SCREW PROPELLER DESIGN IN THE 19TH CENTURY GREAT LAKES: A HISTORICAL ANALYSIS OF RICHARD F. LOPER'S PHILADELPHIA WHEEL

by

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Over the course of the mid- to late-1800s, screw propulsion emerged as an economically viable competitor to sail- and sidewheel-propelled commercial vessels in the United States' coastal and interior maritime industries. One of the earliest propeller designs to receive widespread acclaim belonged to Philadelphia merchant and inventor Richard Fanning Loper. His design quickly gained popularity in the Great Lakes region, where the logistical and economic concerns present in the United States' East Coast commercial shipping industry did not hinder early interest and adoption of screw propulsion.

Due to the fragility of contemporary screw propellers and the financial incentive to recover salvageable steam engine machinery from wrecked and abandoned vessels during the period, propellers were frequently broken or removed from Great Lakes vessels long before any historical or archaeological examination could take place. With the relative scarcity of 19th century propellers, the historical record becomes an invaluable tool in investigating the overall development of screw propeller design as the region shifted towards a new style of steam propulsion. This thesis utilizes a combination of contemporary source material and quantitative statistical information gathered through use of archival databases documenting vessels in operation around the Great Lakes region to outline the application of Richard Loper's "Philadelphia wheel" screw propeller design in the U.S. Great Lakes in the mid- to late-19th century. Measuring the overall popularity of Loper's propeller design allows for a greater understanding of early development and use of screw propellers in the Great Lakes and elsewhere.

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CHAPTER 1 – INTRODUCTION

Introduction

The early- to mid-19th century saw a rapid increase in the popularity of steam propulsion as both a supplement and an alternative to sails in the shipbuilding industries. As the century progressed, the growing popularity of steam-powered vessels fueled innovations and developments in steamship design around the world. Specifically, the development of alternatives to the sidewheel propeller, which was at times viewed as too bulky and too easily damaged to effectively apply to naval or smaller merchant vessels, became an innovative priority (MacFarlane 1851:144).

English shipbuilders were among the most prominent innovators in steamship and screw propeller design, continuously refining and improving previously patented designs over the course of the first two-thirds of the 1800s (Bourne 1867). While the developments made by English shipbuilders and inventors had a lasting effect on the evolution of the steamship and screw propeller, the United States was not without innovators of its own. One such American innovator was Richard Fanning Loper, a former sea captain and amateur inventor working out of Philadelphia, Pennsylvania who patented several designs intended to improve the performance of contemporary steamships powered by sail and auxiliary screw propellers. The most famous of Richard Loper's designs involved improvements on the screw propeller (Figure 1.1). In contrast to contemporary propeller designs popular in American shipbuilding, Loper suggested that three to four propeller blades be affixed to a central hub with no outer ring, as was common in another propeller designed by John Ericsson that was popular at the time (Ridgely-Nevitt 1981:189). The improved propeller design, while incredibly simple in premise, proved itself to be more effective and economical than other contemporary propellers used in American merchant shipbuilding.

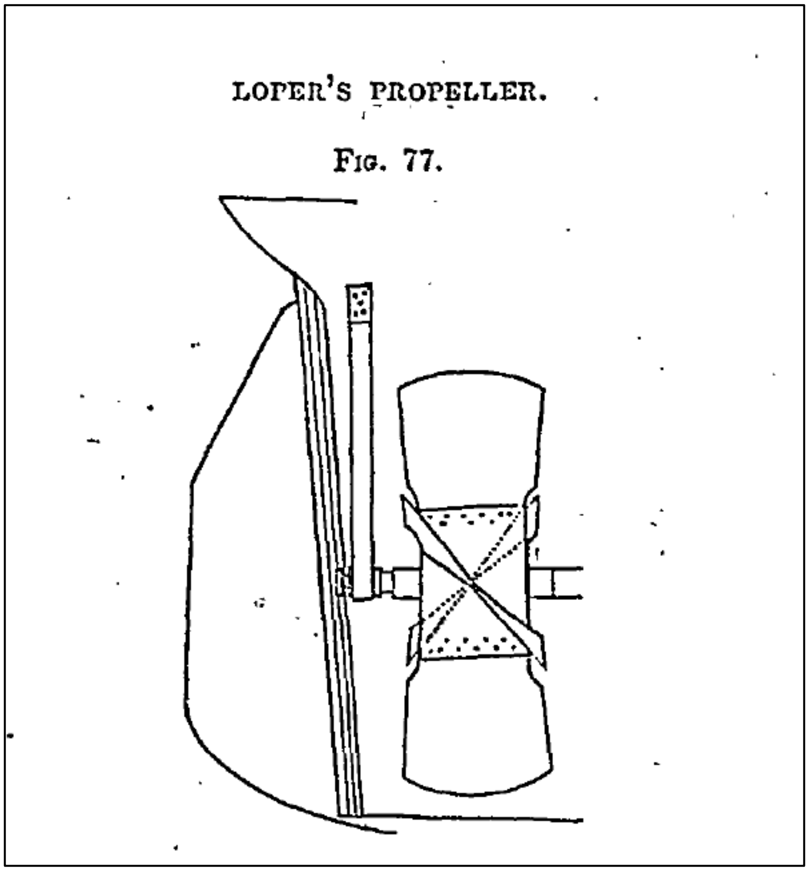

FIGURE 1.1. A drawn representation of the Loper-designed propeller on the U.S. revenue steamer *Spencer* (MacFarlane 1851:119).

Loper's propeller design became incredibly popular in the mid-1800s, especially among merchant shipbuilders in the Great Lakes region. Contemporary works on the development of steamship design praised Loper's "Philadelphia wheel," stating that the design's:

> "Good character is so well-established that it requires no further eulogy than to say, that more of these kind of propellers are now employed on vessels in the United States than any other, and on vessels of every class of burden, from the small canal boat to the first-class steamship (MacFarlane 1851:119)."

Vessels built with Loper propellers developed reputations for success and efficiency on the water, and several are believed to have remained in use through the early 20th century. However, as the wooden steamships of the 19th century fell out of style and construction of metal hulls became common practice, the Loper propeller faded from the consciousness of American shipbuilders and into obscurity. While many enrollment records and newspaper articles identify screw propellers as “of the real Philadelphia pattern” or “of Captain Loper’s patent,” the elements that characterized the Loper propeller design are no longer clear, and only a few propellers believed to exemplify the design have been identified on shipwrecks in the Great Lakes region in modern times (Dappert 2005; Johnston and Robinson 1993; Johnston 1995).

