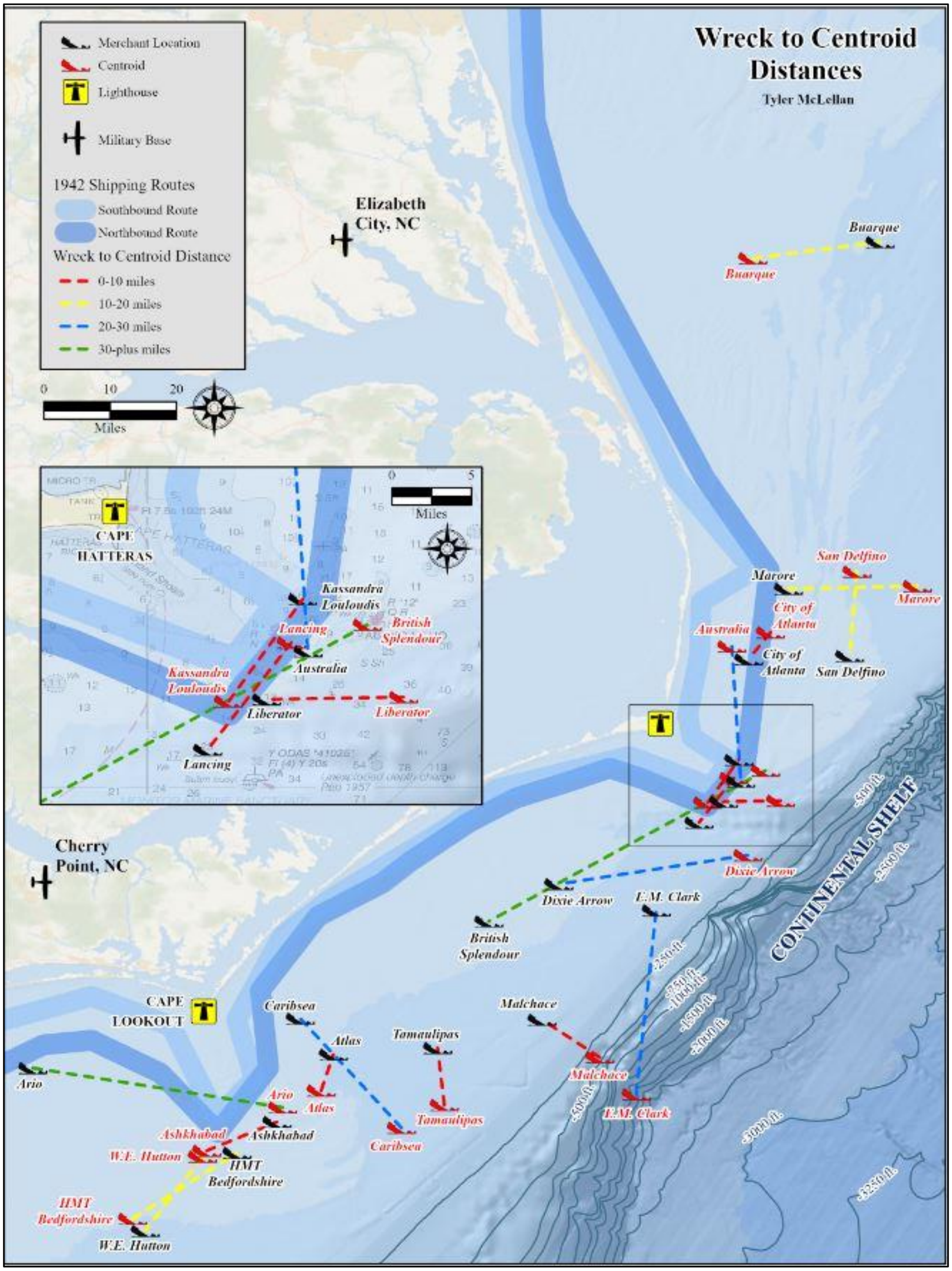


Figure 33: Distance between each wreck and its respective centroid. (Map by author, 2020.)

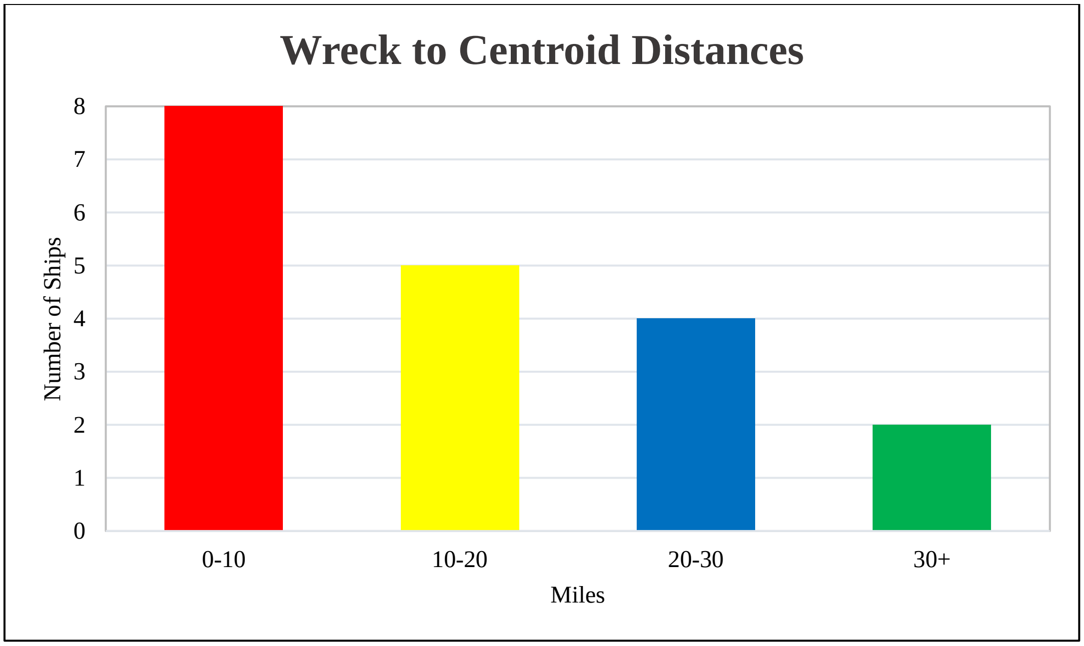


Figure 34: Distance between the wrecks of the merchant vessels and the generated centroid. (Map by author, 2020.)

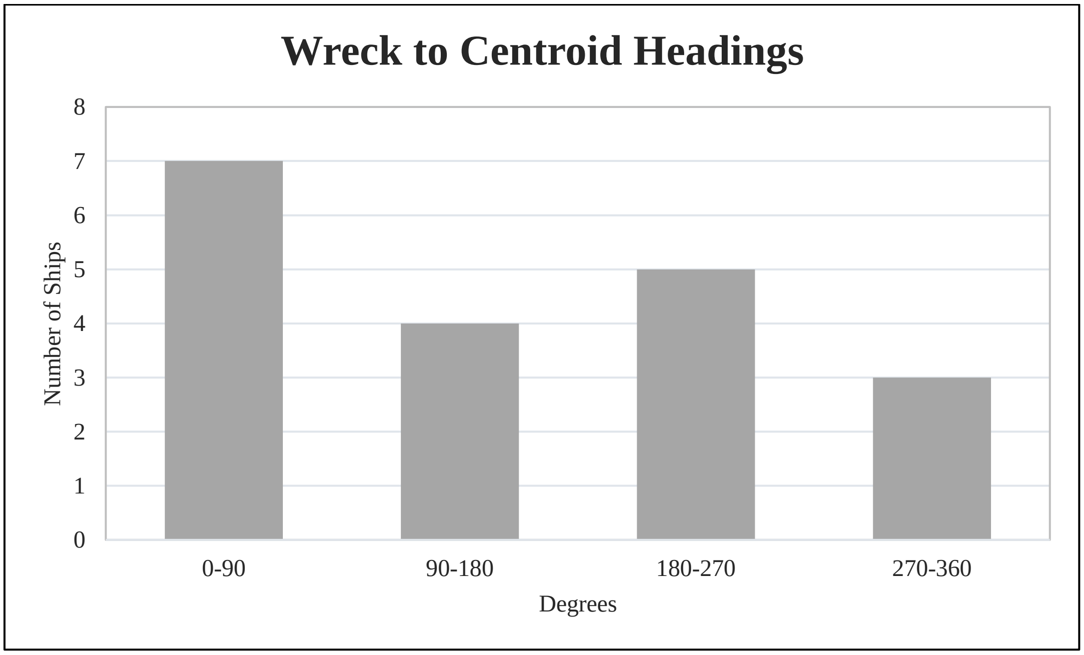


Figure 35: Heading from the wrecks of the merchant vessels to the generated centroid. (Map by author, 2020.)

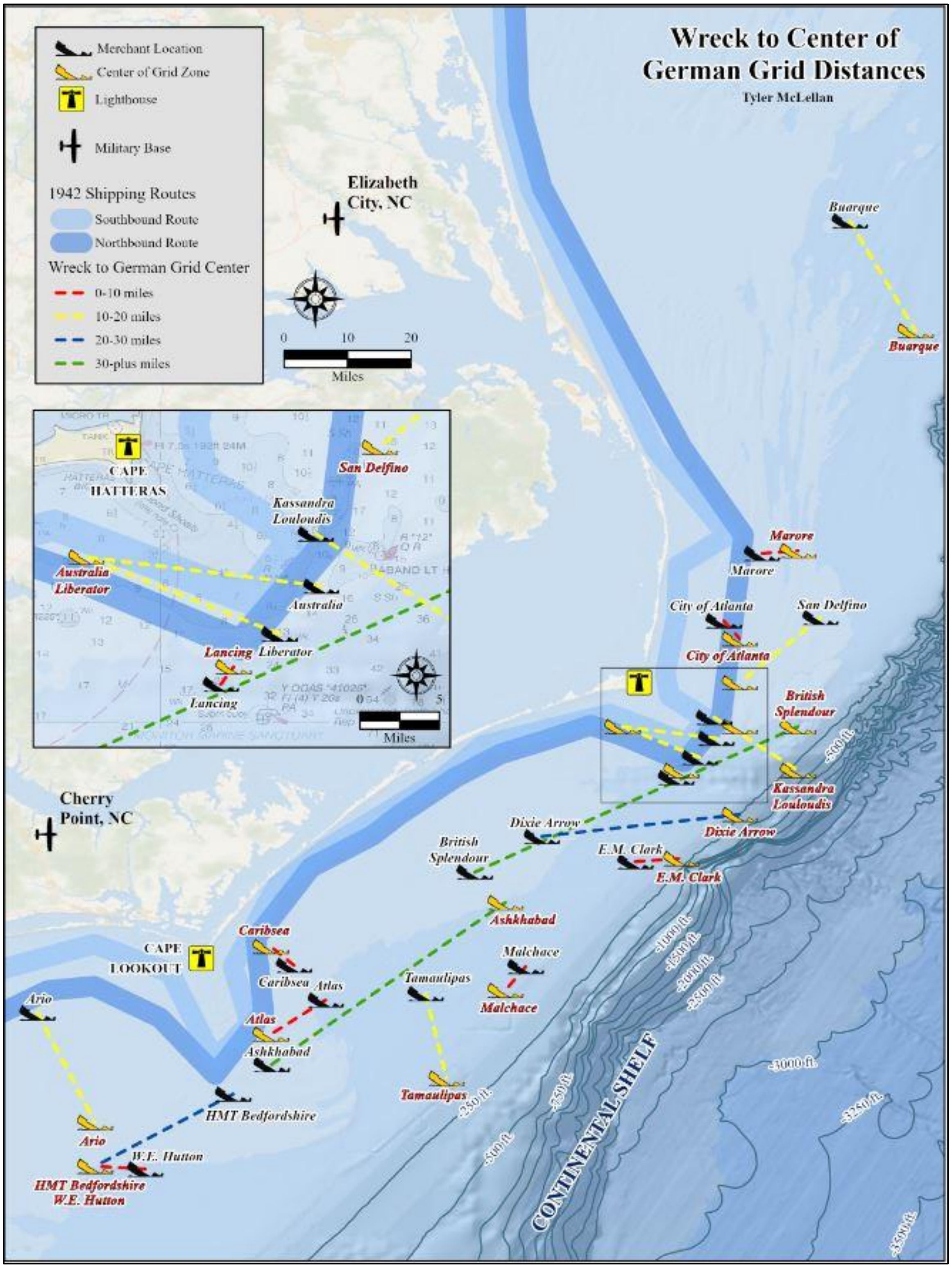


Figure 36: Distance between each wreck and the center of the recorded German grid square. (Map by author, 2020.)

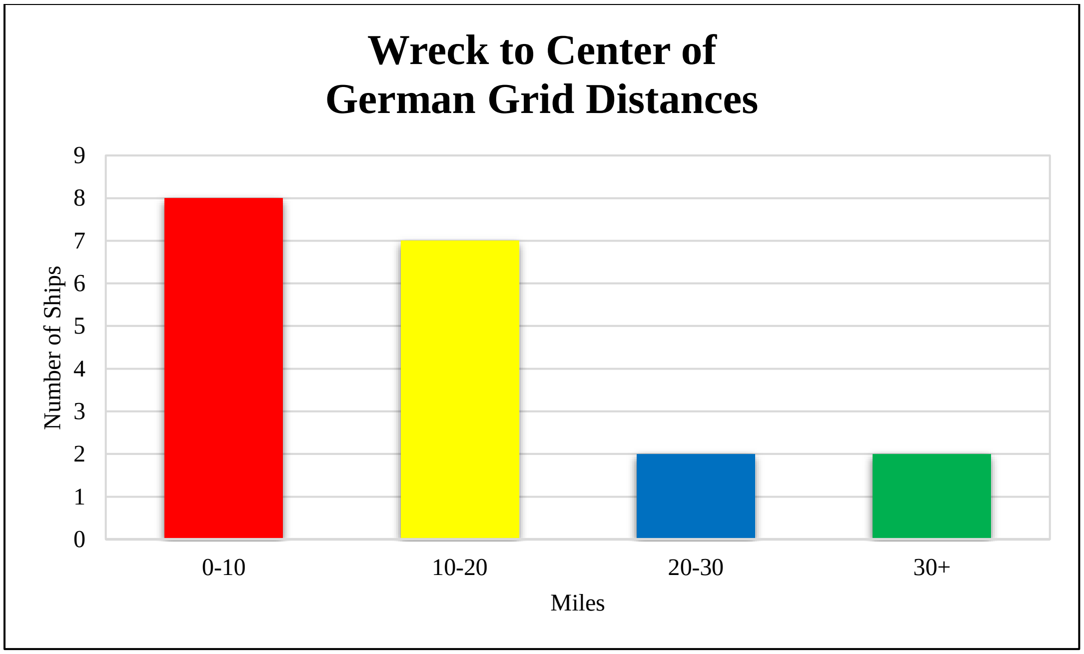


Figure 37: Distance between the wrecks of the merchant vessels and the generated German point. (Image by author, 2020.)

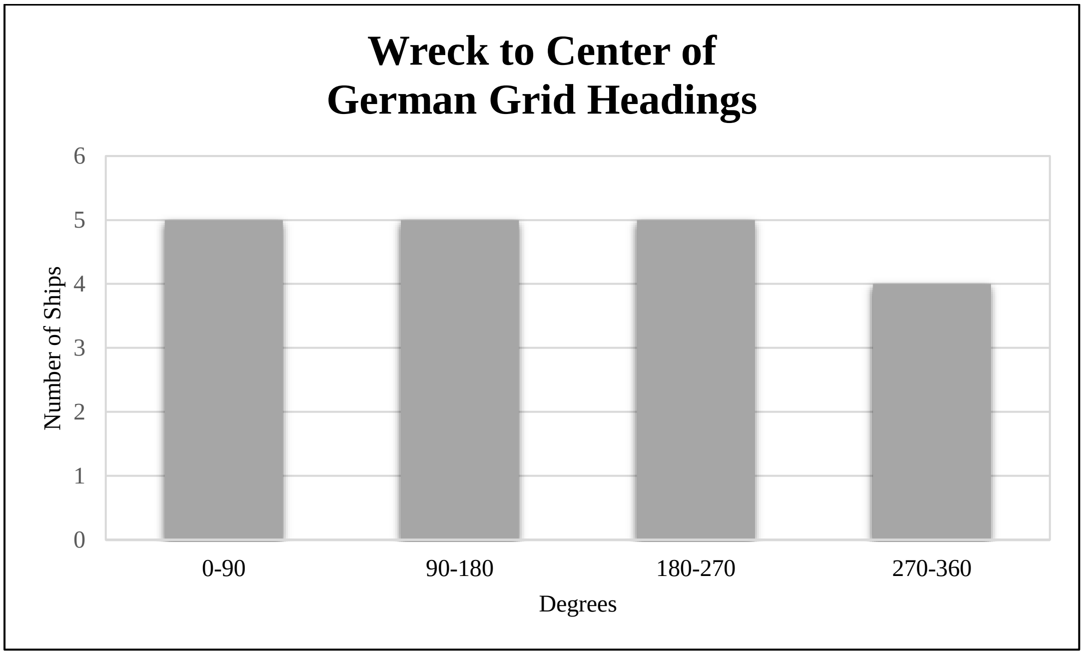


Figure 38: Heading from the wrecks of the merchant vessels to the generated German point. (Image by author, 2020.)

Figures 39 and 40 display the differences in the level of accuracy along the Outer Banks for both the Allied sources and the German sources, respectively. This geospatial representation of accuracy/inaccuracy uses heat maps with brighter colors representing greater levels of inaccuracy, or a denser fog of war. Thus, this visualization displays the density of the fog in relation to the Outer Banks as well as other physical features such as lighthouses and lightships, air bases, and their distance from the continental shelf. These maps show that the Allies were highly inaccurate in the area just south of Cape Hatteras, except for *Australia* near the Diamond Shoals lightship. The Germans were also highly inaccurate for *Australia*, south of Hatteras, as well as around the Cape Lookout lightship. To understand the possible reasons behind this, the statistics of each individual vessel and attack are analyzed in the following chapter.

Figures 41-43 display the distances and headings from the centroid to the German point. This data gives a different level of measurement: precision. Precision denotes how close the different points are to one another rather than how close they are to the desired point, in this case the location of the wreck. Figure 41 displays the distances between the centroids and German grid points. Figure 42 displays this data numerically and shows that there were eight attacks where the precision is close, within 10 miles. The level of precision among the remaining 11 attacks is much more irregular. The heading from the generated centroid to the German point in Figure 43 shows that 12 of the 19 German points were located with a westerly heading. Three of these are located to the northwest, nine to the southwest, and the remaining seven are split between the major easterly headings. Thus, there is a 47% chance that a centroid will be located northeast from the center of a recorded German grid zone, and a 42% chance that the centroid will be within ten miles.

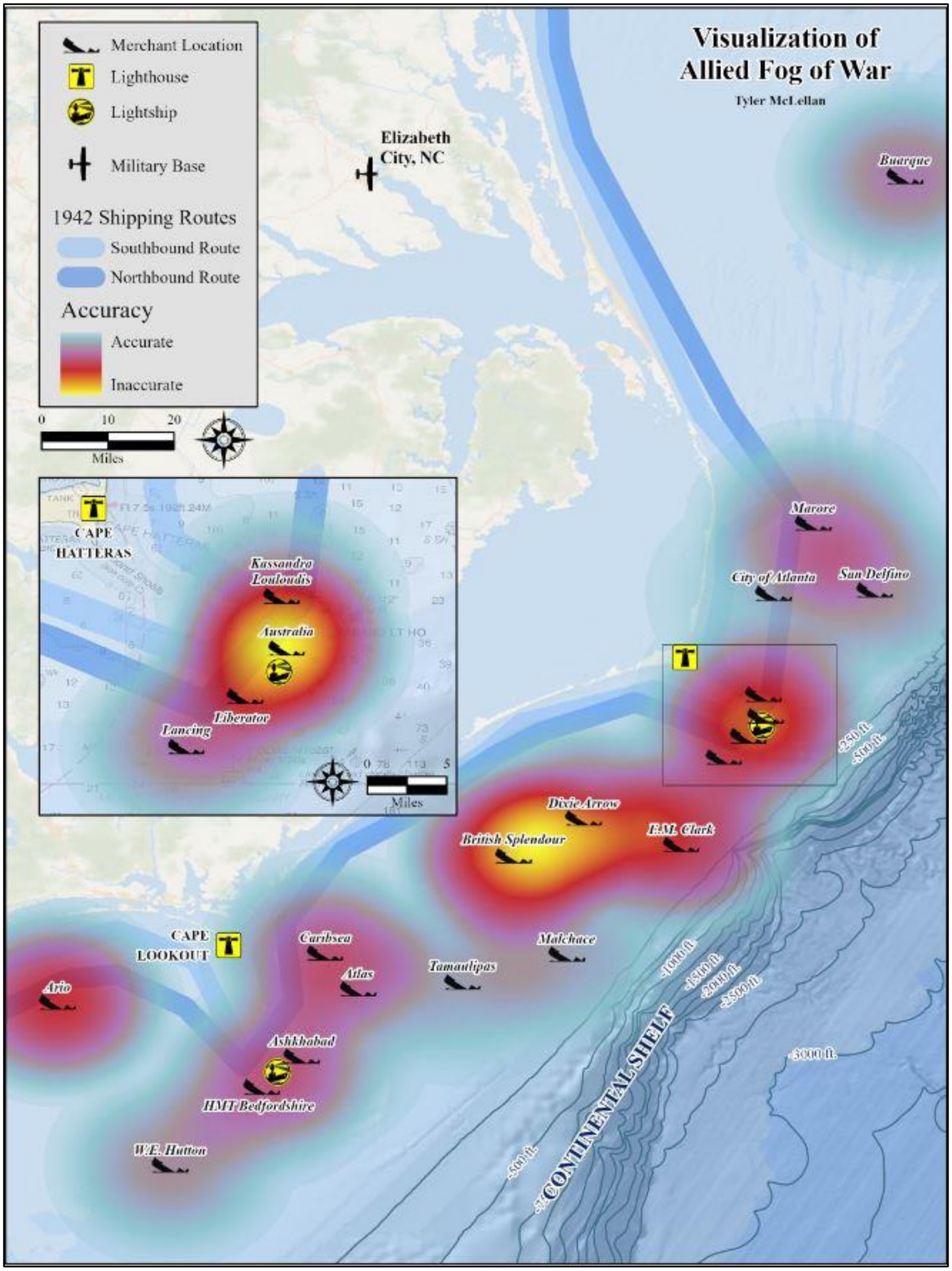


Figure 39: Heat map of Allied accuracy along Outer Banks. (Map by author, 2020.)