This thesis examines available primary and secondary historical sources to outline the introduction and adoption of Richard Loper’s “Philadelphia wheel” screw propeller design in the U.S. Great Lakes region in the mid- to late-19th century. Statistical information concerning the use of Loper-designed propellers is gathered through available online databases documenting vessels operating on the Great Lakes during the 19th century. With data collected on contemporary vessel construction and application of specific propellers over the course of the second half of the 1800s, statistical analysis explores the trends in Great Lakes shipbuilding in the period, potentially identifying the spread of the Loper design from its point of introduction to the Lakes. The gathered vessel data, combined with historical documentation and archaeological reports, are further analyzed to verify the Loper propeller’s ubiquity in the mid-19th century and track the rise and fall of its popularity in the Great Lakes region. Historical source material and modern archaeological records are also examined in order to identify contemporary examples of Richard Loper’s Philadelphia wheel, as well as alternative screw propeller designs.

Research Objectives and Questions

The primary goals of this research revolve around the application of historical source material found in Great Lakes vessel databases and contemporary treatises and news articles to obtain a better understanding of the application of Richard Loper’s Philadelphia wheel in the

Great Lakes region in the mid- to late-19th century. Examples of contemporary screw propellers attributed to Loper and his contemporaries are studied in an attempt to illustrate the advantages of the broader "Philadelphia wheel" design and the evolution of the design over the course of the latter half of the 19th century. Historical research on the Loper propeller as a popular propulsion instrument within the Great Lakes also identifies the propeller's rise and fall in popularity as the 19th century progressed.

In addition, this project attempts to answer a number of questions related to the historical significance of the Loper propeller, and Loper's other patented designs in the mid-19th century:

- Richard Loper's first propeller designs were patented in 1844 (Loper 1844). How long did it take for this new style of propeller to gain popularity? How did the Loper propeller come to be so much more popular in the Great Lakes region than it seemed to be in the coastal Northeast, where it was developed?
- How long was the Loper propeller the dominant style of propeller in the Great Lakes? Did another design replace it as the dominant propeller in the region? If so, what characteristics gave it an advantage over the Philadelphia wheel?
- As it increased in popularity, did shipbuilders across the Great Lakes region utilize the Loper-style propeller design? Or was the Philadelphia wheel a popular propeller design in specific cities or Great Lakes shipbuilding centers?
- In addition to his propeller, Richard Loper also patented designs for steam engines and construction of composite vessels. How popular were Richard Loper's other patented shipbuilding designs?
- If his propeller design was as widely utilized in the United States as some contemporary sources such as MacFarlane (1851) claim, is there a historical

precedent for Richard Loper's general absence from 19th century American maritime history?

Significance

The Loper propeller, often simply referred to as the "Philadelphia wheel" or a propeller of the "Philadelphia pattern," became extremely popular in the Great Lakes region in the mid-19th century and persisted through the turn of the 20th century (MacFarlane 1851:119-120). However, spotty historical documentation regarding the application of the propeller in the Great Lakes and the U.S. East Coast have made quantifying the popularity of Loper's "Philadelphia wheel" difficult during the time period. In addition, little research has been conducted on the overall significance of the Loper propeller and other designs patented by Richard Loper across the span of his career, despite his designs' supposed popularity in the United States during the mid-19th century. Archival research and analysis of contemporary shipping and enrollment records provides insight into the true scope of the Loper propeller's popularity. Archival research determining the ubiquity of the propeller also allows the propeller design's spread to be tracked from the time of its development in Loper's home state of Pennsylvania to its first contact with the Great Lakes region and the subsequent boom in popularity.

Historical and artifactual study of Richard Loper and his patented designs, particularly that of his propeller design, may help to gain a greater understanding of American screw propeller construction, particularly within the Great Lakes shipping economy, during the mid- to late-19th century. Clearer understanding of the progression of propeller design in merchant shipping during the 19th century may also help identify recovered or *in situ* propellers that have yet to be attributed to one specific style or design. Additionally, combined historical research and case study-based artifact analysis conducted for this project help clarify the real-world application of Richard Loper's propeller design and its improvements over time for the purposes of future propeller identification.

Methodology

Historical and archival research is used to clarify the role Richard Loper's designs played in 19th-century American maritime history, as well as provide a basis for statistical analysis of the rise and fall of the use of Richard Loper's propeller design in the Great Lakes area. Historical records relating to Loper are scattered, but records of the application of his designs on Great Lakes vessels are much more widespread; therefore, adequate examination of the use of Loper's propeller design specifically require research to be conducted across several archival collections throughout the Great Lakes region and the U.S. East Coast. Additional information gathered through communication with regional maritime museums, maritime history organizations, and state archaeologists also assist in the historical research process.

In addition to providing the basis for the historical background and context of the thesis, historical research in 19th century enrollment records and contemporary newspapers allows for the identification of vessels throughout the Great Lakes with Loper propellers. To best understand the prevalence and spread of this particular propeller design through the area over the course of the 19th century, statistical analysis is conducted on registered American wooden-hulled screw-propelled vessels launched in the Great Lakes region between 1844 and 1874. Basic statistical analysis methods outline the general demographics of vessels built during this time, indicating the general development and adoption of screw propulsion in the region. Further exploration of the data may also suggest the succession of popularity among contemporary shipbuilders and shipbuilding centers on the Lakes as the screw propeller became the dominant form of commercial vessel in the region. This analysis also assists in outlining the introduction and application of the Loper propeller in the region from the mid- to late-1840s to the time of its disappearance in the historical record, helping to identify the most popular time periods and regions of the Great Lakes in which the Loper-style propeller was utilized.

Limitations

COVID-19 significantly altered the ability of archaeologists, historians, and other researchers to conduct their work in ways that they have become accustomed to in years past. This project is no different, and the potential limitations that COVID-19 and its aftereffects may affect all areas of the project, including access to archival records, travel, and available methodological approaches. Many institutions with materials relevant to the topics covered by this research remain closed or limited in their operations, which presents challenges in accessing information that has not been previously digitized and hinders communication with regional archaeologists and historians. Due to the project's relatively obscure topic and narrowness of scope, many research collections concerning the topic are unlikely to be digitized and require travel and physical access to the research materials. Utilization of available digitized documentation to the fullest extent allows for the most comprehensive historical understanding of the Loper propeller's development and application in the Great Lakes region during the mid- to late-19th century.