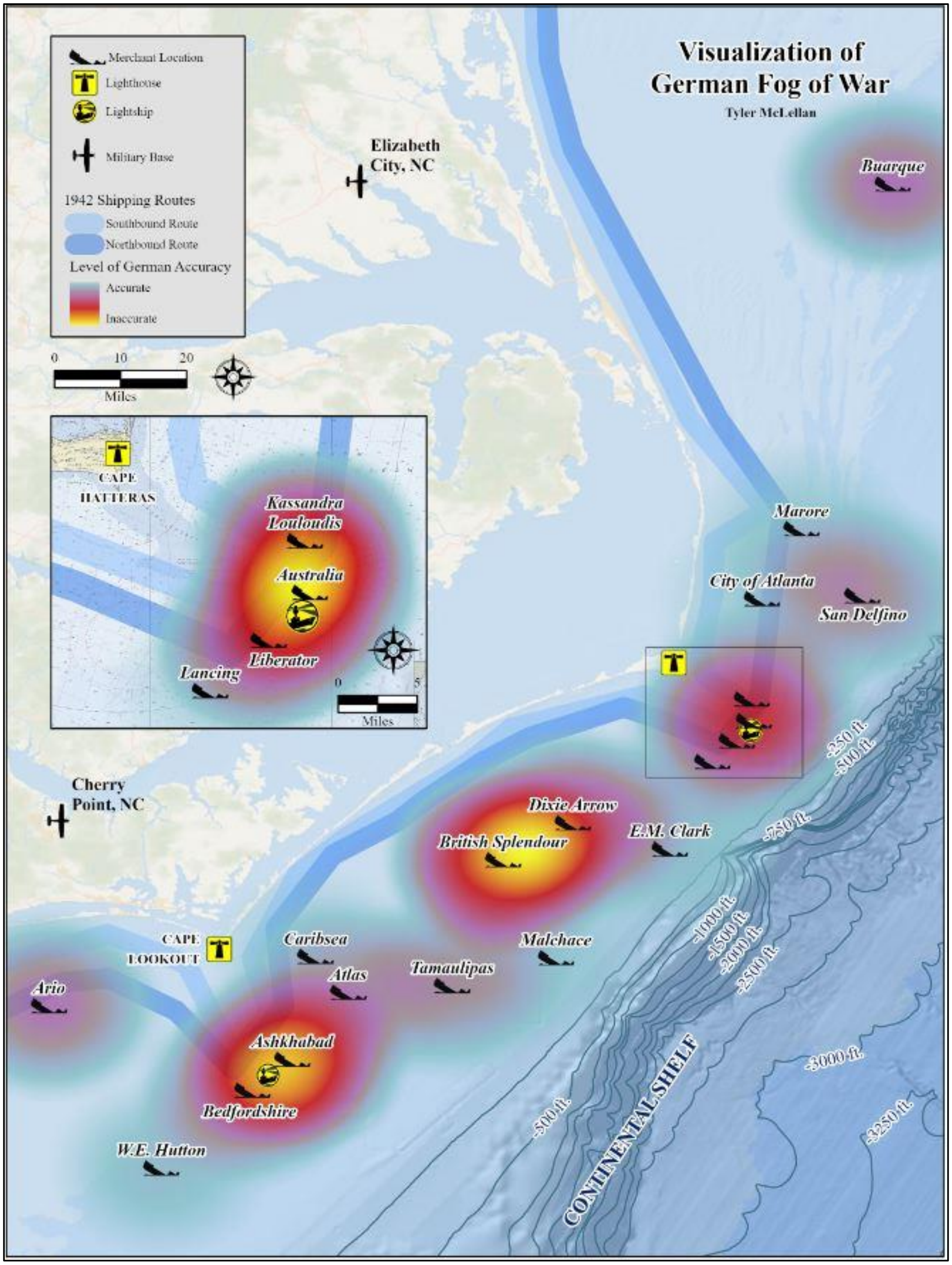


Figure 40: Heat map of German accuracy along Outer Banks. (Map by author, 2020.)

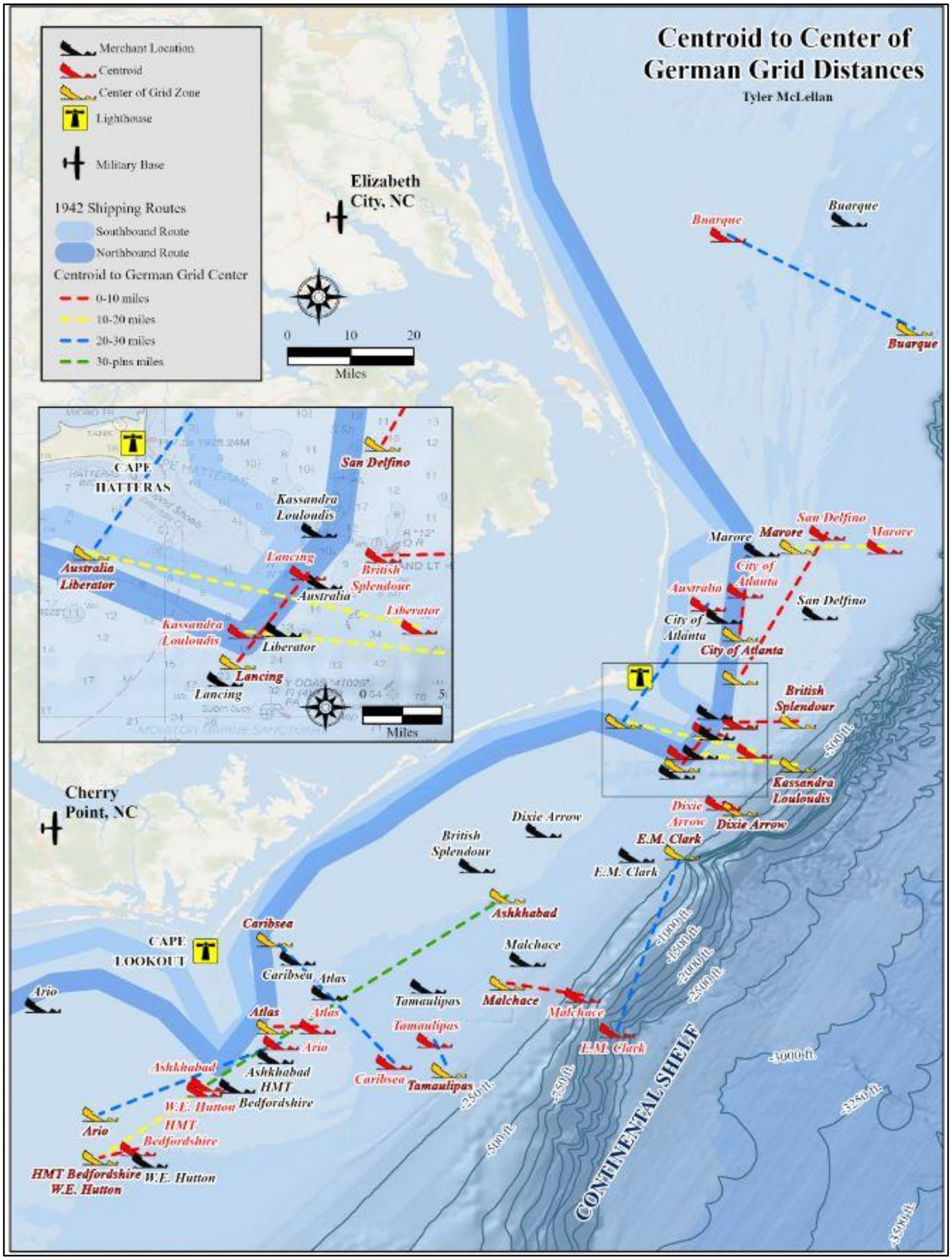


Figure 41: Distances between the generated centroids and the center of the recorded German grid squares. (Map by author, 2020.)

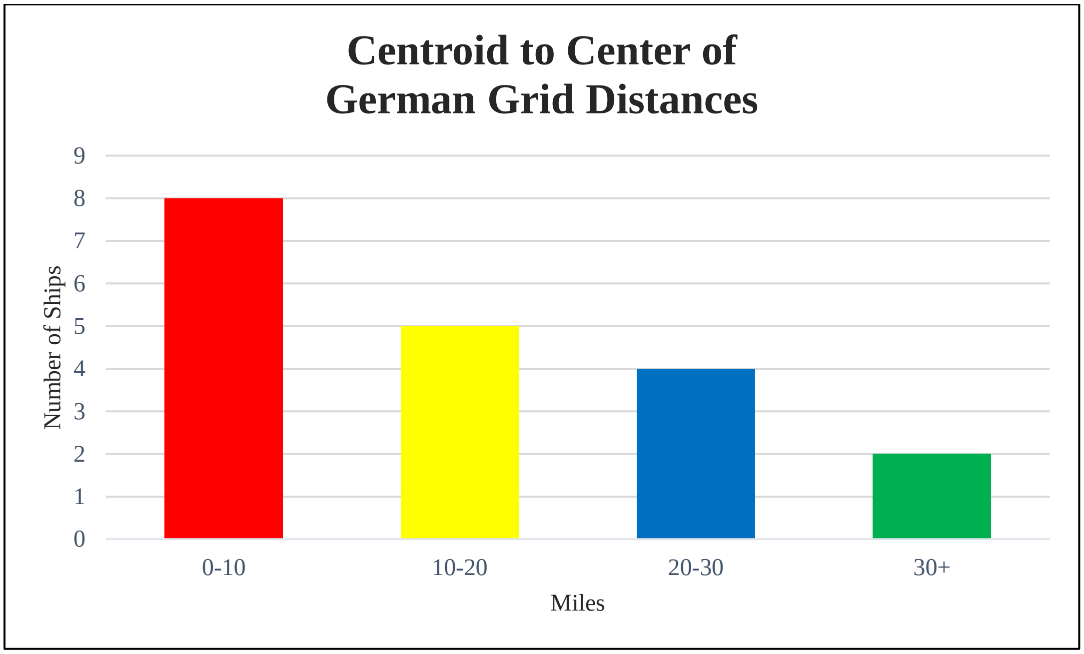


Figure 42: Distance between the generated centroid and the generated German point. (Image by author, 2020.)

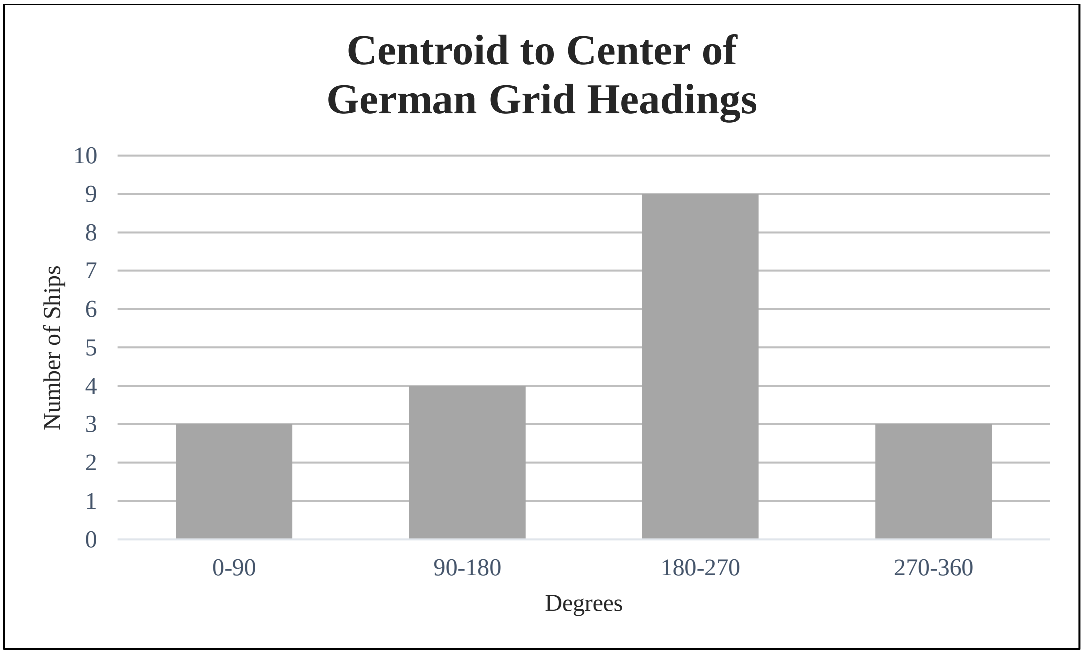


Figure 43: Heading from the generated centroid to the generated German point. (Image by author, 2020.)

In Table 8 and Figure 44, the level of accuracy and precision among individual U-boat commanders is displayed. It is interesting to note that, despite the level of inaccuracy among the Allies (and thus the inaccuracy of the centroids), most U-boat commanders are more accurate than precise. This was not the case for all, however, as exemplified the most by Kapitanleutnant Erich Topp of U-552. Topp had successfully sunk 4 of the 19 vessels compared for geospatial analysis. Of these four, Topp had an average of 11 miles between his position and that of the Allies. While other U-boat commanders had a better level of precision, these were due to their sinking of a single vessel, rather than four. Nevertheless, 6 of the 11 commanders displayed a higher level of accuracy (proximity to the wreck) rather than precision (proximity to the centroid).

Table 8: Comparison of German U-boat commanders' accuracy and precision, including the number of vessels sunk by each commander.

Commander	Number of Ships Sunk	Average Distance to Wreck (mi)	Average Distance to Centroid (mi)
Lassen	1	1	10
Hardegen	1	1	7
Mohr	3	6	21
Rostin	2	8	26
Shultze	2	9	20
Leibe	2	9	20
Mutzelberg	1	12	6
Topp	4	15	11
Krech	1	18	6
Flachsenberg	1	23	2
Forstner	1	35	49

The result of the U-boat type compared to accuracy is noteworthy, as of the commanders listed, Hardegen (U-123) and Mohr (U-124) both had Type IXB, Lassen (U-160) and Rostin (U-158) both had Type IXC, and the remaining commanders had Type VIIC.

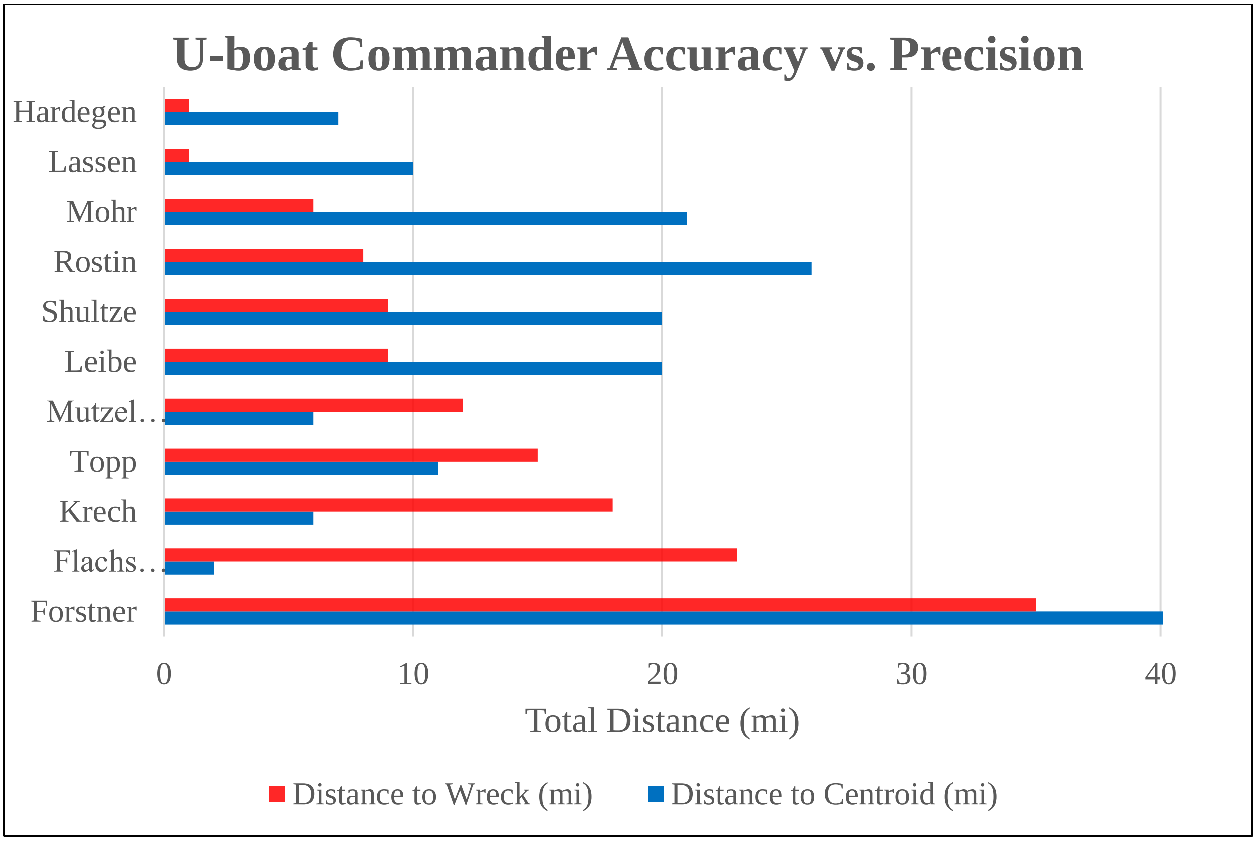


Figure 44: Comparison of German U-boat commander accuracy and precision. (Image by author, 2020.)

The four commanders using a version of the Type IX, as shown in the table above, had the highest level of accuracy. Whether this is coincidental, these commanders were more experienced in position-fixing, or the Type IX's were equipped with better position fixing technology is at present unknown, although it was noted previously that the Type IX models were fitted with additional radar equipment.

In conclusion, 6 of the 11 commanders averaged an accuracy below 10 miles and three below 20 miles. This is again due in part to low numbers of attacks for each commander; thus, it would be erroneous to determine that one commander is more accurate than another. Along with the accuracy of the Germans, this study hoped to attain a level of accuracy for Allied sources, such as the records of the Navy and Coast Guard, including vessels and aircraft, all of which served as convoy escort and were utilized for both patrol and as U-boat hunters. Unfortunately, much of this was unavailable at the time of this writing. However, select digital archives were found to have some data utilized for the survey of the U-boats sunk in this theater of battle.

GIS Data Analysis of U-boats

This study includes analysis of four U-boat wrecks. A full geospatial analysis was not conducted. The number of wrecks is low, giving a small sample size, and the position of U-576 did not have a respective centroid (reported position) that could be used for analysis. Nevertheless, three recorded positions of U-boats were plotted, each sunk under very different conditions: U-352 during the day by USCGC *Icarus*, U-85 at night by the destroyer USS *Roper*, and U-701 during the day from above by Lt. Kane's A-29 bomber. Conclusions drawn are limited due to the small size of the data set, as any similarities between these events under different circumstances can be easily defined as coincidental.

The locations of the three wrecks were compared to the recorded coordinates of the U.S. forces. These recorded coordinates were retrieved from the Navy Department's Office of the Chief of Naval Operations Op-16-F-9 (1942:1) and Op-16-Z (1942a:1) for the attack on U-85 and U-352, respectively, as well as a memorandum to the Commanding General, I Bomber Command dated 9 July 1942 for the attack on U-701 (Moore 1942). The spatial distribution of the four U-boat wrecks as well as the three historically recorded coordinates are displayed in Figure 45. The distance and heading between the wreck, recorded by NOAA's MNMS, and the position historically recorded is displayed in Table 9. The accuracy of the Navy/Coast Guard is high, while the accuracy of the Air Force was found to be much lower.