Several factors also limit the overall scope of the study to a statistical and historical analysis of the Philadelphia wheel's use in the Great Lakes region. Screw propeller wheels are a relatively uncommon find on 19th century shipwrecks in the Great Lakes, due to a combination of the fragility of wheels made at this time and the contemporary salvaging efforts frequently made to recover vessel machinery and hardware for reuse (Wayne Lusardi, pers. comm.). The rarity of extant propellers on shipwrecks, combined with the relatively large size of propeller wheels equipped on mid- to late-19th century screw-propelled vessels, correlates to a dearth of contemporary propellers found in maritime museums across the Great Lakes region and the United States' East Coast. Extant mid- to late-19th century propellers relevant to this study have been discovered throughout the Great Lakes and outside the United States, making travel to examine a necessary number of historically relevant propellers both incredibly costly and difficult with current international travel restrictions. Thus, examination of contemporary propeller designs in the context of this study is limited to the designs as represented in patents and available archaeological reports.

Thesis Structure

This thesis consists of five chapters. Chapter 1 serves as an introduction to the topic, research questions, methodologies, and limitations of the project. Chapter 2 provides an historical background of the development of American screw propulsion in the 19th century, as well as providing a brief biography of Richard Loper and historical backgrounds of several vessels which operated with Loper propellers and their contemporary alternatives. Chapter 3 outlines the methodologies utilized in the study's historical research and provides statistical analysis of the prevalence of Loper propellers in the Great Lakes area. Chapter 4 describes and interprets the results of statistical analysis conducted to better understand general trends in contemporary Great Lakes shipbuilding, as well as synthesizes available statistical data with historical research to outline the regional popularity of the Loper propeller within the Great

Lakes region in the latter half of the 19th century. Chapter 5 provides a synthesis of the information gathered throughout the body of the thesis and answer the proposed research questions, as well as provides concluding remarks and a discussion of the potential areas of further research on the topic.

CHAPTER 2 – HISTORICAL BACKGROUND

Introduction

Similar to the slow adoption of steam power as an alternative to sails over the course of the 19th century, the adoption of the screw propeller as an alternative to the paddle wheel was a slow process in the general landscape of the United States' maritime world that occurred from around the mid-19th century to the turn of the 20th century. Steam-powered screw propulsion developed sporadically alongside the general development of steam propulsion; however, the viability of the screw-propelled steamship did not enter mainstream maritime consciousness until well into the 1800s, when its purported advantages over side-wheel steamships led to isolated explosions in screw propeller use and development in localized U.S. maritime shipping industries. As economic and urban development of the Great Lakes region increased in the first half of the 19th century, shipbuilders responded to increased demands for cheap shipping costs through early adoption of screw technology. Through the 1840s and 1850s, the construction of screw propellers outpaced paddle wheel steamers in the Great Lakes for commercial shipping lines, while coastal shipping lines continued to rely heavily on sail-powered packet vessels (Dohrman 1976:54). Outside of the specialized pockets of U.S. maritime industry that quickly adopted the newly developed technology in the first half of the 19th century, screw propellers did not overtake paddle wheels in mainstream U.S. shipbuilding until the late 19th century (Gardiner 1993:53).

Despite the slow adoption of screw technology during this time period, the introduction of improved screw designs and related mechanical developments in steam vessel construction allowed for the rapid development of steamship technology and the later success of U.S. screw steamers through the beginning of the 20th century. Richard Loper's propeller design was particularly influential in the development of screw propellers as a popular propulsion style in the mid-19th century, facilitating the adoption of screw propellers in both naval and merchant marine shipbuilding. Mid-19th century screw propellers like *Indiana*, *Monohansett*, *Monumental City*, and *Goliath* can provide additional context for early screw development and the evolution of propeller design within the merchant marine.

Early United States Steamship Development

Western maritime history generally attributes the development of successful steam-powered watercraft to British and U.S. inventors during the 18th and early 19th century (MacFarlane 1851). Patent records in the United Kingdom demonstrate British development of steam-powered watercraft as early as 1737, when an early example of a "stern-wheeled" steam vessel was patented by inventor John Hulls (MacFarlane 1851:13). The earliest application of steam propulsion to U.S. watercraft, however, seems to be a point of contention in the historical record. Two contemporary inventors, John Fitch and James Rumsey, developed early iterations of the steamship in the 1780s. James Rumsey, an engineer living in Shepardstown, Virginia, created a steam vessel involving a pump that drew water through a central trunk extending from the bow to the stern. The water expelled from the stern would then propel the vessel forward. Rumsey experimented privately with his vessel in 1784, but did not publicly display his invention until 1787, which resulted in no small amount of animosity for his contemporary and more widely attributed "earliest United States steamship inventor," John Fitch (MacFarlane 1851:17-20). Fitch's design, first proposed in 1786 and patented in 1787, was markedly different from Rumsey's, involving the use of a steam-powered piston system that propelled the vessel with a series of paddles or oars meant to simulate the paddling of a canoe (Morrison 1967:8).

While Fitch's 1787 vessel proved too slow in public trials to be put to any meaningful commercial use, the event sparked public interest in the development of a viable steam-powered vessel (Ridgely-Nevitt 1981:14).

In the years following Rumsey and Fitch's experimentations with steam propulsion, several other early steam vessels were developed on U.S. rivers. Samuel Morey, John Stevens, and Oliver Evans each contributed to the continued development of steam power in the United States through the turn of the 19th century (Gardiner 1993:44). It was not until the great success of Robert Fulton's steam vessel in 1807, however, that the viability of steamships for commercial purposes was truly realized in U.S. waters. Fulton, partnering with fellow amateur inventor and politician Robert Livingston, designed and contracted the construction of a paddle-wheeled steam vessel using their combined technical experience from years of experimentation and observance of steam vessel development in both the United States and Western Europe (Morrison 1967:19-20). Launched onto the Hudson River in New York in the summer of 1807, *North River Steamboat of Clermont*, more commonly referred to as *North River Steamboat* or *Clermont*, immediately proved itself to be a fast and relatively reliable form of waterborne transportation. Fulton and Livingston would go on to build several more steam vessels for passenger transportation on the Hudson River, as well as inspire the development of sidewheel steamboat lines along the Mississippi and other western rivers (Morrison 1967:27).

Early steamship experimentation utilized a range of propulsion styles from stern and side wheels to paddles and poles, but it is important to note that screw propellers do appear in this early stage of steamship development. John Stevens experimented briefly with the application of rotary engines and screw propellers on watercraft as early as 1802; however, a lack of proper tools and shipbuilders experienced in the construction and operation of high-pressure steam engines forced him to explore other modes of steam propulsion (Morrison 1967:17-18). The technological state of steam engines and steamboat construction in the early 19th century United States were simply not developed enough to produce a propeller-driven steam vessel viable for commercial shipping.

Screw Propellers' Popular Introduction in the United States

While early U.S. steamship development occasionally made use of screw propulsion, paddle wheels were favored over early screw designs in the first commercial steamships. These sidewheel steamers became an integral part of riverine trade in the United States and slowly gained a foothold in coastal and oceanic trade over the first few decades of the 19th century. It was not until the late 1830s that John Ericsson reintroduced the U.S. to screw propulsion with a design that could be considered viable in commercial maritime settings. At the same time, another inventor in England, Francis Pettit Smith, developed a different style of screw propeller that gained popularity with the Royal Navy before making its way to U.S. shipyards.

<u>John Ericsson and the Ericsson Propeller</u>

John Ericsson's (1803-1889) engineering background provided a strong foundation from which he could create the first mainstream screw propeller in the United States. Born in Sweden to a topographical consultant, Ericsson exhibited an aptitude for mathematics and engineering in his early years and began working as an engineering and survey illustrator at 13 years old. He began developing his first steam engine designs during his years of service in the Swedish Army; however, Ericsson desired more contract opportunities for his inventions and left for England in 1826 (Hylton 2008). After unsuccessful ventures into the development of a locomotive engine, he turned his attention to the development of a steam-powered engine and propulsion system for watercraft and obtained a patent for his original screw propeller design in 1836. Ericsson's designs were rejected in England but earned the attention of Robert F. Stockton, a United States Navy captain, who convinced Ericsson that his propeller design would see greater success in the United States. With the promise of a sponsorship to develop a screw steamer for the United States Navy, Stockton prompted Ericsson to immigrate to America in 1839, where he would remain for the rest of his career. Operating out of New York, Boston, and Philadelphia over the next several decades, Ericsson found his propeller designs to be fairly successful in the merchant marine sector of the U.S. maritime economy (Warren 1998:40; Ridgely-Nevitt 1981).

Ericsson's original 1836 propeller design was patented in Great Britain as a twin-screw system with two propellers rotating in opposite directions along the same propeller shaft, each composed of an outer set of blades and an inner set of angled "spokes" that would propel the vessel forward (Figure 2.1) (Ericsson 1836). The inner spokes of the propeller, attached to the central hub at their base and to the first and primary ring of the two wrought iron support rings at their outermost extremities, primarily provided structural support to the propeller. However, the angle of the spokes suggests that they would also have provided some small amount of propulsion. From this primary ring extended eight wrought iron plates that served as the blades of the propeller. While blade angle was not specified in the 1836 patent, the plates are described as being twisted to form a spiral propulsion pattern. The associated drawings do illustrate this twisting effect as a slight increase in angle as the outer blades extend from the main cylindrical hub. Each plate was riveted to the primary support ring; though the means of fastening is unmentioned in the patent, the drawings suggest that an additional metal joining piece connects the plates to the primary ring. At the outermost edge of the two propellers, a second wrought iron ring composed of shorter segments riveted to the extremities of each plate provides even more structural support (Ericsson 1836).

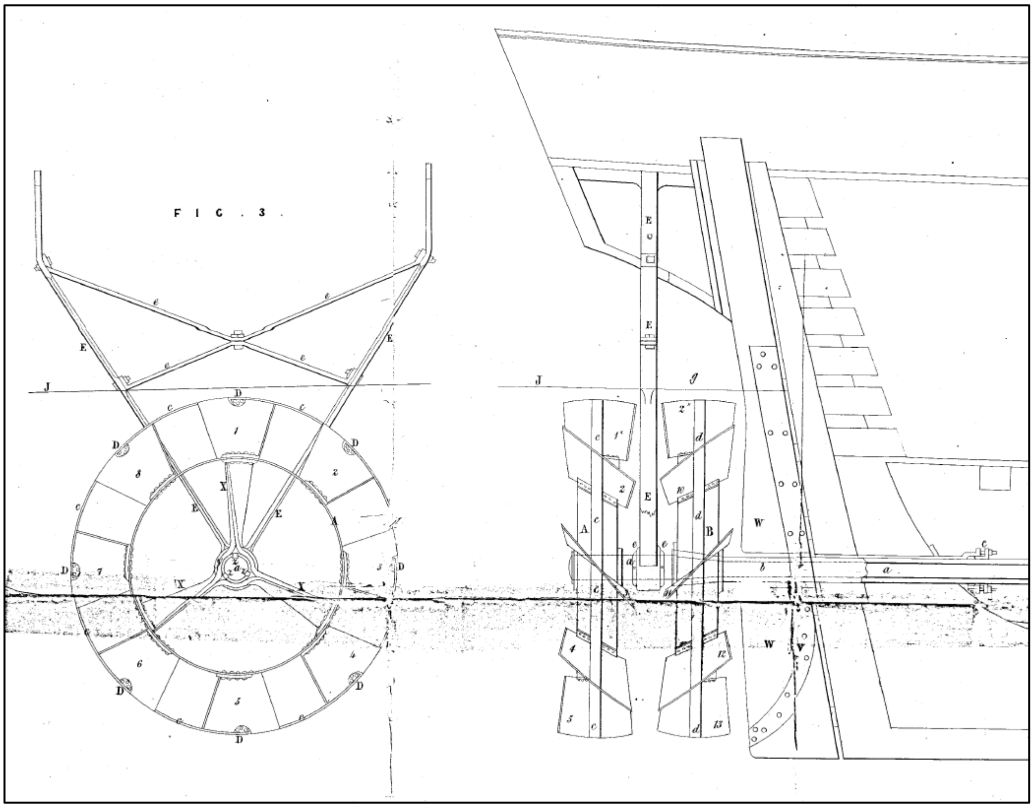

FIGURE 2.1. John Ericsson’s 1836 patent drawings (Ericsson 1836).

Later propeller designs patented by Ericsson during his time in America, such as one particular 1845 patent simply titled “Screw-Propeller,” exhibited many of the same characteristics as his initial design; however, some key differences in the construction of the propeller are apparent (Ericsson 1845) (FIGURE 2.2). The inner spokes and outer plates present in the 1836 propeller were combined, creating a six-bladed propeller with a much more angular design revolving around an angled, star-shaped central hub. Only one ring outside of the central hub provided support in the newer design, riveted diagonally in segments around the approximate midpoint of each blade. Lastly, due to the angled edges of the blade extremities, the outermost wrought iron ring was removed from the 1845 design (Ericsson 1845). Overall, the alterations made to the original Ericsson propeller made it more useful on single-screw vessels and would have made the propeller more economical in U.S. shipbuilding markets.