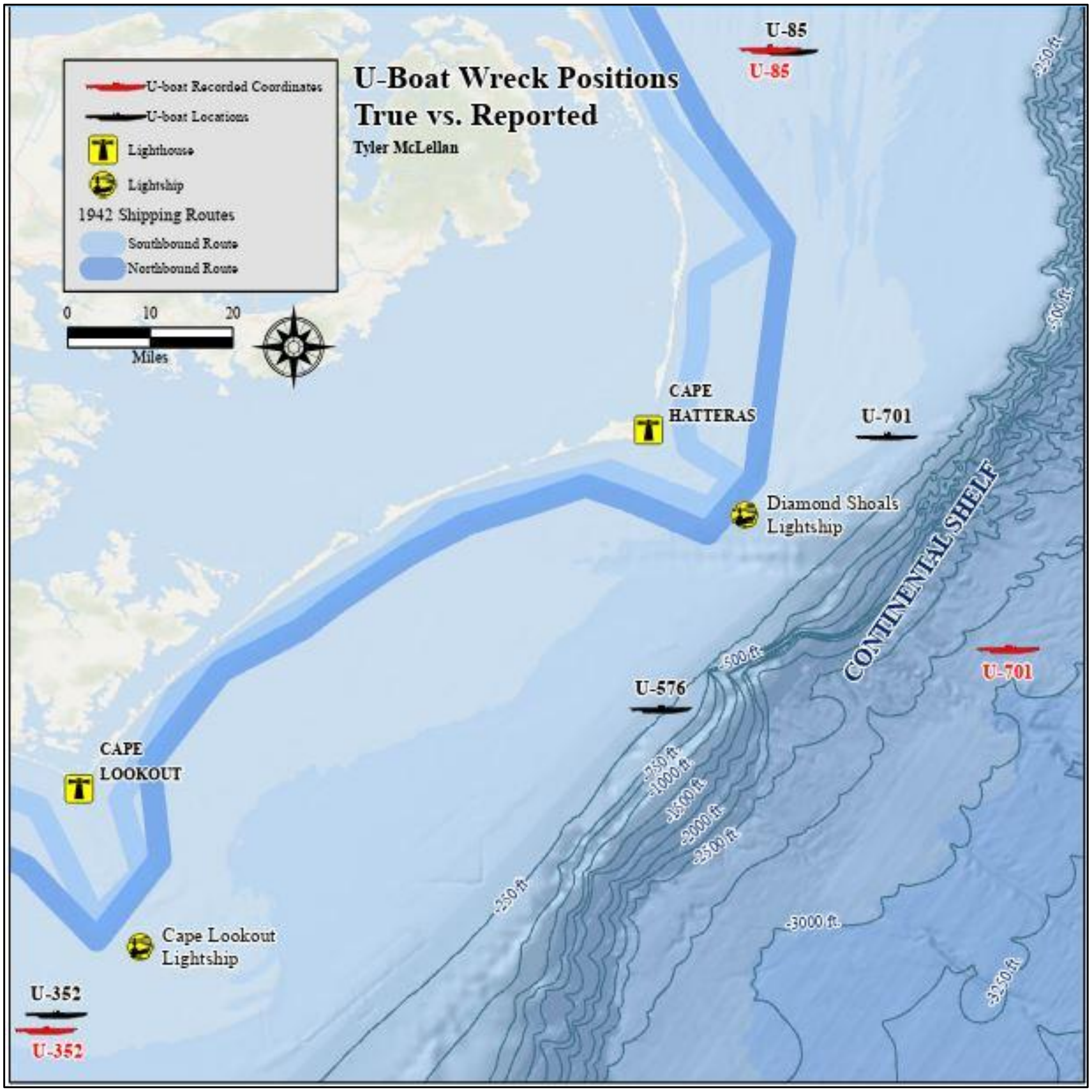


Figure 45: Map of the positional accuracy of the U-boats sunk by Allied craft. (Map by author, 2020.)

Each of these U-boat wrecks is unique, although as far as a military analysis is concerned, the range of the 3-inch guns on the destroyer and Coast Guard cutter are similar. The major atmospheric difference between the Navy's attack on U-85 and the Coast Guard's attack on U-352 is that of time and daylight.

Table 9: Positional accuracy of successful U.S. attacks on U-boats.

U-Boat	**Sunk by:**	**Method**	**Distance to Point (mi)**	**Direction (Wreck-Point)**
U-85	Navy Destroyer	3-in gun	1.71	274
U-352	US Coast Guard Cutter	3-in gun, depth charges	2.13	208
U-701	Army Bomber	Depth charges	28.33	155

The Navy destroyer USS *Roper*'s attack on U-85 was made at night and assisted by the destroyer's large searchlight to illuminate the U-boat, whereas the Coast Guard cutter's attack on U-352 was made during daylight. The factor that caused the U-352 to come into view was the use of depth charges that caused the U-boat to surface, where it was then destroyed by the deck gun. It is also interesting to note that of these two examples involving warships, the U-boat fired the first shot (both firing a torpedo at their pursuers) and while U-85 remained on the surface, U-352 dove, which resulted in the use of depth charges by the attacking cutter USCGC *Icarus* (Hickam 1989:155-160,200-205).

While each U-boat was sunk by a different branch of the U.S. military at different times and under different lighting, both U-boats were actively engaged (rather than the attacks being a surprise) and both received and were ultimately sunk by surface gun fire from their respective attackers. While these factors are not enough to explain the high level of accuracy, particularly due to the low number of examples, the similarities are noteworthy. The final attack on U-701 was unique because the attacking aircraft was a surprise, which is why the U-boat failed to dive in time, as opposed to the other U-boats sunk in North Carolina that were all actively engaged with their attackers.

Conclusion

In the preceding paragraphs, several maps and tables displayed the historical and modern coordinates and the generated centroids and German grid points. These were then compared to determine a level of accuracy, based on the distance between the wreck and centroid, as well as the heading between the wreck and centroid. This was only taken into consideration for analysis on wrecks where the vessel did not drift. Additionally, the positions recorded by the U-boat commanders were also compared to both the wreck site and the centroid. Thus, measures of accuracy and precision were understood for the U-boat commanders. Many had a higher level of accuracy over precision, although some were very precise and less accurate. It was determined that there was an inadequate number of examples for a determinative explanation. Regardless, the previous data is insufficient for analysis unless understood in the context of each attack. Each factor, such as vessel type, attack location, and time, contained different characteristics that may have affected geospatial accuracy, thus leading to larger distances between vessels, centroids, and German points. The characteristics for each attack were quantified into datasets to understand the potential level of accuracy/inaccuracy.

CHAPTER 6: LIFTING THE FOG OF WAR: GEOSTATISTICAL ANALYSIS OF THE VESSELS OF TORPEDO JUNCTION

Introduction

Geostatistical data was extracted from the geospatial data displayed in the previous chapter, which was then analyzed for patterns. The geostatistical data was further divided into three broad categories for organization, each representing a group of factors associated with the level of accuracy. The first dataset includes characteristics of the merchant vessels, such as armament, speed, draft, number of potential escorts, vessel and cargo type, speed of the attack, and level of violence. The second dataset contains atmospheric information such as weather, time of day, currents, and wind. The third and final dataset includes physical features such as bathymetry, distance from shore, and proximity to military installations. The level of accuracy was analyzed for each of the factors in the three datasets so that their effect on accuracy could be understood. Further, the number of vessels affected by each of these factors was considered, as a low number of vessels with a particular attribute would not support that factor’s effect on positional accuracy.

Analysis of Vessel Characteristics

Prior to completing this analysis, the qualitative characteristics of all the merchant vessels were translated into quantitative data (via categorization). These characteristics include armament, nationality, size, age, speed, draft, type (determined by the location of the engine and the purpose of its construction), cargo, convoy status, as well as the speed and the level of violence of each attack. The accuracy of vessels with similar characteristics were compared to determine the presence of patterns. These patterns indicate the possible influence of a certain characteristic on the merchant vessel's accuracy, and therefore hold clues to answering the secondary research questions proposed in this study.

There are 26 merchant vessels in this study group, along with one warship, all of which vary in size, type, and age. The largest vessel was the tanker *Australia* at 11,628 registered gross tons (RGT), while the smallest was the bulk cargo-carrier *Bluefields* at 2,063 RGT. The two types of merchant vessels were engine amidships and engine aft. Freighters typically had engines located amidships with short composite or split superstructures and a single small smokestack (Schuirmann 1944:8). A diagram of an old tramp freighter, which is a classic example of an engine amidships vessel is displayed in Figure 46.

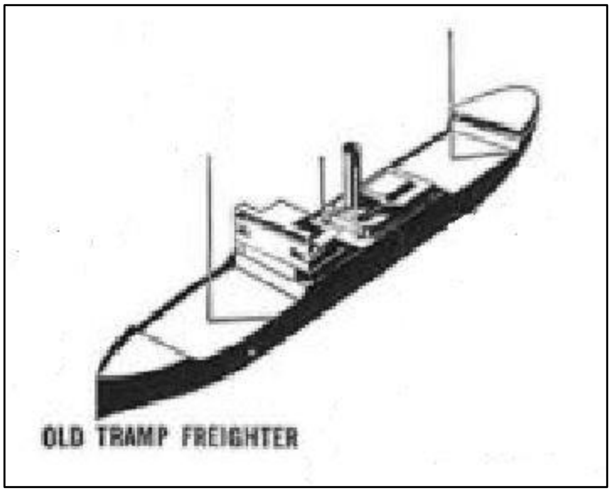


Figure 46: Shape of an Old Tramp Freighter, according to Office of Naval Intelligence Report 223M: Merchant Ship Shapes (Schuirmann 1944:8).

There are only 11 engine amidships vessels in this study, which range from *Caribsea* at 2,609 RGT to *Lancing* at 7,866 RGT. *Lancing*, although it retained its engine amidships, was converted into a whaling ship and again into a tanker when the Second World War erupted

(NOAA 2020b). These are also the oldest vessels in this study, with *Lancing* constructed in 1898 and all vessels except one being constructed within the first two decades of the 20th century. The only exception is the armed *Manuela,* constructed in 1934. These vessels typically had steam triple-expansion engines located amidships (as registered by *Lloyd's Register of Shipping* 1942, 1943). The average RGT of these freighters is roughly 5,107 tons. It is interesting to note that both armed vessels, *Liberator* and *Manuela*, were freighters. Of the 19 vessels that did not drift, 8 were classified as engine amidship vessels with an average distance of 10.39 miles from the centroid. The heading, however, varies greatly, from 33 to 358 degrees from the wreck to the centroid. The Germans were slightly more accurate, with an average distance of 11.9 miles. This measure is to the central point of the recorded grid zone, thus the distance between the center and the edge of each grid zone includes a margin of error (roughly three miles). The German's error in heading, however, is equally varied, from 5 to 310 degrees from the wreck to the German grid point. The distribution of these vessels as well as a display of the accuracy of both the Allies (centroids) and Germans (center of grid zones) is displayed in Figure 47.

Engine aft types consisted mostly of tankers, which made up the largest number of vessels lost at Torpedo Junction. These vessels contain a mix of old and modern tankers as well as bulk cargo-carriers which transported cargo that required the use of a single large continuous hold (Schuirmann 1944:10). Of special note, only two vessels were classified as bulk cargo-carriers, *Marore* and *Bluefields*. A diagram of an engine-aft tanker is shown in Figure 48. Engine aft vessels also had the largest variety in size (*Australia* to *Bluefields*), with an average of 7,525 RGT. Many of these were relatively modern vessels at the time, with only three constructed prior to 1920: *Atlas* in 1916, *Bluefields* in 1917, and *Tamaulipas* in 1919.

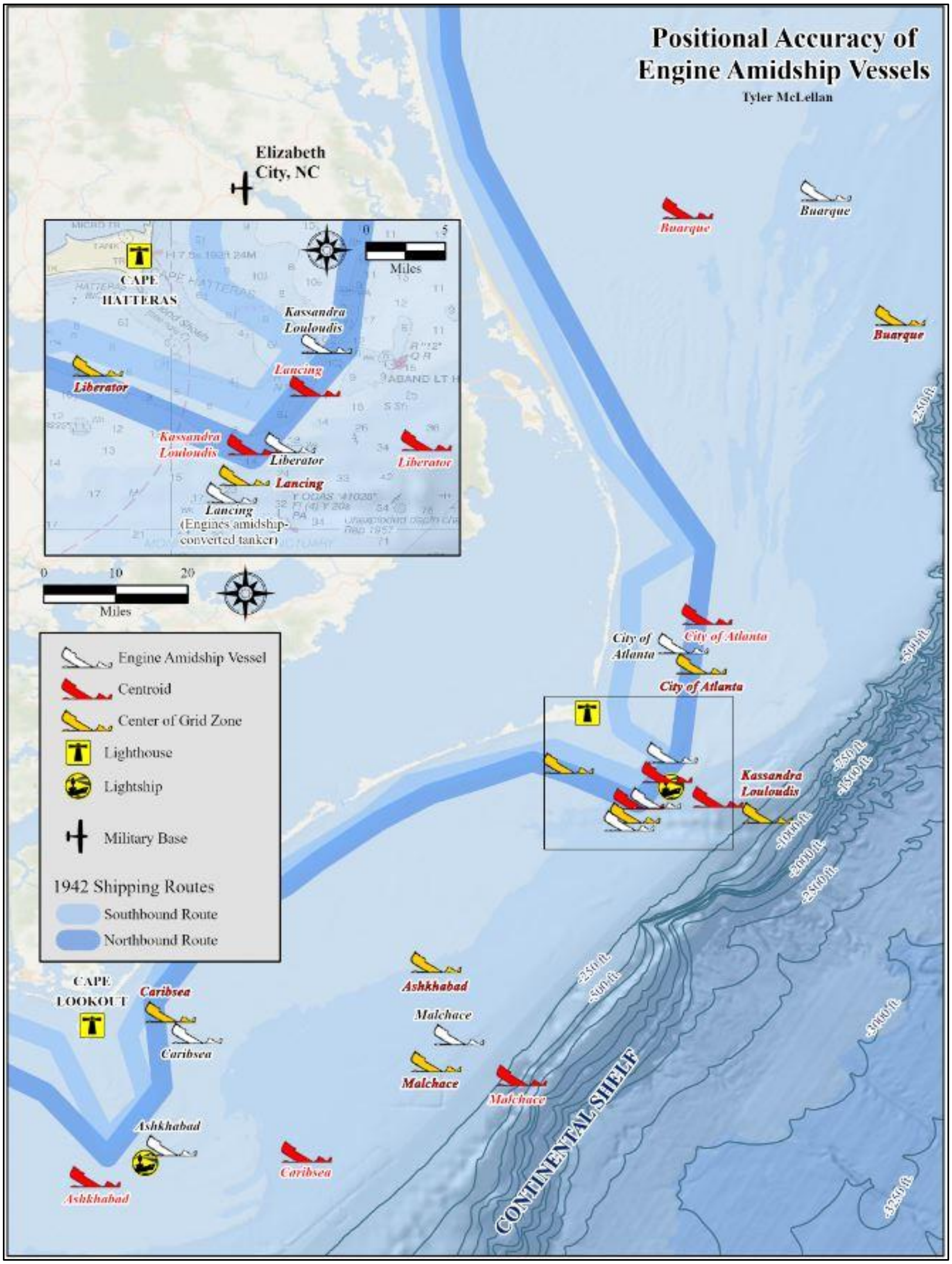


Figure 47: Distribution of engine amidship vessels compared to their respective centroids and German points. (Map by author, 2020.)

Three engine aft vessels, *Empire Gem* (1941), *Esso Nashville* (1940), and *San Delfino* (1938) were constructed within five years of the U.S. entry into the war in 1941. Most, however, were constructed in the 1920s and early 1930s. Many of these engine aft vessels were converted from steam engines to oil, with two or four stroke single acting engines (*Lloyd's Register of Shipping* 1942, 1943). Of the 19 vessels that did not drift, 10 were engine aft. Therefore, 8 were engine amidship, 10 were engine aft, and the final vessel was the lone warship: the armed trawler HMT *Bedfordshire*.

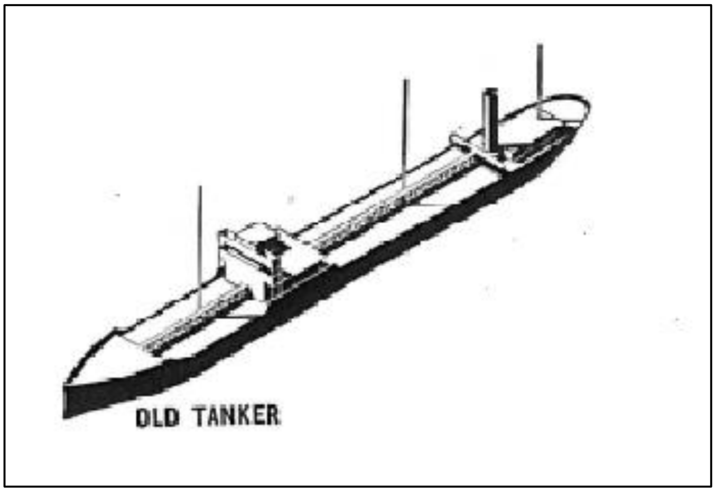


Figure 48: Shape of an engines-aft tanker, according to Office of Naval Intelligence Report 223M: Merchant Ship Shapes (Schuirmann 1944:10).

Engine-aft vessels have an average of 20.07 miles between wreck and centroid and 15.86 miles between wreck and German point. Despite averaging a distance further apart than engine amidship vessels, all engine aft wrecks are located at a heading less than 200 degrees from their respective centroids (with the exception of Australia at 357 degrees). Only two are greater than 180 degrees (*Atlas* and *E.M. Clark*). Conversely, the Germans' headings varied from 61 degrees to 278 degrees. The distribution of these vessels as well as a display of the accuracy of both the Allies and Germans is displayed in Figure 49.

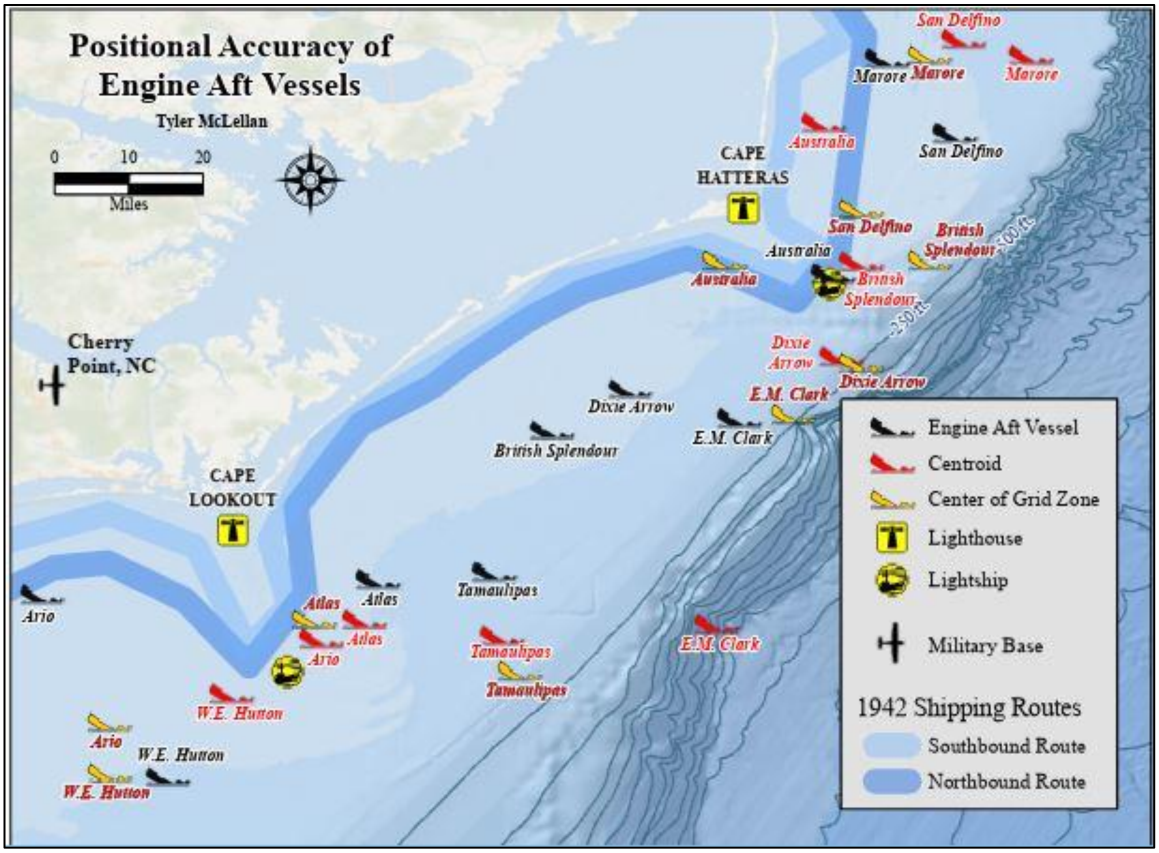


Figure 49: Distribution of engine aft vessels compared to their respective centroids and German points. (Map by author, 2020.)

The cargo of these ships also varied, although these can be placed into two broad categories: flammable and nonflammable. Flammable cargo, upon ignition by a torpedo strike, often caused a fast and violent end to the transporting vessel. This includes petroleum products as well as certain minerals such as manganese ore, the dust of which is highly flammable (carried by *Caribsea* and *Equipoise*). Other flammable chemicals included sulfur, often transported in a molten state (carried by *Liberator*) and calcium carbide (carried by *Bluefields*) (NJ Health 2011, 2012, 2016; NOAA 2020b). Of the 26 merchant vessels, 16 carried cargos of flammable materials. Engine-aft tankers comprised 11 of these 16 vessels. Additionally, the group includes one engine-aft cargo-carrier (*Bluefields*), one engine amidships-converted tanker (*Lancing*), and three freighters (*Caribsea*, *Equipoise*, and *Liberator*). Ten vessels carried nonflammable materials. The seven engine amidship freighters that were considered to have nonflammable cargo carried a mixture of general goods including sugar, soda ash, food, and even passengers. Three engine aft vessels were considered nonflammable, two of which were traveling in ballast, or without cargo, while the third, the bulk cargo carrier *Marore*, was transporting iron ore (NOAA 2020b). Table 10 lists the vessel type, age, size, and flammability of cargo.

Table 10: Vessel type, age, size, and flammability of cargo.