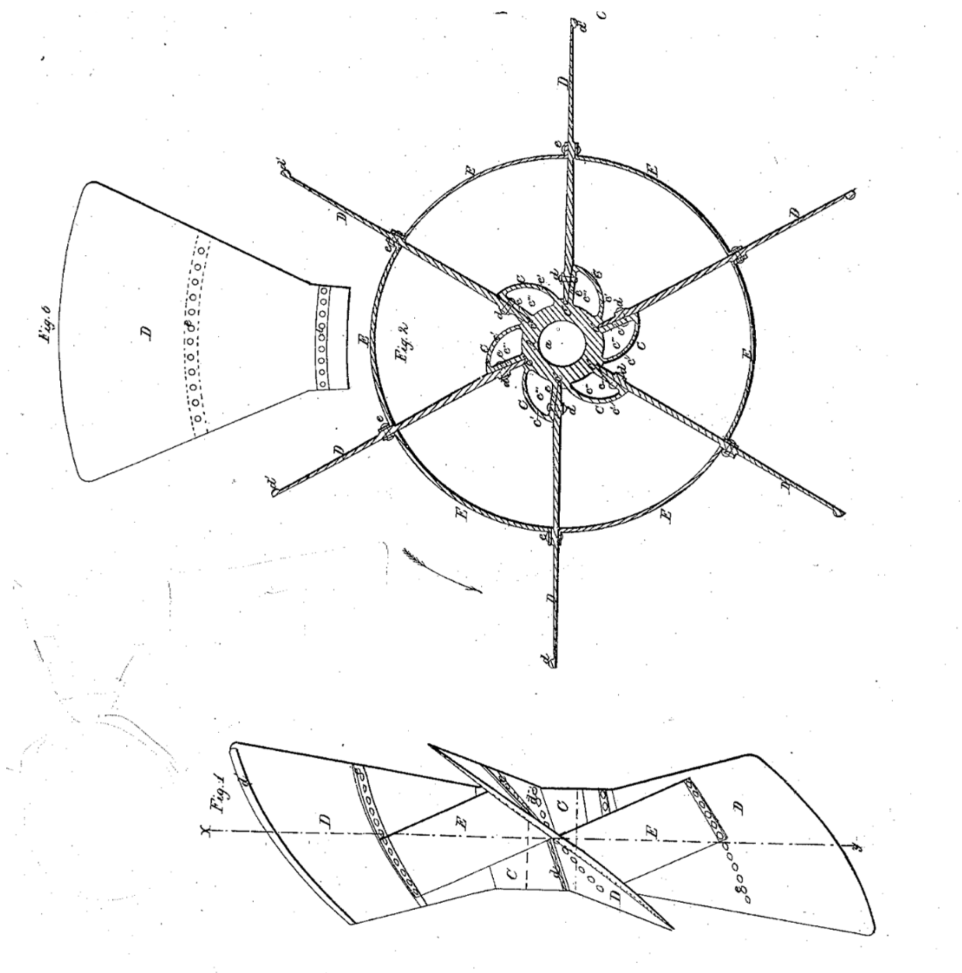

FIGURE 2.2. John Ericsson's 1845 U.S. patent drawings (Ericsson 1845).

Ericsson's arrival in New York in 1839 was accompanied by the arrival of his screw tug *Robert F. Stockton*, launched the year prior in England to prove the viability and practicality of his propeller design to his new eponymous sponsor (Bourne 1867:91). The vessel received immediate attention in the United States, and Ericsson was contracted to oversee and assist in the construction and refitting of a series of auxiliary vessels launched in the five years following his arrival, including the steamships *Clarion*, *Midas*, and *Marmora* (Ridgely-Nevitt 1981:85-88). The popularity of Ericsson's design spread quickly, becoming an increasingly common screw propeller design amongst merchant shipbuilders in the United States over the course of the 1840s. USS *Princeton*, launched out of New York in 1843, was Ericsson's first major project with the United States Navy under the sponsorship of Robert F. Stockton (Ridgely-Nevitt 1981:189). Ericsson designed several aspects of the vessel including *Princeton*'s engine, propellers, and one of two large deck guns. The other deck gun, designed by Stockton as a modified version of Ericsson's gun, exploded when firing a ceremonial round during a cruise in 1844, killing six and injuring several more. As a seasoned naval officer and political figure, Stockton escaped the majority of blame for this accident at Ericsson's expense, leading to a rift between Ericsson and the United States Navy that was not closed until the United States Civil War, when Ericsson assisted in the development of the ironclad *Monitor* (Hylton 2013). The significance of Ericsson's introduction of the screw propeller to East Coast shipbuilders and United States maritime industries in general cannot be overstated. Earlier inventors in America had begun to explore the use of screw propulsion in watercraft, but John Ericsson's design was the first widely recognized screw propeller considered a viable alternative to the paddle wheel.

<u>Francis Pettit Smith and the Smith Propeller</u>

Francis Pettit Smith (1808-1874) was born into a farming family near Kent, England, and while he had no familial connection to shipbuilding or seafaring, he developed a fascination for vessel design and propulsion at an early age. In the early 1830s he began to fully devote his time to experimentation on the use of screw propellers on watercraft, particularly the Archimedean screw, a corkscrew-like design successfully used as a pump for centuries prior (Brown 2013).

His first patent, obtained in May 1836, involved the placement of a double turn screw between the sternpost and rudder of a vessel. In his initial trials of the double turn screw, the propeller broke mid-trial; however, the broken screw, now involving only a single turn, performed better than his original design, prompting Smith to patent and begin testing the viability of single turn screw propellers (Warren 1998:39). In 1838, Smith installed his single turn propeller design on the small steam vessel *Archimedes*, which undertook a number of tests from 1838 to 1840 that garnered attention from both British merchant shipbuilders and the Royal Navy.

Smith's single turn screw propeller design, patented in England in the late 1830s following the outcome of his double turn screw experiment and represented here by the U.S. patent Smith received in 1841, deviates in general form from typical wheel-like screw propellers like the one designed by Ericsson (Figure 2.2). Adopting the Archimedean screw concept, Smith's propeller, described as a "broad-threaded, revolving screw or worm," resembles a corkscrew with an iron thread serving as the propeller's blade wrapped around a central cylindrical axis (Smith 1841). The iron thread, according to the patent, could potentially make up to one full turn around the axis, but it was also acceptable for the thread to make less than one full turn around the axis if size or shipbuilder preferences warranted it. While thread angle was not specified in the patent, descriptions of his designs published alongside illustrations in England during the late 1830s indicate that the thread ends formed an angle of approximately 40 degrees with the propeller's shaft (Scientific American 1874:151). While Smith notes that propeller size and length would change depending on the scale of the vessel for which it was built, he provided an example for reference, stating that a 237-ton vessel with a draft of approximately 9 feet would require a single turn, 8-foot-long screw (Smith 1841). General guidelines for the application of two threads on either side of the central axis were also provided on the patent and in the associated drawings, noting that the number of turns and length could be halved on propellers equipped with two threads.