Vessel Name	**Vessel Type**	**Age**	**Size (RGT)**	**Flammable Cargo**
Bedfordshire	Engine Amidships	1935	443	No
Malchace	Engine Amidships	1920	3516	No
Kassandra Louloudis	Engine Amidships	1919	5106	No
Buarque	Engine Amidships	1919	5152	No
City of Atlanta	Engine Amidships	1904	5269	No
Ashkhabad	Engine Amidships	1917	5284	No
Ario	Engine Aft	1920	6952	No
Marore	Engine Aft	1922	8215	No
Caribsea	Engine Amidships	1919	2609	Yes
Tamaulipas	Engine Aft	1919	6943	Yes
W.E. Hutton	Engine Aft	1920	7076	Yes
Atlas	Engine Aft	1916	7137	Yes
British Splendour	Engine Aft	1931	7138	Yes
Liberator	Engine Amidships	1918	7720	Yes
Lancing	Engine Amidships	1898	7866	Yes
Dixie Arrow	Engine Aft	1921	8046	Yes
San Delfino	Engine Aft	1938	8072	Yes
E.M. Clark	Engine Aft	1921	9647	Yes
Australia	Engine Aft	1928	11628	Yes

Figures 50-52 compare the data further and shows the accuracy of each attribute among Allied and German sources. The graph in Figure 50 shows no correlation among different sizes, ages, or levels of accuracy. Figure 51 displays the accuracy of different vessel types. Both engine amidships and engine aft vessels are shown, and a figure has been drawn around each type to show groupings. This graph shows that engine amidships vessels (freighters) are often more accurate for Allied sources than tankers. The German sources do not show any correlation in the vessel type and accuracy. In Figure 52, the potential effect of the vessel's cargo is displayed in relation to accuracy. These vessels are shown to be much more intermixed. As such, the flammability of the vessel's cargo does not appear to have any direct effect on positional accuracy for either German or Allied sources.

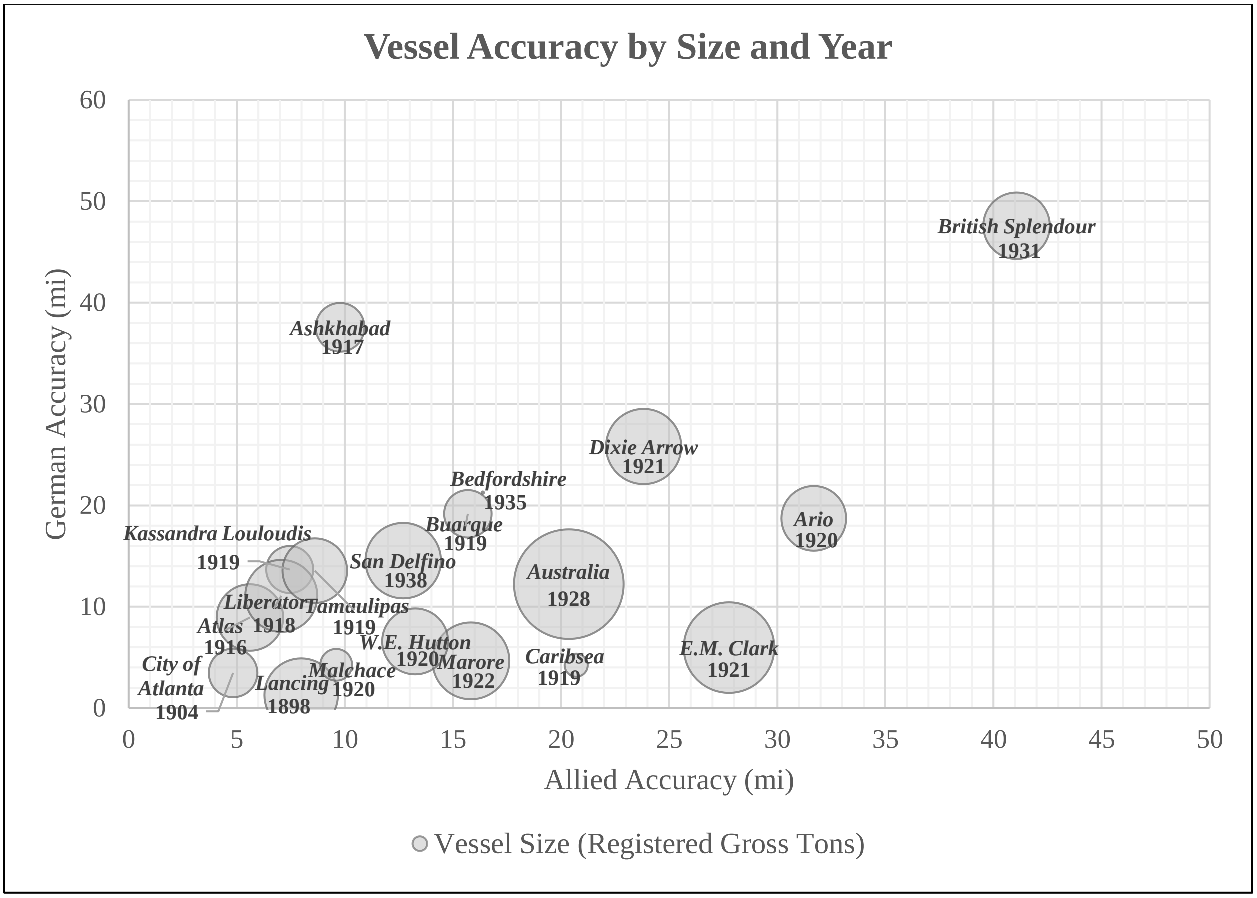


Figure 50: Accuracy of vessels in relation to size and age. (Image by author, 2020.)

Another factor considered for analysis is the presence of naval guns on a merchant vessel. Out of the study group, there were two confirmed vessels that were armed: *Liberator* and *Manuela*. On 25 June 1942, *Manuela* was part of a makeshift convoy consisting of 11 merchant ships and 4 escorts. It was armed with one 4-inch gun and two .30 caliber guns (Browning 1996:154). The vessel was hit at around 1920 hours to starboard amidships but did not sink, rather it was towed for a day towards Morehead City before it succumbed to the damage and sank. The distance of the wreck of *Manuela* from its centroid is 25.96 miles, whereas the wreck is located within 10 miles from the center of its recorded grid. The likelihood of error is high, however, as it is unknown if the position was recorded at the time of the attack or after being towed, and thus it was not included as one of the 19 vessels used for analysis.

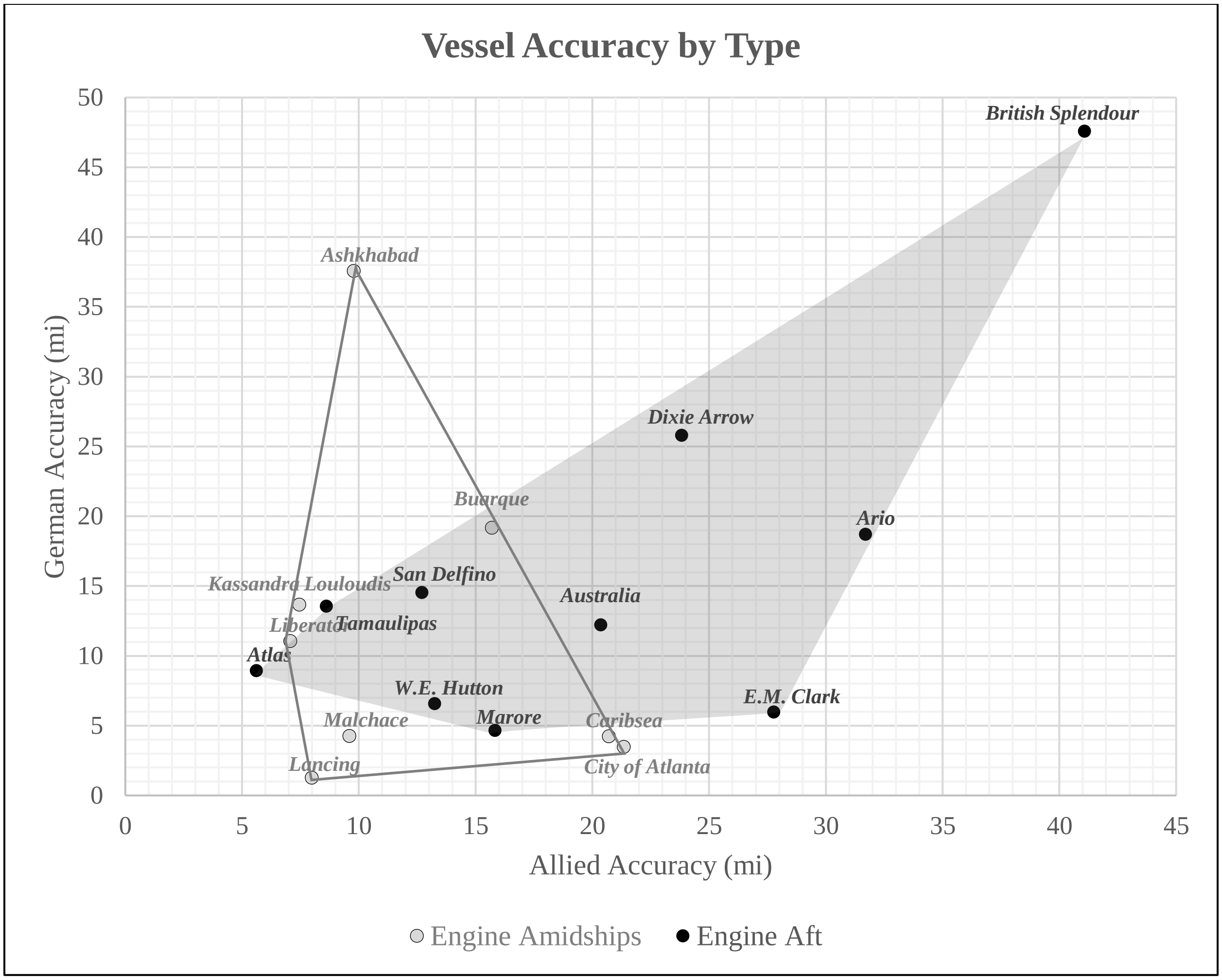


Figure 51: Accuracy of vessels by type (engine location). (Image by author, 2020.)

Liberator was sailing alone and armed with one 4-inch gun when it was attacked on 19 March 1942 at 0942 hours (Browning 1996:52). The vessel was hit once and sank quickly. Vessel armament was determined to possibly affect positional accuracy due to an increased sense of security from the crew because of the presence of the gun and gun crew. The psychological effect of battle has been noted in many previous studies, such as Fox (1993). An increased sense of security may have led to an improved response to an attack, which, in turn, may have led to a less dense fog of war and better positional accuracy (although the opposite effect is also possible). Further research is needed to discuss the positional effectiveness of armed merchant vessels, as not enough merchant ships were present in this study to determine if they made a difference.

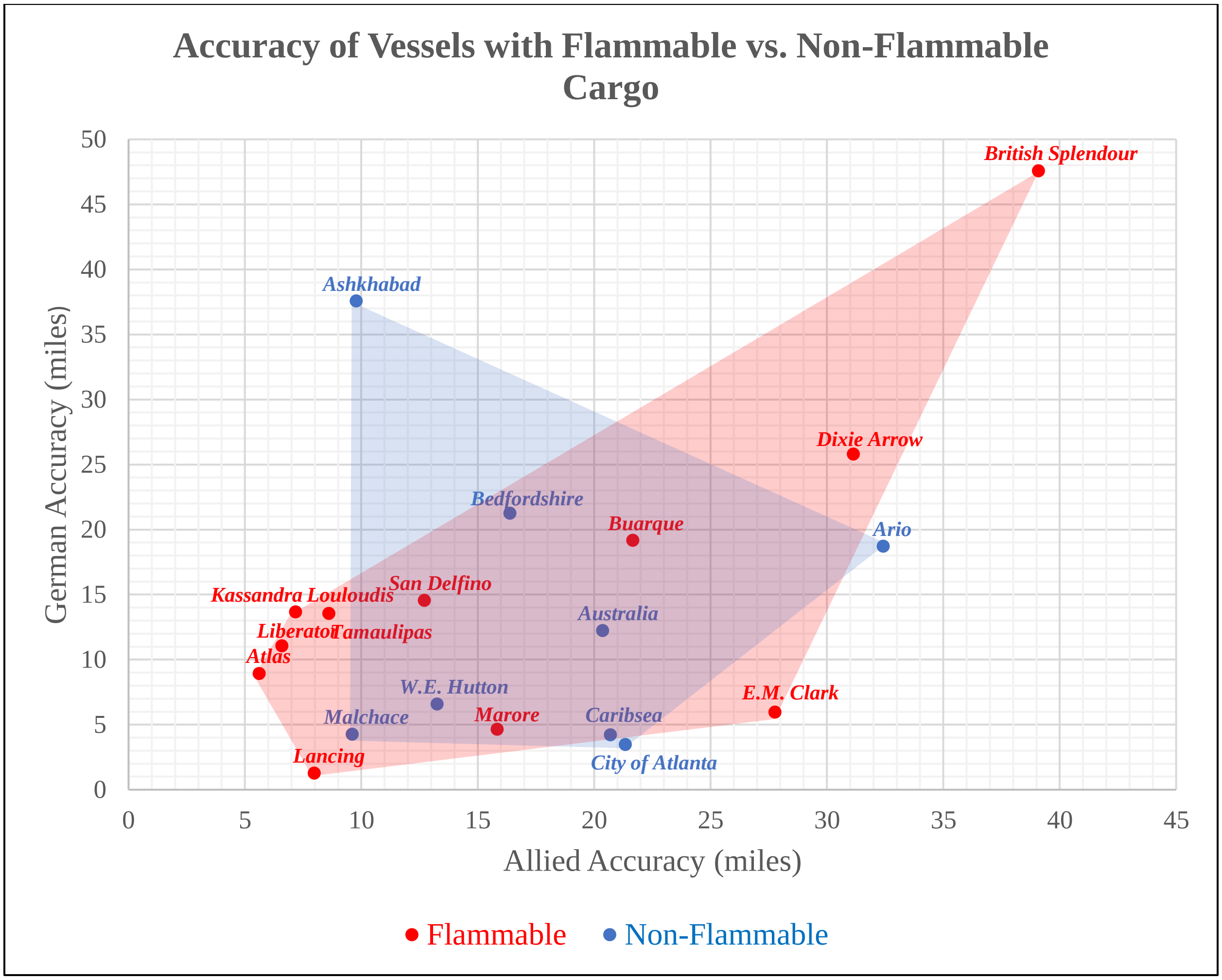


Figure 52: Accuracy of vessels with flammable and non-flammable cargo. (Image by author, 2020.)

Nevertheless, *Liberator*'s calculated distance from its centroid is displayed in Figure 53 as 7.06 miles while its bearing is 88 degrees northeast. Its distance and bearing from shore are

12.97 miles at 323 degrees northwest. The vessel was located 11.07 miles at a 296-degree heading from the center of its recorded grid zone, CA7959. Thus, the Germans were just as accurate, although they may not have known that the vessel was armed.

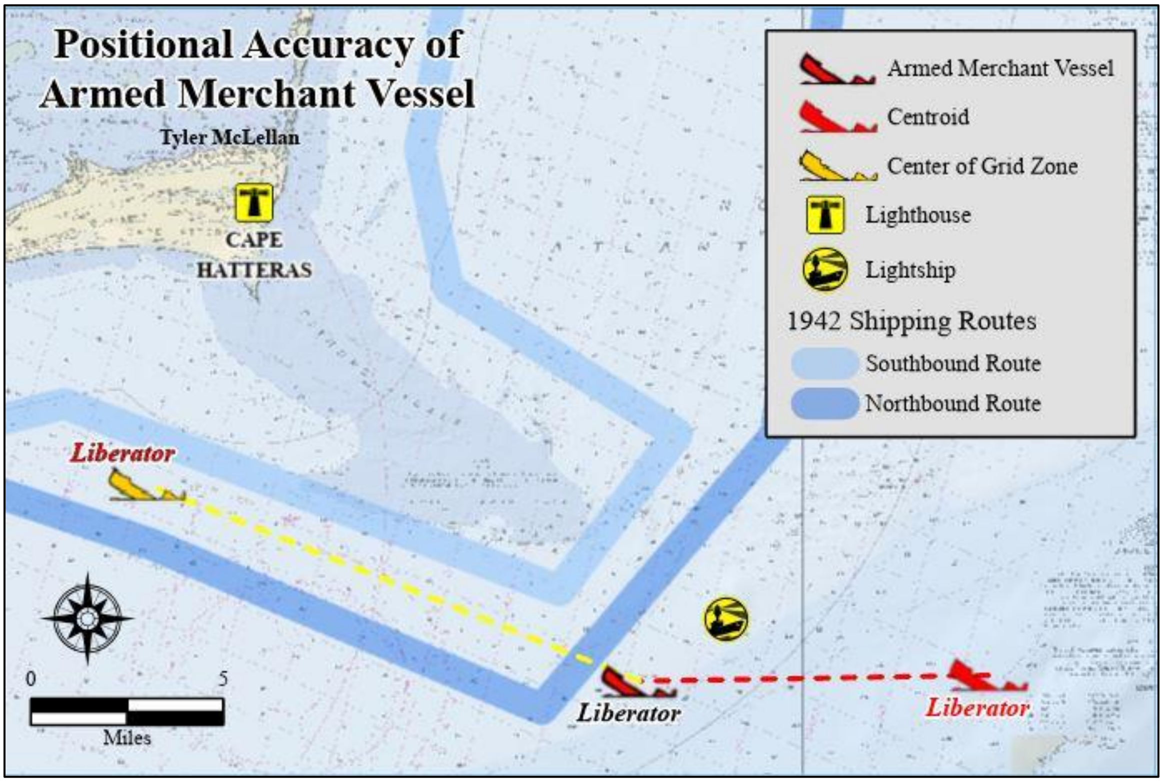


Figure 53: Analysis of the accuracy and location of the armed freighter *Liberator*. (Map by author, 2020.)

The only warship in this study is HMT *Bedfordshire*, which is a unique case due not only to its purpose, but also its size. HMT *Bedfordshire* was registered at only 443 gross tons, making it the smallest vessel by far in the study group. The warship was tracking U-558 when the U-boat surfaced and launched two torpedoes from 1,000 meters away and dove. U-558 then resurfaced and fired a third torpedo from under 600 meters, which quickly destroyed the small vessel (Hickam 1989:217-218; NOAA 2020b). The centroid generated from the recorded coordinates of the attack on the lone warship is located 16.38 miles at a heading of 233 degrees from the wreck. Krech aboard the U-558 marked the attack in grid zone DC1183, the center of which is 24.26

miles away at a 238-degree heading (Figure 54). This inaccuracy in recording the location of an attacking warship as opposed to a merchant vessel may also be attributed to fear.

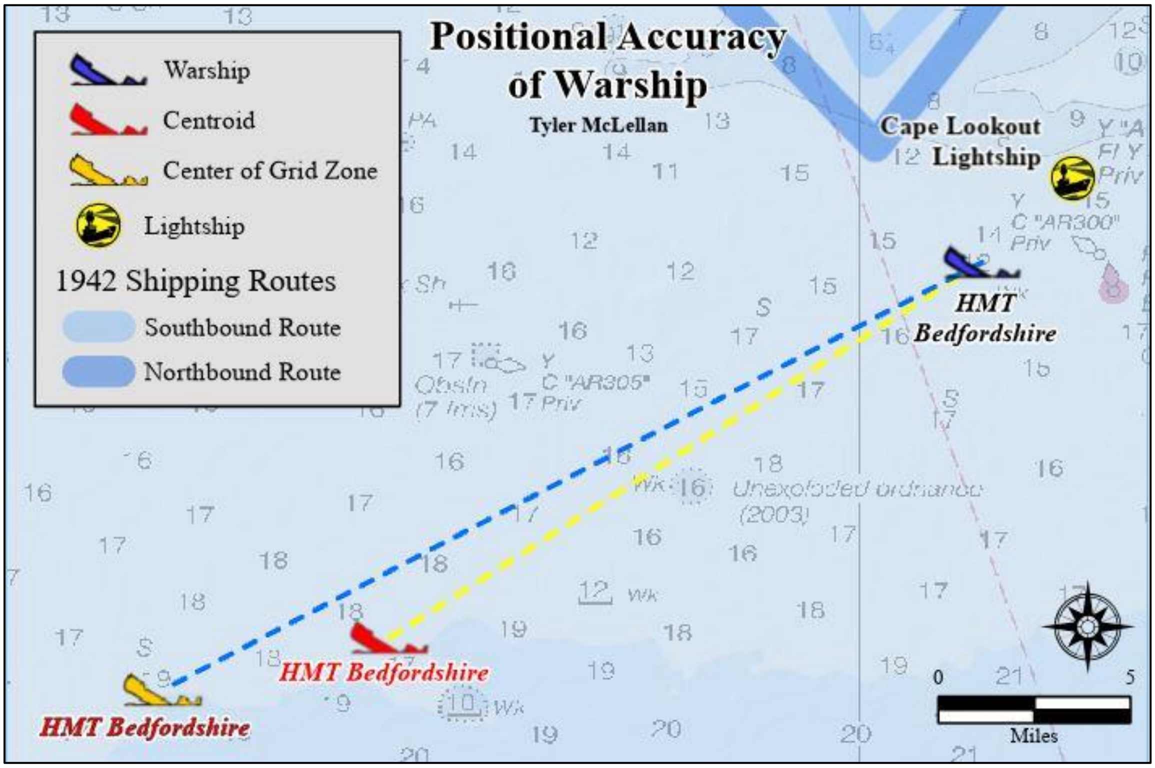


Figure 54: Analysis of the accuracy and location of the antisubmarine trawler HMT *Bedfordshire*. (Map by author, 2020.)

The final category of vessel analyzed in this study are escorted vessels. Despite the vulnerability of the merchant vessels as well as their importance to the war effort, of the twenty-six, only six were traveling in concert with other vessels at the time of attack. Of these, three are available for analysis with their respective centroids and German positions: *Ashkhabad*, escorted by one anti-submarine trawler, *British Splendour*, escorted by two anti-submarine trawlers, and *Kassandra Louloudis*, sailing in a small impromptu convoy with two other merchant ships and escorted by USCGC *Dione* and USS *Dickerson*. The other three vessels include *Manuela* and *Bluefields*, both part of larger convoys, and *Empire Gem*, which sailed with another merchant vessel (Hickam 1989; NOAA 2020b). The distances and headings between the three wrecks, their centroids, and the center of their recorded grid zones (as well as the grid zone name) are displayed in Table 11. The distribution and accuracy of the three escorted vessels are displayed in Figures 55 and 56.