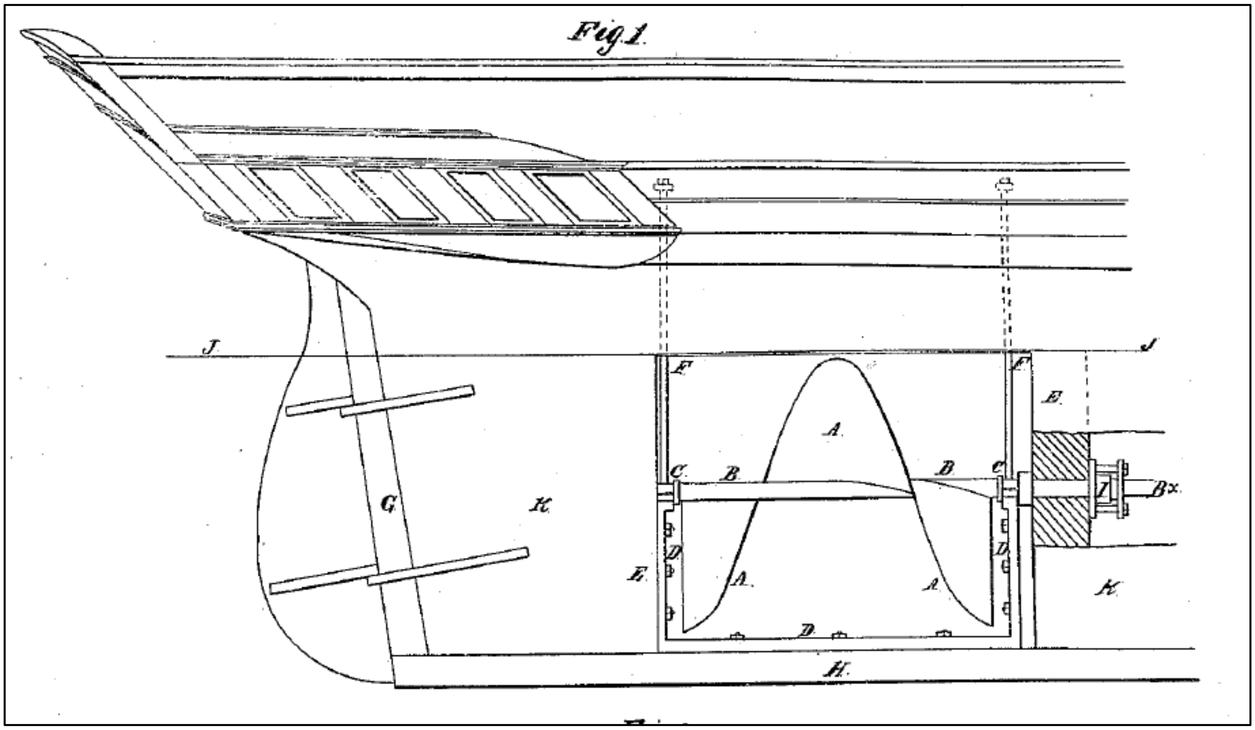

FIGURE 2.3. Francis Pettit Smith's 1841 U.S. patent drawing (Smith 1841).

Unlike Ericsson, Francis Pettit Smith gained the interest of the Royal Navy with the success of *Archimedes* and his associated screw propeller design and, following a series of time trials and tests, began to develop screw-propelled Royal Navy vessels (Brown 2013). Over the course of the 1840s and 1850s, Smith was closely involved with Admiralty experiments with screw-propelled naval vessels; furthermore, he was tasked with overseeing the construction of dozens of Royal Navy vessels built with his propeller. As late as 1867, British publications describing the development of screw propulsion claimed that all Royal Navy vessels built to that point were equipped with Smith's propeller (Bourne 1867:89). Outside of its popularity as a naval propeller, Smith's design saw modest success among British and U.S. merchant shipbuilders. His design was popular enough to seek a U.S. patent in 1845 for his propeller on United States vessels; however, his impact on the development of the screw propeller in the United States was limited.

Advantages and Disadvantages of Early Screw Propellers

As the screw propeller gained traction in various maritime industries, discussions arose concerning the characteristics of screws that provided an advantage over the sidewheel steamers that dominated steam-powered watercraft of the time. Among contemporary sidewheel steamers, "optimal" speed and performance relied on a paddle wheel's immersion level remaining within a specific range during operation. Listing to either side would either lift the paddle wheel to a point that less water was being propelled than necessary or submerge the paddle wheel to a point that propulsion would become difficult or hazardous to machinery and crew. Variations in wheel immersion, caused by differential loading of goods and passengers during voyages, the depletion of fuel stores, and natural phenomena such as wind and waves, led to inconsistencies in the level of a paddle wheel's operational status at any given point in time (Gardiner 1993:16). Screw propulsion did not have to deal with immersion level management, as propellers were meant to be fully submerged at all times.

The second, and perhaps most obvious, advantage of screw propellers over sidewheels involved the amount of space freed up through the repositioning of major propulsion equipment from the sides to the stern. The removal of wheelhouses from the decks and cargo holds of steam vessels allowed for greater and more balanced cargo capacities and distributions. This allowed screw vessels to carry more cargo, passengers, and fuel on each voyage, reducing shipping rates for those looking to transport goods and increasing profits for the vessels' owners (Labadie et al.

2021). U.S. Navy vessels, while among the slowest to adopt screw propulsion on a large scale, enjoyed several tactical advantages that were not as important to the merchant marine. Moving the steamship's main propulsion equipment from the sides of the hull allowed for broadside guns to be placed around the vessel with little interference compared to the limitations on broadside guns on one or both sides of vessels equipped with paddle wheels. The shift in the vessel's propulsion equipment also provided much better protection. A screw propeller's position underwater and at the stern of the vessel was considered to be less vulnerable than a paddle wheel, which made for an easy target that, when damaged, could completely immobilize a vessel in combat (Brown 2013).