Table 11: Accuracy of escorted vessels.

Vessel Name	Distance to Centroid (mi)	Heading to Centroid (deg)	Distance to Center of German Grid	Heading to Center of German Grid	Grid Name
Kassandra Louloudis	7.45	209	13.67	129	CA7993
Ashkhabad	9.78	243	37.57	49	DC1121
British Splendour	41.07	58	47.59	61	CA7969

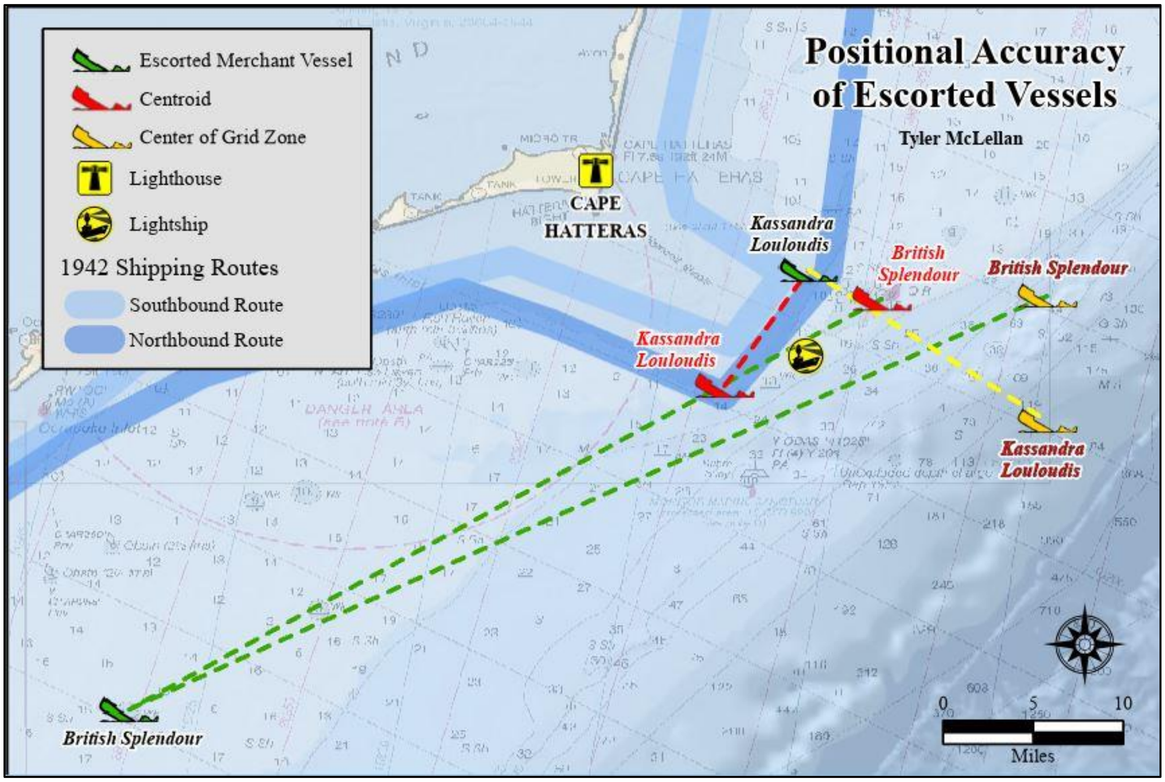


Figure 55: Analysis of the accuracy and location of the escorted vessels *Kassandra Louloudis* and *British Splendour* off Cape Hatteras. (Map by author, 2020.)

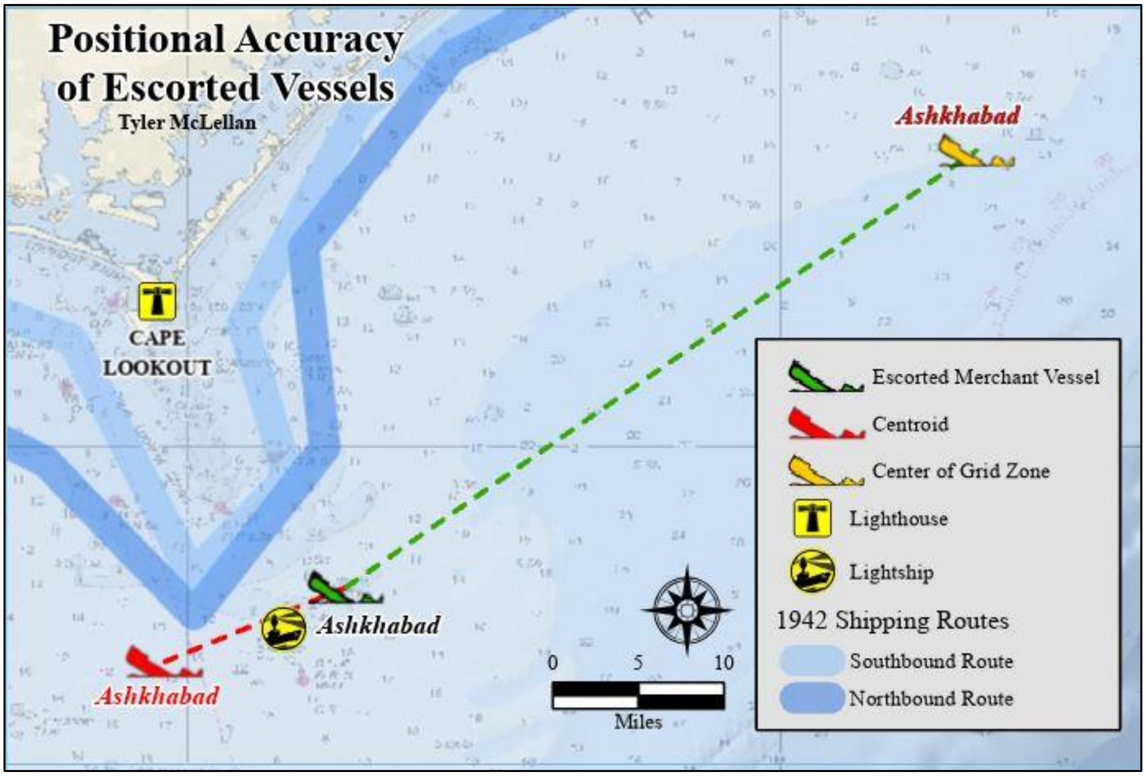


Figure 56: Analysis of the accuracy and location of the escorted vessel *Ashkhabad* off Cape Lookout. (Map by author, 2020.)

It should be noted, however, that the data size of vessels in a convoy is too small to draw conclusions. The graph in Figure 57 compares the positional accuracy of armed, escorted, and unprotected merchant vessels as well as the warship. As displayed, the escorted vessels had a high level of accuracy among Allied sources, whereas the German accuracy was much lower (apart from *British Splendour*). The armed *Liberator* also displays a high level of accuracy among Allied sources as well as German recordings, however, it is unknown whether the Germans knew that this vessel was armed. HMT *Bedfordshire* displays a medium level of accuracy for both sources, although no survivors were found from the vessel and no SOS was received. As such, its positional accuracy may be more speculation in Allied sources, whereas the German recording is quite inaccurate in comparison to other vessels. This may lead to the observation that U-boat commanders inaccurately recorded the location of an attack on vessels that display a threat to the U-boat, such as vessels escorted by other warships. This observation requires more testing as the dataset presented is too small to draw any substantial conclusions.

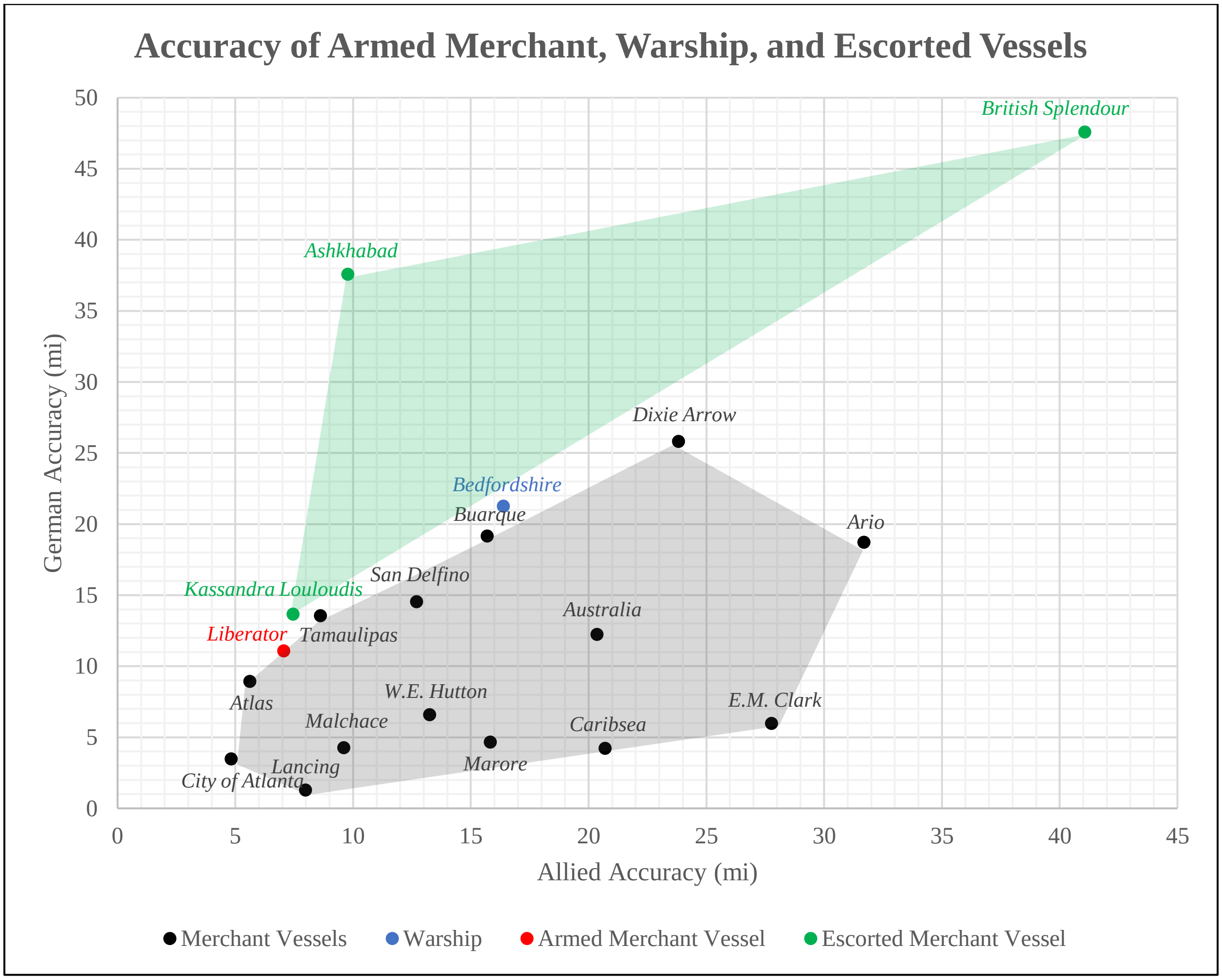


Figure 57: Comparison of the accuracy of armed merchant vessels, warships, and escorted vessels. (Image by author, 2020.)

The vessels in this study group comprise eight different nationalities, shown in Figure 58 (not including the German U-boats). These include 17 U.S.-registered vessels, 4 British, and a single vessel each from the countries of Brazil, Greece, Nicaragua, Norway, Panama, and the Soviet Union. As shown in Figure 59, the registered nationality does not appear to be a factor of significance. This is exemplified by *Buarque*, which at the time of its sinking was flying a neutral Brazilian flag, as well as the fact that many of these vessels, including *Ashkhabad*, had transferred ownership numerous times prior to the war. Additionally, many vessels had crews of different nationalities and background (Hickam 1989; NOAA 2020b).

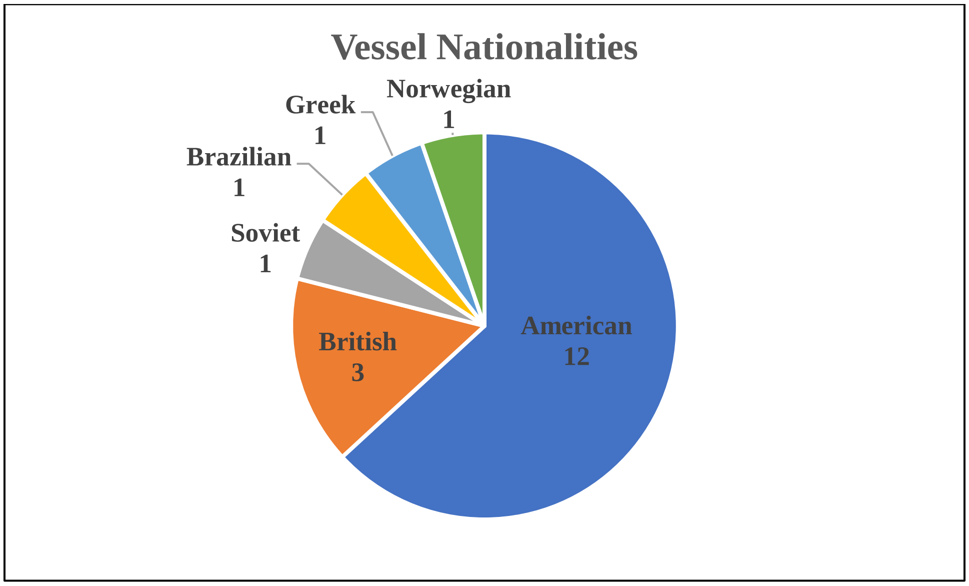


Figure 58: Vessel nationalities represented in this study. (Image by author, 2020.)

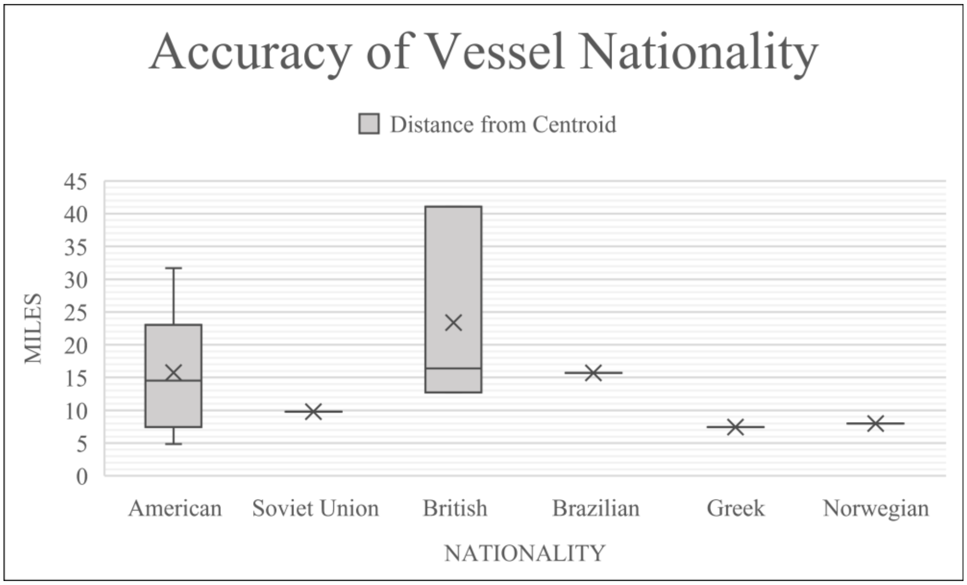


Figure 59: Accuracy of different vessels based on nationality. (Image by author, 2020.)

Additionally, the speed and draft of the Allied vessels can be analyzed. Within the study group, both the slowest vessel *Caribsea*, which was recorded as traveling at 4 knots (Browning 1996:43) and many of the fastest vessels, recorded at 11 knots (Browning 1996:16) were located roughly 20 miles from their centroids and within 5 miles of the center of their recorded grid zone. This is shown in Figure 60, with *Caribsea* highlighted since it was going much slower than any other vessel. Further, vessels with shallow drafts (*City of Atlanta* at 17.08 ft. and Malchace with 20 ft.) and deep drafts (*Atlas* and *Tamaulipas* at over 27 ft.) were all located at less than 10 miles from their centroids, while also being within 15 miles of their grid zones. Thus, the data does not point to any correlation between speed or draft and accuracy, although as with vessel armaments and escorts, the sample size used for this analysis is too small to draw a conclusion.

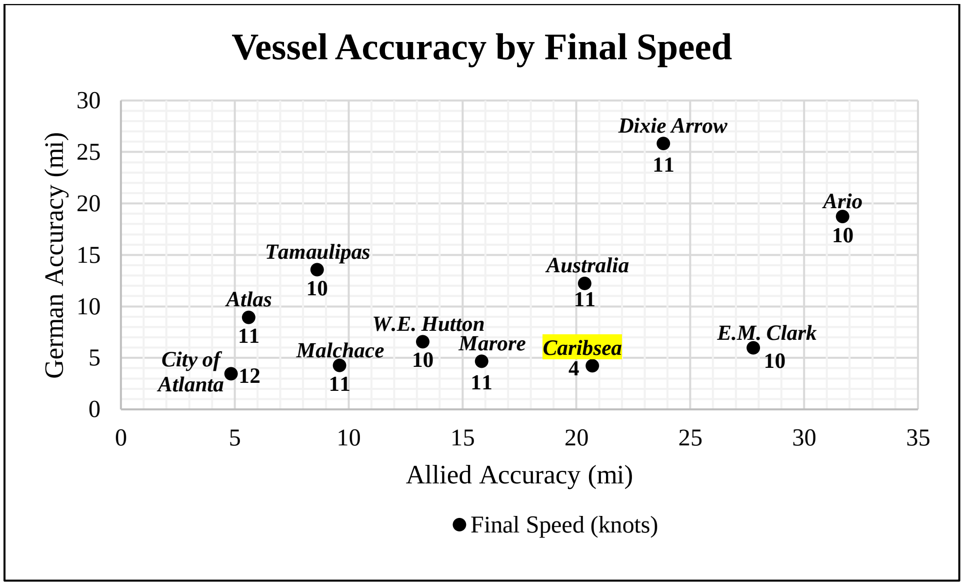


Figure 60: Vessel accuracy based on final recorded speed. (Image by author, 2020.)

A set of calculated circumstances accounted for in this study are those surrounding the nature of the attack. This includes the speed of the attack (duration) and the level of violence, broken down into two broad categories each. The speed of the attack can be either quick or slow, and the level of violence can be either violent or calm (definitions provided in Chapter 3). Of the 19 vessels analyzed, 11 were deemed to be violent attacks, while 8 were determined to be calm attacks. For speed, 13 were determined to be quick attacks, while 5 were designated as slow. The accuracy of both German and Allied sources for each category are shown in Figure 61.

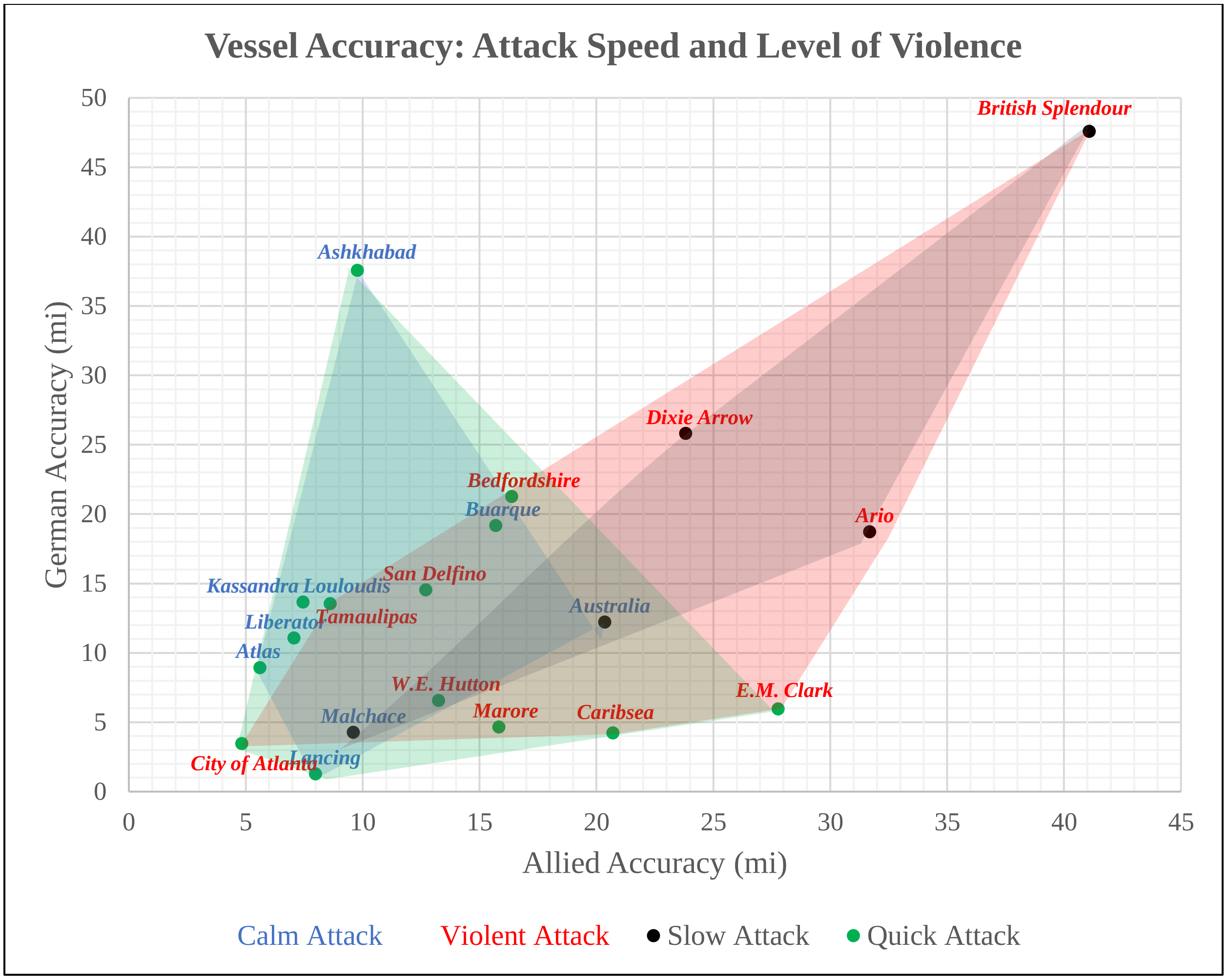


Figure 61: Vessel accuracy compared to the speed and level of violence of the attack. (Image by author, 2020.)