Several additional economic advantages of the screw propeller over the sidewheel steamer presented themselves as it became more popular in the United States. Screw propellers, while requiring a different kind of steam engine than the typical sidewheel steamer to achieve the rotation speeds necessary for movement, were much simpler and cheaper to build. Once built, screw propeller engines only required around one-fourth of the fuel needed for a sidewheel steamer to travel the same distance and could be operated with half as many crew members (Labadie et al. 2021). These economic advantages alone made screw propulsion an attractive alternative to the paddle wheels of the mid-19th century; however, structural limitations within contemporary steam vessels held screw technology back from dominating the general maritime world.

Despite the numerous advantages screw propellers offered to U.S. merchant and naval shipbuilding during the mid-19th century, several disadvantages of the developing technology were also made apparent. The rapid movement of the engine and propulsion equipment necessary to propel screw steamers often led to intense vibration that could distort major structural components of larger wooden-hulled vessels, effectively limiting the size of screw-propelled steam vessels until the widespread adoption of metal hulls in U.S. maritime industries in the later 19th century (Warren 1998:41-42). Apart from the issues with hull vibration caused by the new style of engine and propeller equipment, the areas at the stern of the vessel where the propeller shaft extended from the stern quickly became worn, risking significant amounts of hull damage. While metal stern tubes could be installed around the propeller shaft to mitigate damage to the wooden hull, wear to these metal shaft tubes required frequent repairs and were a major deterrent to early adoptees during early screw propeller development (Warren 1998:41). Additionally, in the event that a screw propeller or any associated shaft components were damaged or broken during a voyage, there was no easy way to repair early screw propellers outside of port. Compared to the relative ease in repairing or addressing malfunctions in a paddle wheel located at the surface of the water, any failure or malfunction of the propeller mid-voyage would force the vessel to make their way back to port for repairs using auxiliary sails (Ridgely-Nevitt 1981:188). Complete inability to repair screw propellers mid-voyage is likely one, if not the main, contributing factor to U.S. oceanic shipping's hesitance to adopt screw propellers on a large scale during the 19th century, and explains why they were generally fitted with one or two masts regardless of planned distance from shore while sidewheel steamers began to operate without auxiliary sails.

The shift from wooden to metal hulls was an equally slow process in U.S. shipbuilding as the transition from sail to steam or the transition from sidewheel to screw; however, designs for metal hulls or hull components that would improve the overall lifespan and performance of screw propellers began appearing almost as early as the propellers themselves. By the late 1840s, shipbuilders in the U.S. were attempting to implement metal hull elements in screw steamships to improve their performance and lifespan (Loper 1847). Unfortunately, these composite or entirely metal-hulled ship designs were not considered viable in commercial shipping for the majority of the 19th century due to the industrywide attachment to wooden shipbuilding, which prevented widespread recognition or adoption by United States shipbuilders for several decades.

Richard Loper and the Philadelphia Wheel

Following the successful introduction of Ericsson's screw propeller to U.S. shipbuilders on the East Coast, many U.S. engineers and inventors saw potential in refining and experimenting with its design to create a faster, stronger, and more economical model. As mentioned above, John Stevens briefly experimented with screw propulsion at the very beginning of the 19th century; however, technological limitations of the time period prevented its practical adoption (Morrison 1967:17-18). A few U.S. inventors, such as Richard Gatling (of Gatling gun fame), began experimenting with designs for screw propellers in the 1830s, within the same few years that Ericsson and Smith patented their propeller designs in England and America (*Philadelphia Inquirer* 1918). Perhaps one of the most prolific of Ericsson's immediate successors, however, was Richard Loper.

The Life of Richard Loper

Richard Fanning Loper was born in Stonington, Connecticut in 1802 (*New York Times* 1880). His seafaring career began very early in life, working as a crewman on a sailing vessel at just ten years old and assuming command of a schooner for the first time at fifteen. Loper commanded a handful of vessels over the span of his active seafaring career, involving himself in such ventures as seal-hunting expeditions and packet shipping along the eastern coast of the

United States. In 1831 he retired from active command and began operating shipping and shipbuilding firms out of Philadelphia, Pennsylvania (*New York Times* 1880).

Recognizing the potential for newly introduced screw propeller technology brought to the United States by John Ericsson in the late 1830s, Loper experimented with steamships and screw propellers and patented his own designs for an improved screw propeller in 1844 and 1845 (Loper 1844; Johnston 1995:345). Initially partnering with the small Philadelphia ironworks firm Reaney, Neafie, & Levy to use the propeller designs in the manufacture of their wooden steamship engine components, Loper's propeller, colloquially referred to as a "Philadelphia wheel" in contemporary enrollments and news articles, quickly became one of the most popular screw propeller designs of the period (Heinrich 1997:20). Around this time, Loper began to have an increased involvement in the shipbuilding process and patented several more designs to further improve the performance of wooden steamships, such as designs for a propeller boiler and engine, as well as an 1847 design proposing composite construction of steamships with a wooden hull and iron frames (*New York Times* 1880; Loper 1847). Loper generally took over construction of the vessels for which he would design propellers and other machinery, commissioning the construction of the wooden hull and machinery to various specialists in the Philadelphia area. All the while, he supervised construction to ensure that the vessels were structurally suitable for the designed propulsion (Ridgely-Nevitt 1981:189). Over the course of just five years spanning from 1847 to 1852, Loper constructed around 200 vessels of various sizes, styles, and purposes in this fashion (*New York Times* 1880).

During the Mexican-American and Civil Wars, Richard Loper was employed by the U.S. Navy to construct and charter much-needed transport vessels to expediently move U.S. troops in and out of their respective warzones (*New York Times* 1880; Gibson 2011:39). Senate investigations in 1862 into Loper's financial dealings and profits during his period of service to the Navy ultimately led to accusations that he abused his position during the Civil War and had unduly profited from chartering naval vessels (Gibson 2011). Loper soundly refuted this, and while the exact circumstances of the accusations are not completely clear across the several documentary sources detailing the conflict, the Senate ultimately absolved Loper of all accusations against him (Loper 1863; *New York Times* 1880). Richard Loper continued to operate in the commercial shipping and shipbuilding spheres through the 1860s and 1870s until the time of his death in the fall of 1880.

The Loper Propeller

Loper's 1844 propeller design is noticeably simpler when compared to the Ericsson propeller; however, in contrast to the corkscrew-like Smith design, it maintains a traditional bladed propeller shape (Figure 2.3) (Loper 1844). In lieu of an outer ring containing inner blades and providing a base for shorter, outer blades, Loper reverted to an older, classic style of screw propeller in which the propeller's four blades extended freely from a central hub. This design was considered to be a much more practical and economical option in mid-19th century U.S. shipbuilding, when iron typically needed to be imported (Loper 1844; Ridgely-Nevitt 1981:189). The patent indicated that the propeller's central hub could be made in a single piece or composed of two joined pieces of cast iron (Loper 1844). While the option to construct the hub in two pieces may relate to the propeller's size, it would also be a useful option when building a replacement propeller for a steam vessel with an intact propeller shaft.