As shown, quick and calm attacks tended to be more accurate than violent and slow attacks. Slow attacks especially appear to have a high level of inaccuracy. This can be due to the potential effect of drift (examined in the following section) as well as the psychological impairments that may occur to crewmembers witnessing their vessel slowly sinking (in addition to burning, as is the case in violent attacks). The factors analyzed thus far are directly attributable to the individual vessels. Other sets of data independent of the vessels were also considered, including atmospheric circumstances, which may have had an impact on the level of positional accuracy.

Analysis of Atmospheric Data

Information used for the analysis of atmospheric data included the dates and times each attack took place. This allowed for a determination of sunlight if the attack occurred between sunrise and sunset as well as the amount of moonlight, based on the moon phase recorded for the date of attack. Of the 27 vessels analyzed in this study, only 6 sunk in daylight. The remaining 21 vessels were all attacked at night. Time was determined based on the average of all recorded times within the historical sources for each attack and compared to the sunrise and sunset times recorded for the dates of each attack in eastern North Carolina. Only one attack occurred within proximity to either sunrise or sunset, *Kassandra Louloudis*, which had an average time among historical sources of 1914 hours, with a sunset time of 1911 hours, thus making the attack right at sunset.

The other four vessels attacked during daylight were *Liberator*, *Manuela* (both of which were armed), *Dixie Arrow*, *Bluefields*, and *Australia*. Because *Manuela* was towed away from the attack site before sinking, it is not included in the 19 vessels used for geospatial comparison with their centroids and German points. Further, the analysis of *Bluefields* was not included because the Germans' recorded location of the attack was lost when U-576 was sunk immediately after – before it could report the location of the attack back to Doenitz. Of the four remaining vessels attacked during the day, the distance from the wrecks to their respective Allied centroids and German points are shown in Figure 62 and Table 12. The graph in Figure 63 displays these distances in comparison to one another.

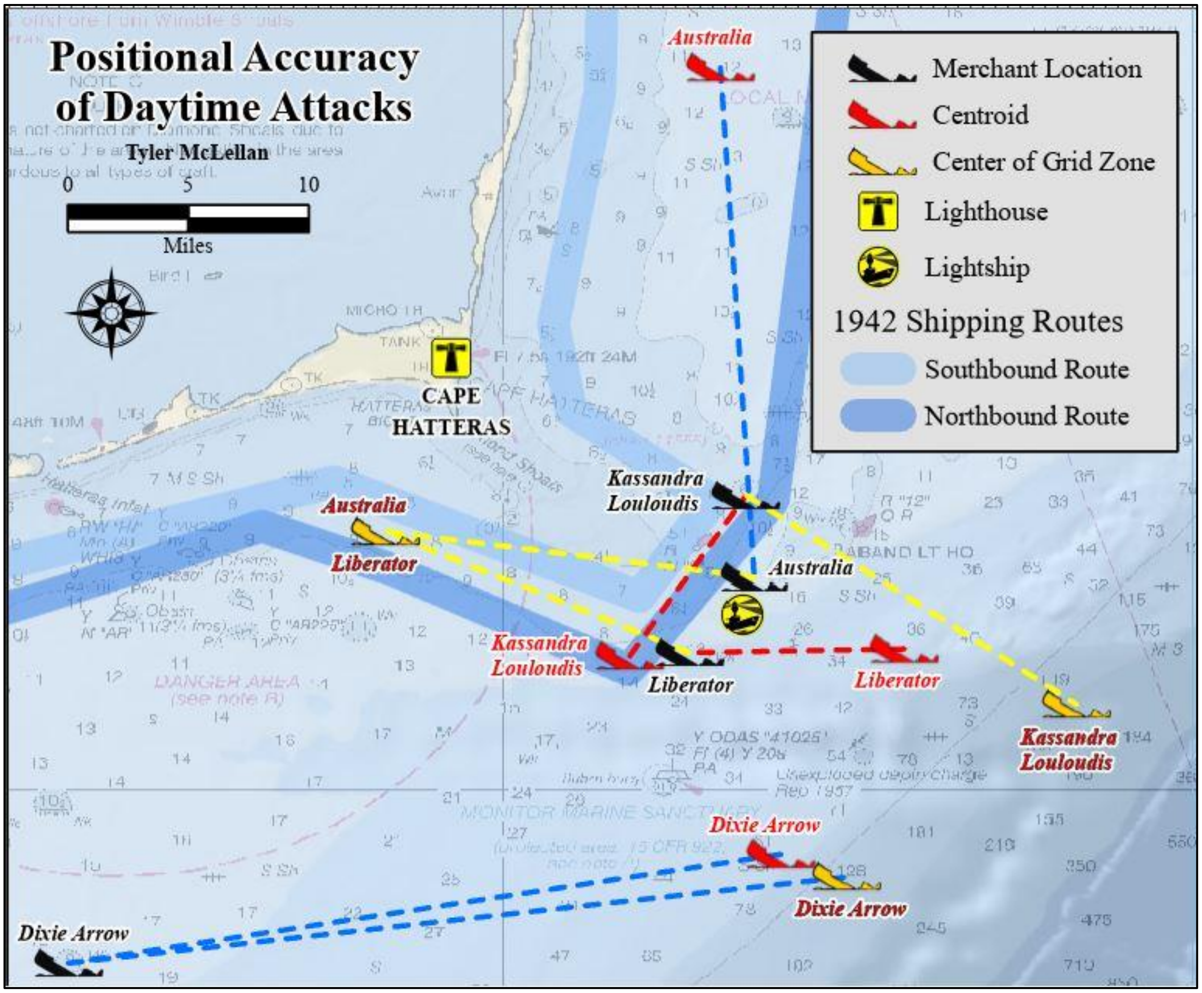


Figure 62: Map of the distances from the wreck to the Allied centroid and German grid point for vessels attacked during the day. The different colors in distances are shown in Table 12. (Map by author, 2020.)

Table 12: Distance from the wreck to the Allied centroid and German point for daytime attacks.

Vessel Name	Time of Day	Allied Accuracy (mi)	German Accuracy (mi)
Liberator	Morning	7.06	11.07
Kassandra Louloudis	Evening	7.45	13.67
Australia	Midday	20.36	12.23
Dixie Arrow	Morning	23.82	25.81

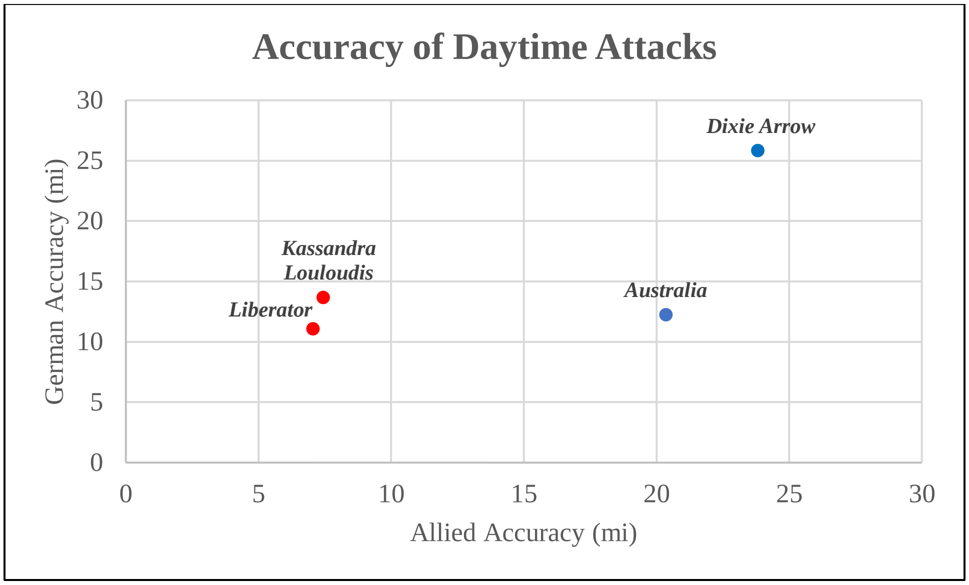


Figure 63: Comparison of German and Allied accuracy for daytime attacks. (Image by author, 2020.)

It should be further noted that both *Liberator* and *Dixie Arrow* were sunk at 1002 hours and 0829 hours, respectively. The time of sunrise for both days was 0658 hours and 0708 hours, respectively. Thus, both attacks occurred within a few hours of sunrise, and both centroids were located east of the wreck, while *Kassandra Louloudis*, which was attacked at sunset, had a centroid located southwest of the wreck. All three of these cases point to the possible effect of sun glare on the surface from a sun low on the horizon, which may have influenced both the U-boat and the vessel in sighting one another and further determined the location from which the attack began. Low visibility due to glare may have thickened the fog of war, further causing positional inaccuracy. Both *Bluefields* and *Australia* were sunk well into the day. While there is potential for sun glare to affect positional accuracy, to confirm this, patterns need to be extracted from vessels that were sunk under similar daylight circumstances. There appears, however, to be no similarities or patterns in these attacks. This statement is again open to further study as the number of vessels analyzed for this factor is small.

The remaining 21 vessels were all attacked at night in different percentages of moonlight, shown in Figure 64. The process of dividing the phases of the moon into percentages is described in Chapter 3. As displayed, most of the attacks, 13 of 21, occurred between the new/first quarter and the third quarter/new phase (25%). This is not surprising considering the low light allowed for U-boats to remain hidden more effectively while providing just enough light for navigation. Additionally, the illuminated U.S. coastline caused many vessels to be silhouetted against the shore. Nevertheless, an immediate pattern between the percentage of moonlight and the level of accuracy for each event cannot be distinguished, as shown in Figure 65, which displays the comparison of accuracy between German and Allied sources for the 19 vessels used in this study in different levels of moonlight.

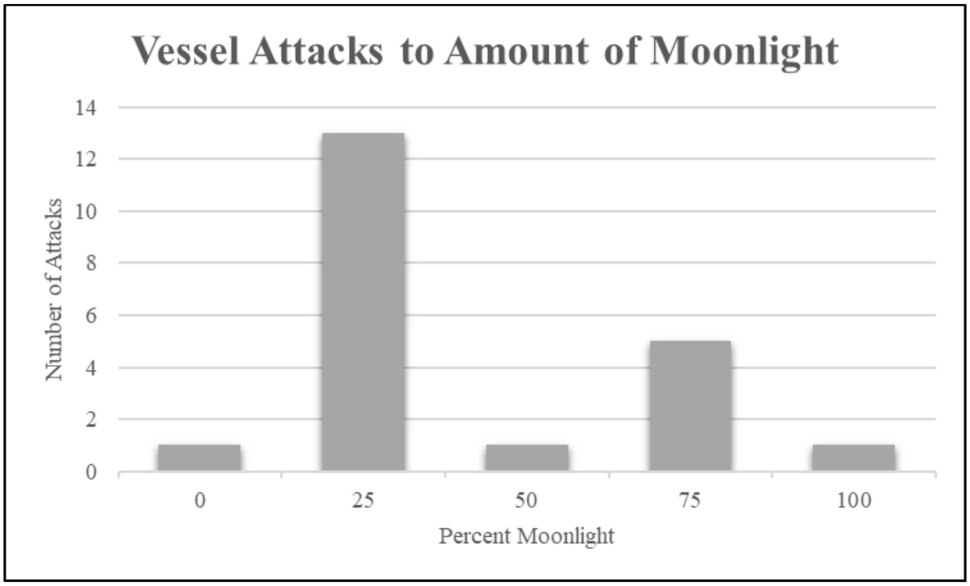


Figure 64: Number of attacks for each percentage block of moonlight. (Image by author, 2020.)

Additional error in the level of visibility during each attack was also considered due to the waves and weather at the time of each attack. The wave activity, however, as well as the weather and visibility, cannot be ascertained for each specific event. This information can be found recorded in the deck logs of naval vessels that were in the proximity of the stricken merchant vessel at the time of the attack. These logs contained a monthly title sheet, a daily remarks sheet, and daily columnar sheet. Each entry was filled out by a different naval watch, broken up into four hours. Spaces on the columnar sheet contained information such as detailed meteorological and navigational data, including wind speed and direction, barometric pressure, water temperature, visibility, and overall weather conditions (National Archives 2018).

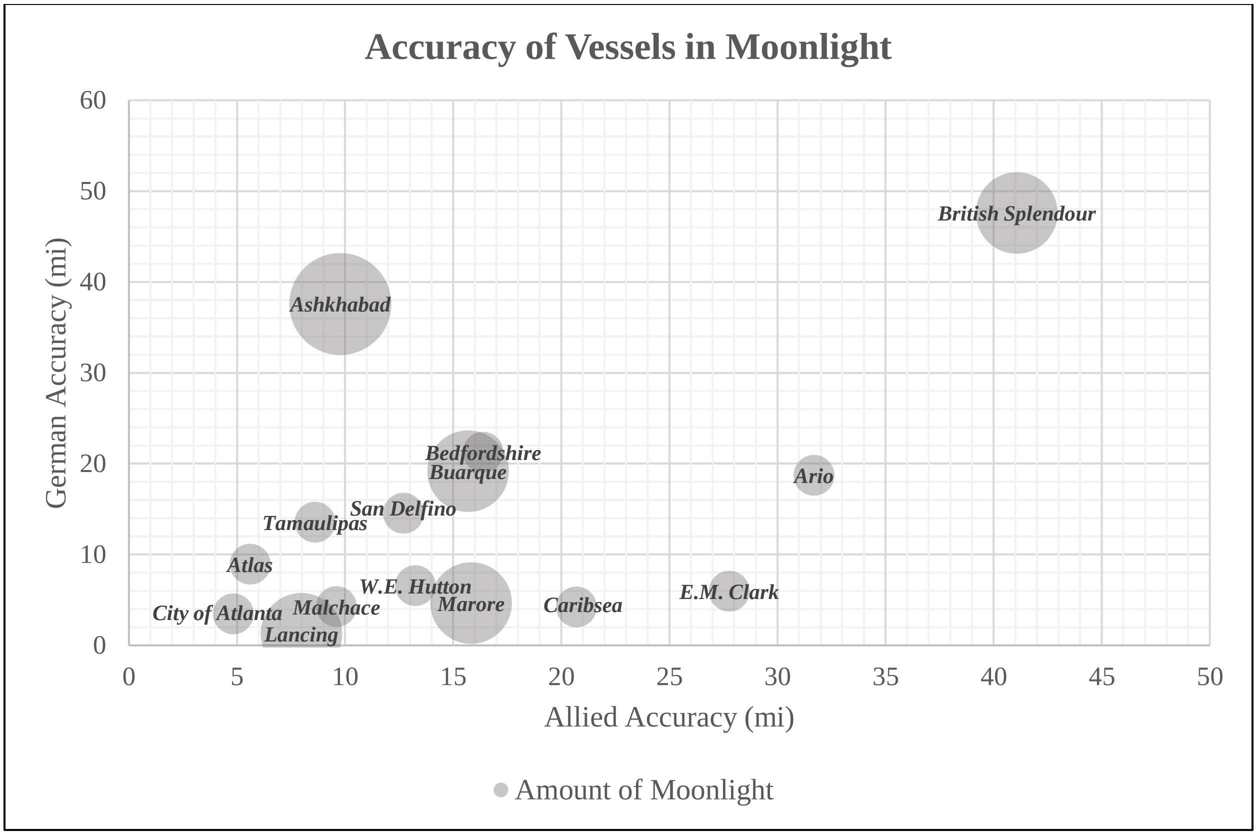


Figure 65: Comparison of German and Allied accuracy in different levels of moonlight. (Image by author, 2020.)

Naval vessels stationed around Torpedo Junction throughout the study period include the destroyers USS *Roper* (DD-147) and USS *Dickerson* (DD-157). The records for both vessels are available in Record Group 24 in the National Archives II at College Park, MD, and were inaccessible at the time of this research. Despite a lack of specific weather data, generalized statements can be determined regarding the average weather of the Outer Banks of North Carolina, including the effect of large-scale meteorological events. The largest events that can affect weather and wave patterns along the outer banks are hurricanes. NOAA's Tropical Cyclone Climatology, 1851-2016 report displays that no hurricanes were recorded in 1942, although an extra-tropical low hit Ocracoke in mid-October, much later in the year than this study (Sefcovic 2020).

Additional generalized statements can be made about the average wave height off the Outer Banks, which is two or three feet. This information, however, was retrieved from a U.S. Geological Report published in 2000, much later than the study period. This same study also detailed the degree in which this average can be thrown off due to winter extratropical storms, called "northeasters," which cause the waves to increase to greater than 5 feet and occasionally up to 30 feet (Dolan and Lins 2000:5). The average level of Allied accuracy was measured for the first five months of 1942 (wherein all 19 vessels used for accuracy comparison were attacked). As shown in Figure 66, the average level of accuracy is less (distance between the wreck and the centroid greater) in the months of February, March, and May, the first two having the highest average "northeasters." This data should be taken with caution, however, as within the study group, only a single wreck was measured each from the months of January, February, and May. The remaining sixteen were evenly split between the months of March and April, which shows a slight decrease in average distance (increase in accuracy) from March to April.

Another factor found to possibly influence the level of accuracy in reported positions is the oceanic current. This factor would prove most influential on vessels that did not sink immediately upon being attacked, but rather continued to drift for more than two hours after attack. This amount of time was chosen with the assumption that upon being attacked, the engines were stopped, and the vessel was moved by natural forces and not of its own power.

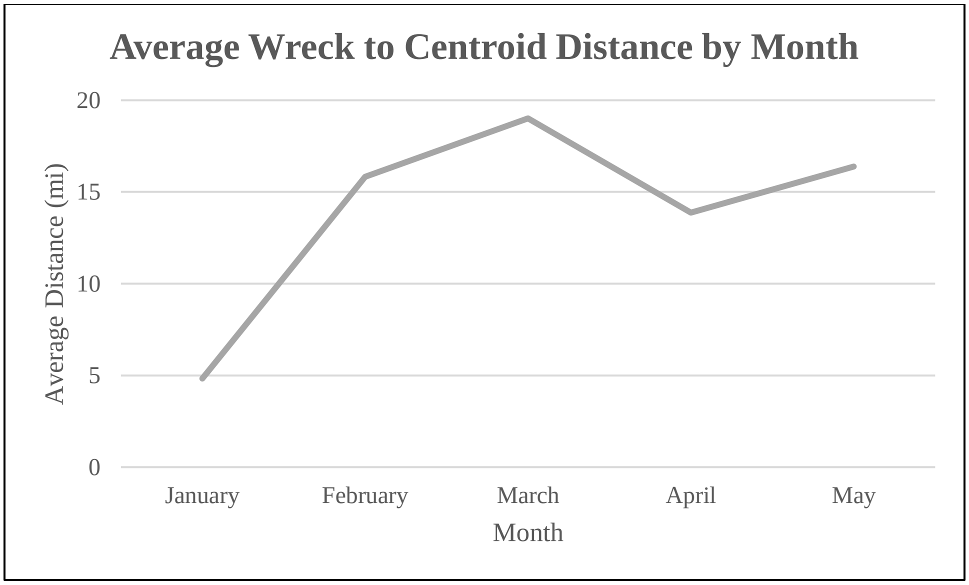


Figure 66: Changes in average distance between the wrecks and centroids from the months of January through May. (Image by author, 2020.)

The error in the level of accuracy by a vessel adrift for this amount of time is considered low enough to regard as sinking within the vicinity of the attack. A vessel abandoned and adrift, or a derelict, can drift as fast as 2.5 knots (2.88 mph) along the Gulf Stream. Its exact speed as well as its direction of drift can vary with the wind speed, wind direction, and where in the current the vessel was struck. The effect of wind is also affected by the ratio of the areas (hull and superstructures of the ship) exposed to the wind and water resistance. Further, the wind can pick up, die down, and change direction in the amount of time a vessel is left adrift, causing the derelict ship to move into different currents and offshoots along the Gulf Stream (International Marine Engineering 1911:406). This level of variation, the size and number of the vessels, as well as the inability to acquire specific wind information puts the factor of current beyond the scope of this study.

As an aside, the vessels of the study group with the largest amount of error (low accuracy) between the wrecks and their respective centroids are *Dixie Arrow*, *British Splendour* and *Australia*. All three vessels were tankers: large (over 7,000 GRT) engine aft vessels transporting flammable material. Additionally, both *Ario* and *E.M. Clark* display a low level of accuracy. It is interesting to note that all these vessels, apart from *E.M. Clark*, remained in sight of their crew for a longer period of time because they stayed afloat. These vessels were too damaged to save, with the stern of *Australia* resting on the bottom (NOAA 2020b), while *British Splendour* and *Dixie Arrow* burned within sight of its crew for at least an hour before sinking (Hickam 1989:103-105,128; NOAA 2020b). *Ario* remained afloat for an hour before the crew attempted a salvage, but quickly sank afterwards. Thus, while the low level of accuracy among these five vessels may result from drift (although both *Australia* and *British Splendour* sank with their bows above the surface and their sterns resting on the bottom [Hickam 1989:128; NOAA 2020b]), the full effect over the course of two hours or less would probably cause at maximum a 5-mile difference, rather than the 20+ miles seen in these vessels. Therefore, the potential impact of psychological factors (fear of the burning vessels remaining in sight) cannot be ruled out and is open for future study.

As displayed, current, wind, time of day, and overall weather are all atmospheric factors that change quickly with time and can vary greatly. Additionally, the impact these factors have on positional accuracy remains unclear. These factors are different from physical or geographical features that remain the same throughout time, which may also influence locational accuracy. The geostatistics of these features are analyzed in the following section.

Analysis of Physical Features

There are four major physical features that were considered in this study. These are (1) bathymetry of the wreck site (and therefore attack site), (2) distance from shore-based military installations, (3) distance of the attack from lighthouses and lightships, and (4) distance from shore (potentially being able to see the shore from the attack). The bathymetry, while important for diving and archaeological purposes, has little impact upon the locational accuracy of these vessels, as all vessels (save for *Bluefields* and U-576) are in water shallower than 200 feet. This depth is important as depth charges can reach 300 feet or deeper. Thus, to move into shallow water within depth charge range is risky for a U-boat and was believed to be unlikely by merchant captains early in the war. Because the wrecks of all vessels save for the two mentioned fall within that range, the effect that bathymetry plays on locational accuracy of U-boat attacks is negligible for this study.

The shore-based military installations that may have affected these vessels include the major naval base at Norfolk, VA, as well as the air bases at Cherry Point and Elizabeth City, NC. These two air bases were chosen as they are the closest in proximity to the attacks off Hatteras and Lookout, with each vessel compared to the closest base. These distances are considered as a means of potential rescue upon receiving a distress signal within the minds of the merchant ships' crews. The spatial distribution of the wrecks and centroids from the military bases at Cherry Point and Elizabeth City as well as the location of the Norfolk naval base are shown in Figure 67. The distances between each wreck and its centroid (accuracy) are compared to the distances between each wreck and the closest air base as well as to Norfolk and are shown in Table 13 and Figure 68. No pattern is visible within these distances.

The distance of the attack from lighthouses and lightships is the third physical factor in this study and consists of both the Cape Hatteras and Cape Lookout lighthouses and lightships. Each of the 19 vessels (except *Buarque*, with a distance 80 miles northeast of Hatteras) used for comparison were graphed with the lighthouse and lightship within closest proximity.

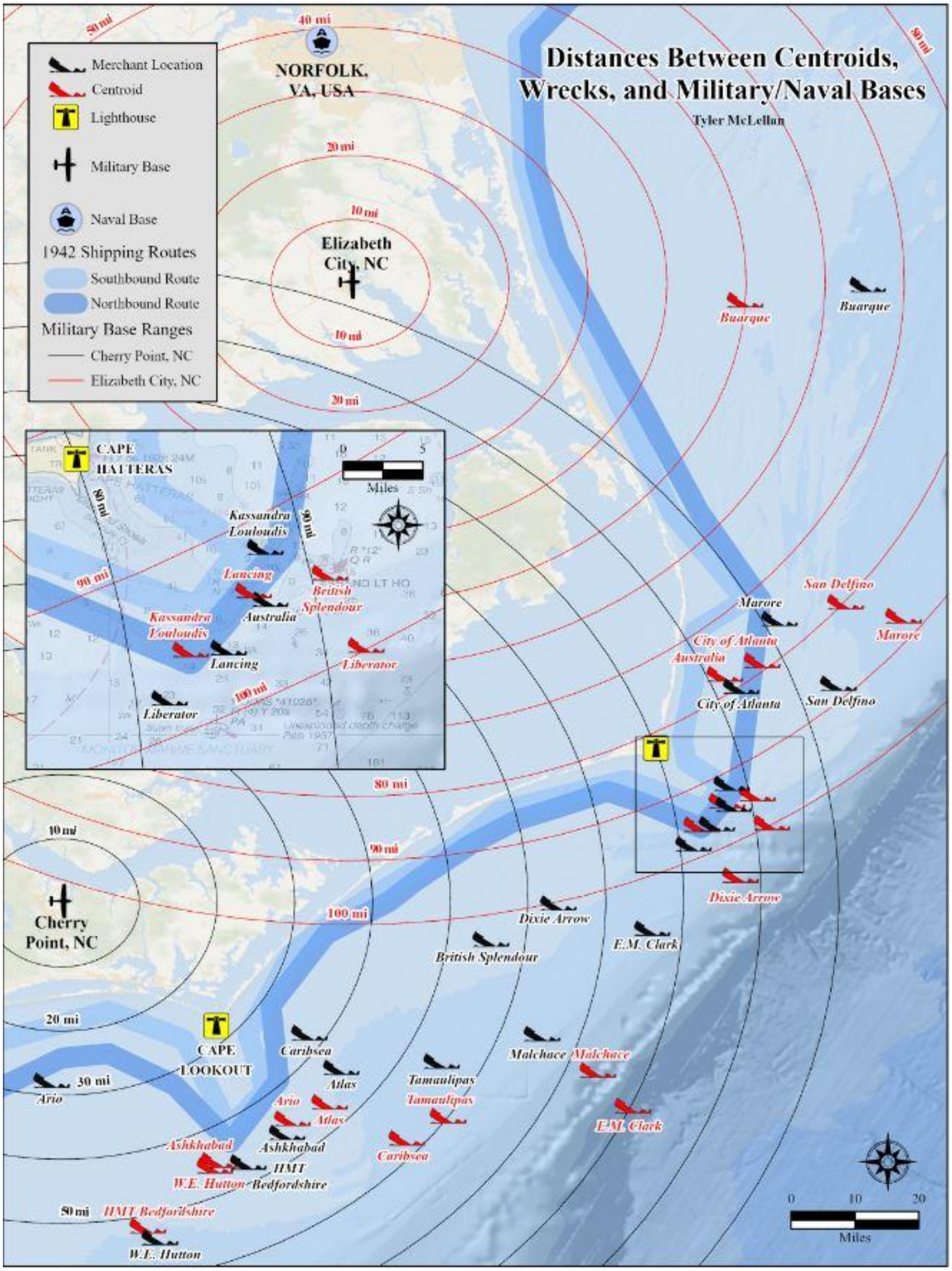


Figure 67: Map of the shipwrecks compared to their respective centroids and the naval base in Norfolk. The distances of each wreck and centroid from the nearest air base is also displayed. (Map by author, 2020.)

Table 13: Shipwrecks compared to their respective centroids as well as the distances from the nearest air base and the naval base in Norfolk.

Ship	Sinking Date	Distance from Centroid (mi)	Distance to Norfolk Naval Base (mi)	Nearest Air Base	Distance from Air Base (mi)
City of Atlanta	1/19/1942	4.83	113.83	Elizabeth City, NC	80.06
Atlas	4/9/1942	5.61	160.13	Cherry Point, NC	44.24
Liberator	3/19/1942	7.06	131.99	Cherry Point, NC	85.1
Kassandra Louloudis	3/18/1942	7.45	126.94	Cherry Point, NC	88.01
Lancing	4/7/1942	7.98	260.78	Cherry Point, NC	81.7
Tamaulipas	4/10/1942	8.61	159.85	Cherry Point, NC	54.83
Malchace	4/9/1942	9.6	157.3	Cherry Point, NC	64.65
Ashkhabad	4/30/1942	9.78	170.3	Cherry Point, NC	46.1
San Delfino	4/10/1942	12.7	119.66	Elizabeth City, NC	87.9
W.E. Hutton	3/19/1942	13.25	187.88	Cherry Point, NC	53.69
Buarque	4/5/1942	15.69	78.54	Elizabeth City, NC	65.37
Marore	2/27/1942	15.83	107.11	Elizabeth City, NC	75.46
Bedfordshire	5/12/1942	16.38	175.13	Cherry Point, NC	47.05
Australia	3/16/1942	20.36	130.04	Cherry Point, NC	87.67
Caribsea	3/11/1942	20.7	154.71	Cherry Point, NC	37.8
Dixie Arrow	3/26/1942	23.82	137.8	Cherry Point, NC	63.88
E.M. Clark	3/18/1942	27.77	144.67	Cherry Point, NC	76.09
Ario	3/15/1942	31.69	165.75	Cherry Point, NC	27.71
British Splendour	4/7/1942	41.07	141.73	Cherry Point, NC	55.53

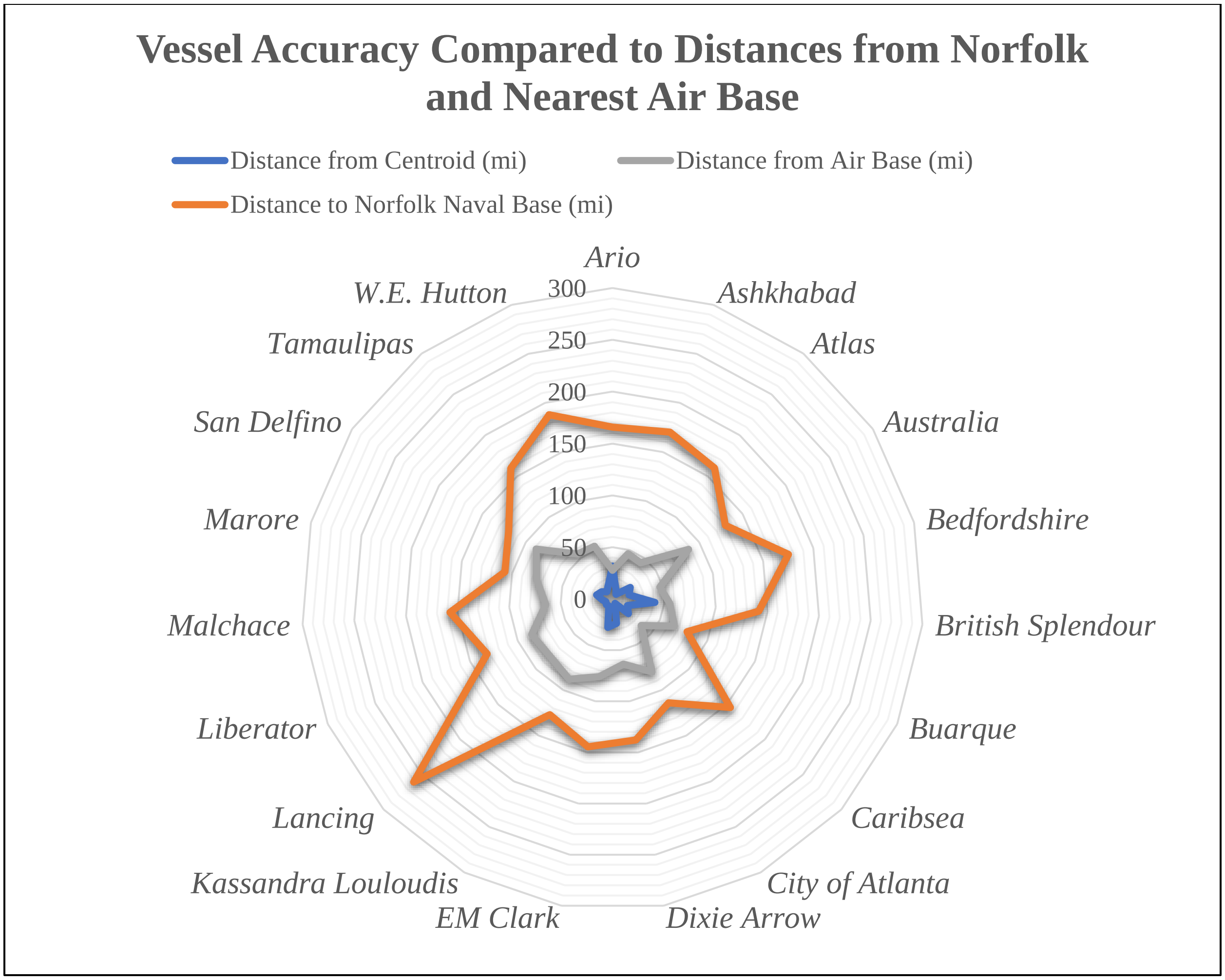


Figure 68: Vessel accuracy relative to its distance to the nearest air base or the Navy Base at Norfolk. (Image by author, 2020.)

Ten vessels were measured around Hatteras, with a comparison of the distance from each wreck to both the lighthouse and lightship (Figures 69 and 70), while Figure 71 shows the difference in accuracy between Allied and German sources. The same is done for the eight vessels around Lookout in Figures 72-74. The nearest wrecks to the Ocracoke Lighthouse, *British Splendour* and *Dixie Arrow*, are over 18 miles away (the stationary lighthouse can be seen out to 14 miles). Therefore, the use of the station for visual navigational purposes is negated for this study. It is interesting to note that the pattern of accuracy shown in the vessels around Hatteras (Figure 71) shows some similarities, but the pattern of accuracy of the wrecks around

Lookout (Figure 74) displays no similarities. This may in part be due to the radio direction finder installed near the Cape Hatteras lighthouse.

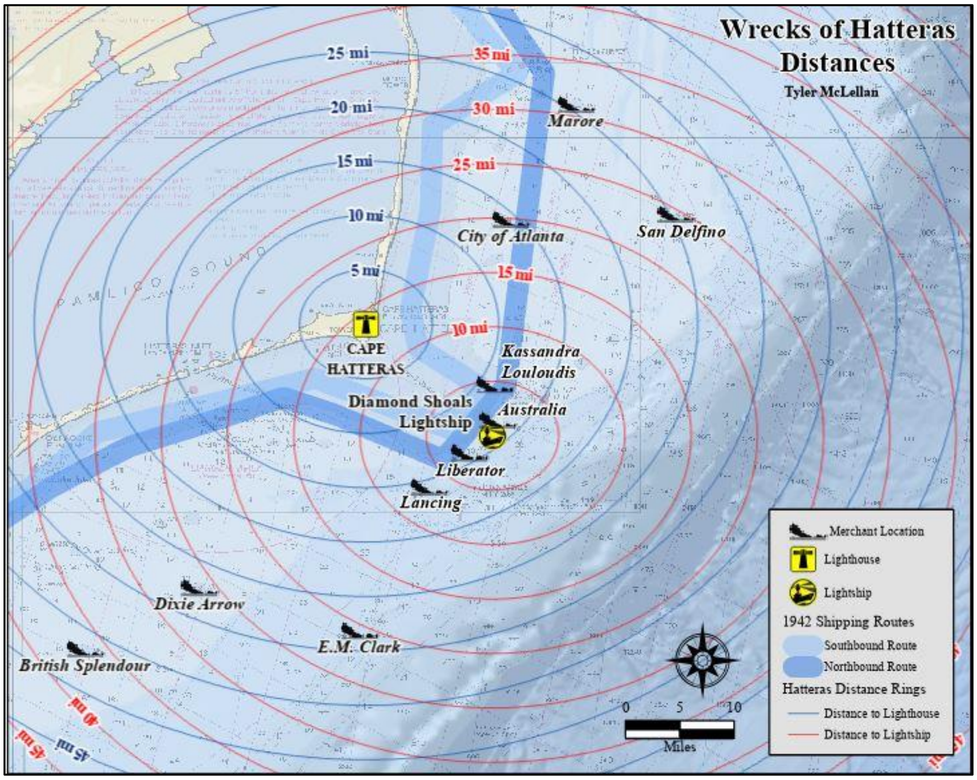


Figure 69: Map of the distances from the shipwrecks nearest Hatteras to the lighthouse as well as the lightship. (Map by author, 2020.)

The final physical factor considered was the distance from the vessel to the shore. The distances were again broken into 10-mile segments. Most of these wrecks occurred within 20 miles of shore. This was measured using the location of the shoreline today. Although the changes in shoreline along the Outer Banks between 1942 and 2020 is not a factor of this study, John Bright (2012:124) mentioned in his thesis, “[i]t is estimated that the islands migrate between 50 to 200 linear feet per century.” Therefore, while the shoreline may have shifted in those 78 years, the amount of error caused would be negligible.

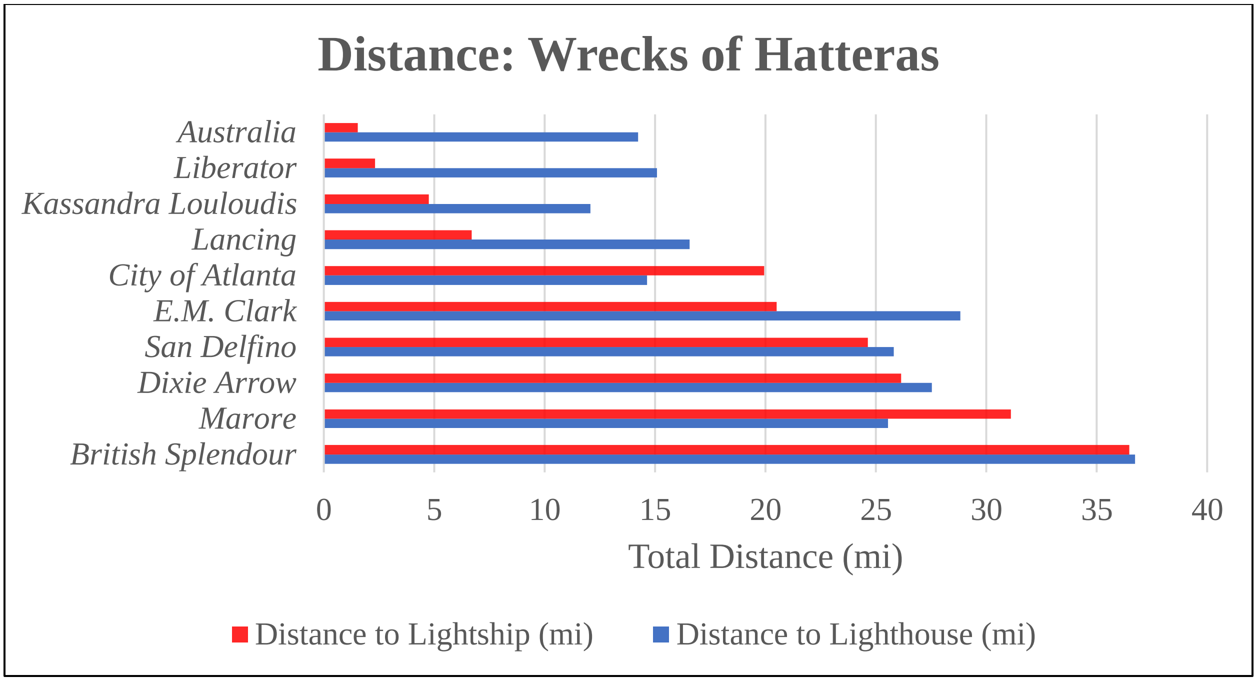


Figure 70: Graph of the distances from the shipwrecks nearest Hatteras to the lighthouse as well as the lightship. (Image by author, 2020.)

The number of vessels (of the 19) within each 10-mile segment from shore is shown in Figures 75 and 76 and compared to their accuracy in Figure 77. As displayed, there appears to be no correlation between Allied vessel accuracy and the distance from shore.

Conclusion

Within this chapter, levels of accuracy were analyzed for different types of vessels and different circumstances of attack. These circumstances included vessels armed with naval guns or escorted by warships, either individually or *en masse*. The different types of vessels were engine-aft types (tankers), engine-amidship types (freighters) and warships (HMT *Bedfordshire*). The locational accuracy of the Allied centroid and the center of the recorded German grid square were displayed for comparison to each vessel.

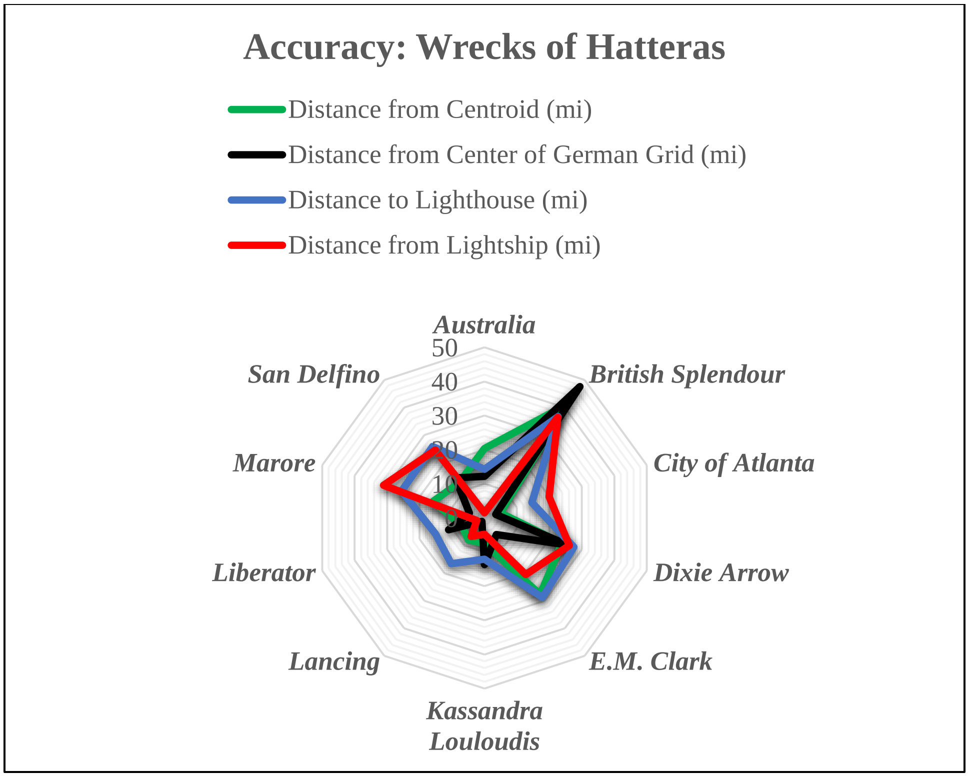


Figure 71: Comparison of German and Allied accuracy for the wrecks around Hatteras. (Image by author, 2020).

Additional vessel factors considered included the final speed and draft, flammability of cargo, speed at which the attack took place, and level of violence of the attack. Each attack characteristic was analyzed for its potential effect on the level of accuracy of reported positions. Other factors examined included weather, wave activity, drift, and bathymetry, all of which were removed as potential factors because this research lacked access to the data, space within the framework, or the factors were determined to have not had an effect on positional accuracy. Additionally, the time of the attack was used to determine the amount of potential sunlight or moonlight for each attack. Finally, different physical features were analyzed for their potential relationship to positional accuracy. These features included the vessel's proximity to naval and air bases, lighthouses and lightships, and shore.

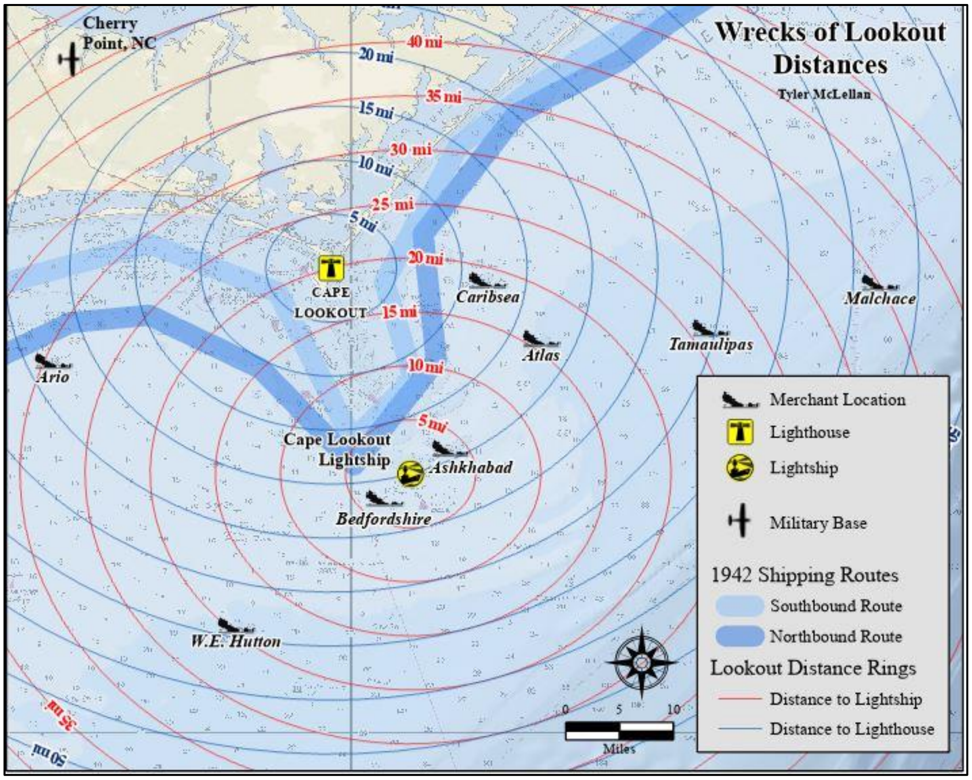


Figure 72: Map of the distances from the shipwrecks nearest to Lookout to the lighthouse as well as the lightship. (Map by author, 2020.)

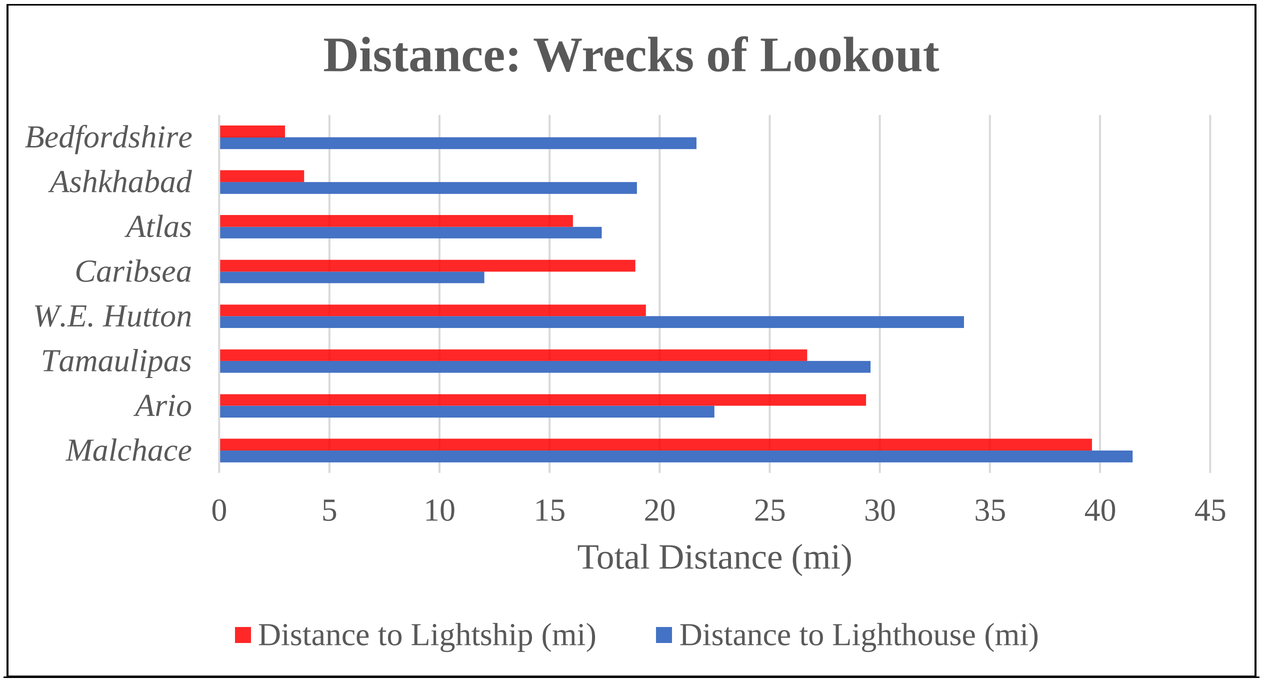


Figure 73: Graph of the distances from the shipwrecks nearest to Lookout to the lighthouse as well as the lightship. (Image by author, 2020.)

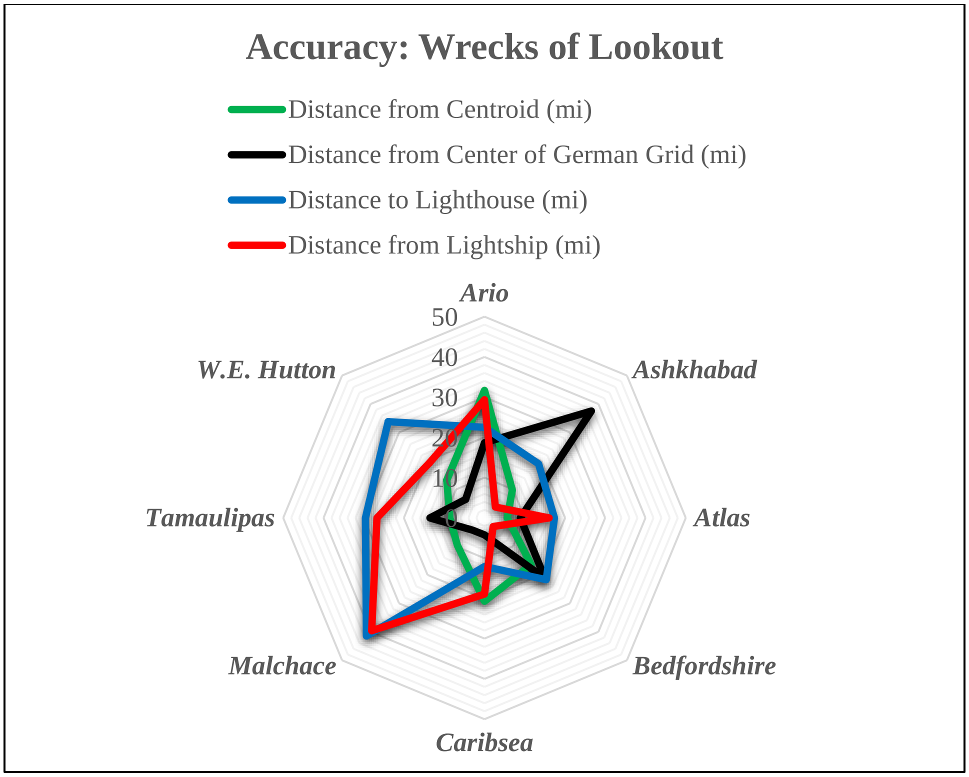


Figure 74: Comparison of German and Allied accuracy for the wrecks around Lookout. (Image by author, 2020.)

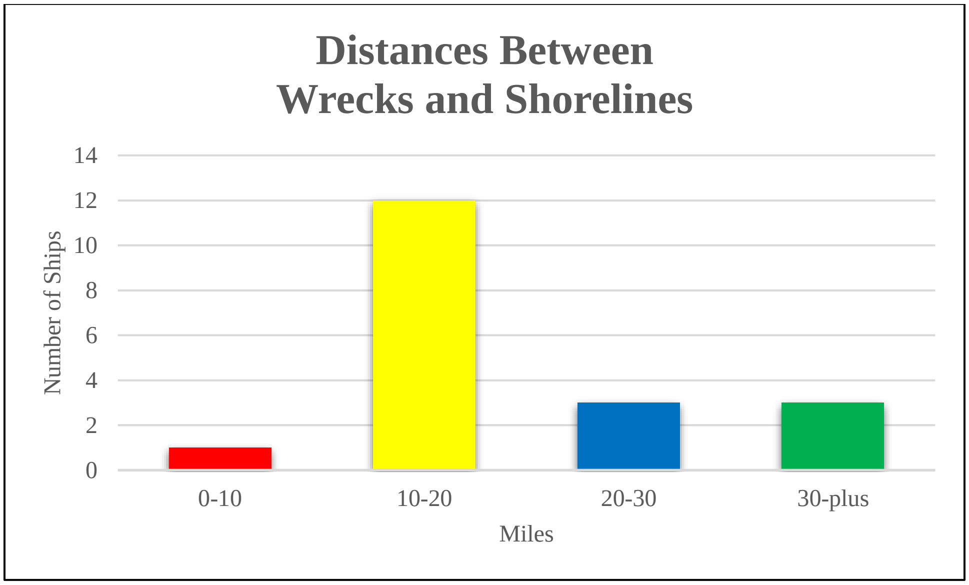


Figure 75: Graph of the distances between the wrecks and the nearest shoreline (linear). (Image by author, 2020.)

Figure 76: Map of the distances between the wrecks and the nearest shoreline (linear). (Map by author, 2020.)

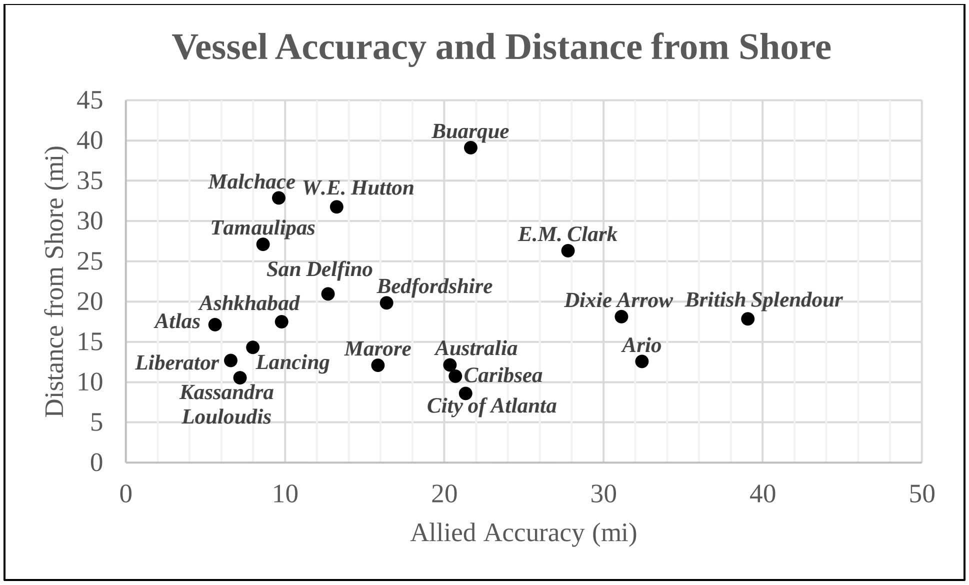


Figure 77: Vessel accuracy to distance from shore. (Image by author, 2020.)

CHAPTER 7: CONCLUSION

Introduction

This study examined the battlefield referred to as Torpedo Junction by merchant sailors. U-boats actively hunted the waters around Cape Hatteras with near impunity through the spring of 1942 during the Battle of the Atlantic. The first chapter of this study outlined the research questions, as well as detailing the historical background of the Battle of the Atlantic up to January 1942. Further, the vessels chosen for analysis by this study were defined. Chapter 2 examined the theoretical paradigms used by this research, those of generalist and battlefield archaeology, including the concept of the fog of war. Finally, the reasoning for utilizing GIS software was explained. Chapter 3 outlined the methods for historical research and building the GIS database. Decisions regarding the inclusion of different factors were also described.

Chapter 4 detailed an in-depth historical narrative of the technological and tactical innovations of the major combatants of the Battle of the Atlantic in North Carolina waters, as well as their position-fixing methods and technology. Chapter 5 created a geospatial analysis of the battlespace of Torpedo Junction to display the level of accuracy among merchant vessels and U-boats. Chapter 6 extracted statistical data from the geospatial analysis to examine different factors that potentially affected geospatial accuracy, such as the distance to the nearest military base or shore and determined which were either too minor or had too small of a dataset to use. Finally, this chapter concludes the study by revisiting the research questions posed at the beginning of this thesis. Many of these questions were unable to be answered by the current research, and as such, are presented as potential topics for future studies. Further, while writing this thesis, several other points of interest arose that potentially pose future research topics. This study ends with both the unanswered research questions and the brought forth research topics outlined for others to explore.

Research Questions

The research questions were separated into a primary research question and several secondary questions. The primary question had several parts:

Given the uncertainty created during naval battles, what knowledge can be attained by reconstructing the battlefield circumstances from the known wrecks, reported wrecks, and the scene of battle from the Battle of the Atlantic off the shores of North Carolina? How can this knowledge assist us in reconstructing other Second World War naval battles, or locating shipwrecks lost to similar methods of war from the period?

The uncertainty, or confusion, of naval battles may be attributed to the fog of war. By attempting to understand this confusion by gaining insight into combatant interactions, the battles were recreated for each vessel through analysis of the geostatistical data and characteristics of 27 merchant vessels and 4 U-boats. This produced a calculated level of accuracy as well as enumerating circumstances affecting that level of accuracy. These circumstances were then analyzed individually to determine their potential effect on positional accuracy. These included vessel characteristics and factors present at the time as well as the location of each attack.

Many of the factors and circumstances analyzed displayed little to no evidence of affecting accuracy, however, this may have been attributed to a small dataset for each factor. Those that were determined to have some level of effect include the speed of the attack (time between initial torpedo strike and the vessel's sinking), drift (also affected by time), and level of violence. Additionally, patterns were noted between the accuracy of both Allied sources and German commanders in relation to the wreck's distance from Cape Hatteras lighthouse/lightship (possibly due to the radio direction finder installed there). Other factors of intrigue include vessels that were escorted having higher nominal accuracy, though this dataset was too small (three vessels) to make conclusive determinations.

Thus, naval battles that took place elsewhere during the Battle of the Atlantic between a German U-boat and a merchant vessel may be determined to have a positional accuracy that was affected by the duration of the attack and the potential presence of naval escorts. Additionally, vessels attacked within relative proximity to a radio direction finding station may have a greater level of accuracy than other vessels. Finally, U-boats lost and recorded by the Navy or Coast Guard may have a much greater level of accuracy to the position of the wreck as opposed to the Air Force. One limitation found during this research was the size of the data set and leaves questions for further investigation. These conclusions created from the data have the potential to be further examined in naval battles between submarines and surface vessels in other parts of the world.

How does the time of day in the accuracy of reported positions? How does weather, bathymetry, currents, distance from shore, or wave activity affect these positions?

This study divided the time of day into two broad categories: day and night. Daytime attacks were determined by the averaged time created from the times recorded in the historical texts compared to the times of sunrise/sunset on the days of the attacks. Few of these attacks occurred during the day, and fewer still were able to be analyzed as many of the wrecks moved from the attack site, either through drift or tow. Thus, with a small dataset, the role of the time of day is unable to be satisfactorily answered at this time. The phase of the moon during each night attack was recorded, however, and while most were attacked on a night with little moonlight, this was determined to not be a factor in geospatial accuracy as no patterns were identified in the data. Additionally, the effect of the weather and wave activity is at present unknown, as the data for these factors was inaccessible, though large-scale weather events were determined to not be present during the narrow time window that the study examines.

The role of currents, which affected the drift of a vessel, is another factor that was unanswerable. However, many vessels in this study drifted for several days and up to 115 miles (in the case of *Papoose*) after being attacked. Thus, while drift was likely a large factor, its full effect is unknown and the ability to measure it holds potential for future research. Finally, the physical features such as the bathymetry of the wreck and its distance from shore were found to have little to no effect on the accuracy of reported positions.

How does the number of vessels present at the time of the attack (such as those in a convoy) and proximity to shore-based military installations affect reported positions?

The number of vessels, or more specifically, the number of vessels within the vicinity of the attacked vessel, was another factor determined to have too little data. This was due to the low number of vessels in this study that traveled in concert with other vessels. Most of the vessels traveled alone, and therefore the effect of other vessels within the proximity of the victim on the accuracy of reported positions is unknown. The wreck's proximity to shore-based military installations, like proximity to shore, was determined to have no impact on positional accuracy.

What was the difference in position accuracy between U-boat captains, U-boat types, armed and unarmed merchant vessels, aircraft, convoy vessels, or naval/Coast Guard vessels?

Due to the large number of U-boat captains, each sinking a relatively small number of vessels (ranging from one to four), the dataset for comparison of the accuracy of individual captains is too small. Nevertheless, on average, German U-boat captains were more accurate with their recorded positions than were the Allied forces. It was also determined that commanders with Type IX U-boats were more accurate than commanders with Type VII models. Whether this was coincidental or the result of better position-fixing technology in Type IX U-boats is a potential topic for future research. The differences between armed and unarmed vessels as well as vessels in a convoy have similar setbacks as the dataset for the U-boat commanders. Convoy vessels, however, display a unique level of inaccuracy among U-boat commanders as compared to Allied sources. Allied attacks on U-boats utilized a different dataset. While the data that displays the difference in positional accuracy of aircraft and naval/Coast Guard vessels is also too small to make any reliable statement, the low level of accuracy of the Army aircraft that attacked the U-701 as compared to the high level of accuracy of the Coast Guard Cutter and destroyer that attacked U-352 and U-85 is interesting to note and has potential for further research.

How does the duration of an attack affect the accuracy of reported positions?

To answer this question, duration was split into two categories: quick and slow. Quick attacks were attacks that occurred within minutes, while slow attacks were attacks where the vessel remained afloat for an hour or longer after the first torpedo hit. Vessels slow to sink additionally had drift affect their locations, as well as other vessels responding to the scene. It was determined that the duration of the attack did affect locational accuracy, as vessels slower to sink, especially ones that were violently attacked, contained a higher level of inaccuracy as opposed to vessels that sunk quickly. This may in part be due to drift as well as the effect of the fog of war.

What similarities can be examined between reported attacks with accurate positions versus inaccurate positions?

The similarities between vessels which contained highly inaccurate positions analyzed in this study (i.e., without the consideration of armaments or convoys) were that these attacks were determined to be slow, and in particular, both slow and violent. The vessels with highly inaccurate positions remained afloat for longer periods of time following their attack, often with flammable material burning.

Limitations and Potential for Future Research

Throughout this study, several factors arose that have potential for further research. One of these is how the decisions of the of the merchant vessel masters around the Outer Banks affected the potential for their vessels to be hit. Did the masters heed the orders of Admiral Andrews and other naval commanders to keep their running lights out and zigzag around Hatteras, or were they moving straight to save time? What effect did their individual years of experience have on this decision-making process, and did they have any prior encounters with U-boats or similar threats? Did their years of experience assist them in their decision to abandon ship and ensure the survival of their crew? How did the presence of gun crews/naval guns on merchant vessels affect crew morale/sense of security? How did this affect their decision making? These are all questions to which future research into the backgrounds of individual captains of the merchant vessels may yield answers. Additionally, these factors may contribute to the psychological component of the fog of war. How did the individual soldier or sailor react to a U-boat attack? How well did they perform their duties aboard their respective vessels? How did the U-boat war off the Outer Banks affect the local population? This may also address the potential impact of human error in misreporting positional accuracy, which could prove difficult to differentiate from psychological distress. Further research on these topics may contribute to the narrative of the Battle of the Atlantic.

The weather is an additional factor that had limited study value due to the temporary shutdown of many prominent archives during the COVID-19 pandemic. This is another aspect that can be further researched, as the weather had a direct effect on visibility for all the combatants. The weather also affected the wave activity, which can further negate visibility, as large waves can both hide a U-boat’s periscope while simultaneously hindering its capacity for observation. To what extent the weather affects accuracy is unknown, as the specific weather data for the days/times of the attacks on the vessels in this study is inaccessible. The final research topic uncovered in this study, and one with perhaps the most potential, is the factor of drift. As stated in Chapter 5, drift can vary greatly as currents and wind continuously shift, with offshoots from the Gulf Stream sending vessels either closer to shore or off the continental shelf. Vessel size (tonnage affecting the speed of drift) and shape (superstructure size catching the wind), as well as its orientation and potential level of damage (partially sunk), may have changed the amount and direction of drift. By studying the direction and vessel data of ships that were attacked and subsequently drifted for a set time and distance, predictive models can be made to determine the effect of drift on other vessels. Hopefully, these topics will be utilized by students of marine archaeology, battlefield archaeology, and the Battle of the Atlantic off Torpedo Junction in the future.

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