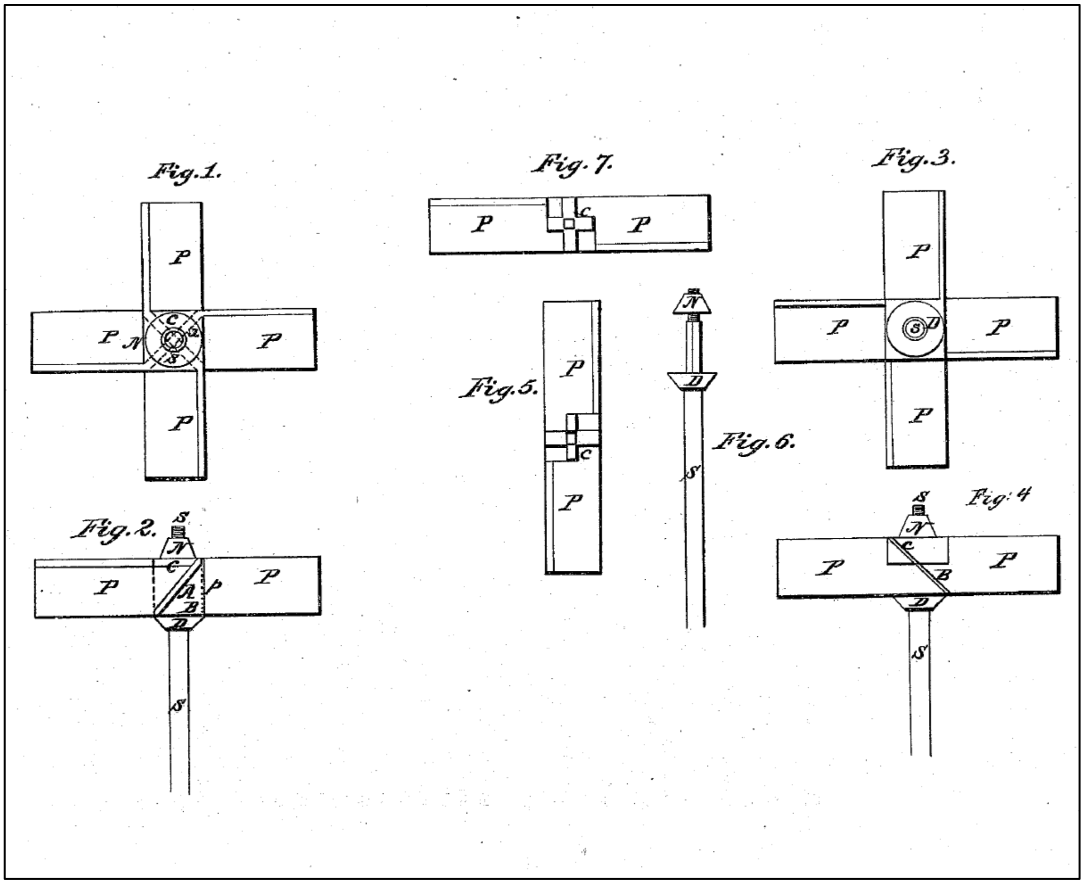

FIGURE 2.4. Richard Loper's 1844 patent drawings. Note that the drawn blades do not include any of the patent's suggestions of a twist or change in blade shape extending from the hub (Loper 1844).

Original design specifications indicate that Loper's propeller was constructed with a cast iron hub and wrought iron blades, which were riveted to the base at premade extremities extending from the central hub. Some of the earliest examples of Loper propellers exhibit this combined cast and wrought iron construction. Due to fragility and frequent replacements needed for broken wrought iron blades, however, Loper's propeller design later evolved to construct the entire propeller, hub and blades, out of cast iron (Ridgely-Nevitt 1981:189). The four blades are not illustrated in the official U.S. patent to have any noticeable angle or change in dimensions, but Loper notes that the blades can be curved and widened at the ends to increase the amount of propulsion generated. Blade angle is neither specified in Loper's patent description nor suggested in the associated drawings; however, documentation detailing the specifications of the Loper propeller on the newly launched *Phoenix* in 1845 indicates a blade angle of 32 degrees at the central hub and 52 degrees at the blades' extremities (*Daily National Pilot* 1845a). Variations in blade angle and size depended on the dimensions of the vessel the propellers were built for, with most common propellers ranging from 8 to 11 feet in diameter.

Application of the Loper Propeller

One of Richard Loper's first applications of his screw design appeared in cooperation with the United States Navy with the launch of the U.S. Revenue steamer *Spencer* in 1844. While *Spencer* ultimately failed its trials, it did so by a small margin and did not deter the United States Navy from continuing to work with Loper through the Civil War (Frazer 1846). Loper's design quickly gained popularity along the East Coast as the ideal propeller for coastal steam liners and towing vessels, and over the course of the late 1840s and early 1850s Loper and his manufacturing partner Reaney, Neafie, & Co. took part in the construction of dozens of steam vessels of varying sizes and purposes (Ridgely-Nevitt 1981:189-202). As the design gained popularity along the East Coast and in the U.S. interior, various monikers for Loper's propeller, often incorporating Loper by name or simply referring to the propeller's design or pattern being "of Philadelphia" began to appear in news articles and enrollment papers, both indicating the design's popularity as well as slowly complicating the exact classification of propeller wheels built in the Loper style.

Though the Loper propeller was a product of Northeastern U.S. shipbuilding innovation, it found most of its success in the Great Lakes maritime industries. As early as the late 1840s vessels equipped with Philadelphia wheels were plying the waters of the eastern lakes, but by the

1850s Loper propellers dominated the screw propeller market in the region, outnumbering all other screw propeller styles by a wide margin (Oswego Palladium 1857). While the development of other screw propellers for use in the Great Lakes region in the late 1850s and 1860s likely affected the ubiquity of the Loper design in the later years of the 19th century, vessels continued to be constructed with Philadelphia wheels through the 1870s and continued to operate on the Great Lakes through the turn of the 20th century (Dappert 2005).

On a broader scale, contemporary sources suggest that the Loper propeller was among the most popular screw propeller designs in America during the mid-19th century, with one author stating that "more of these kind of propellers are now employed on vessels in the United States than any other, and on vessels of every class and burden, from the small canal boat to the first-class steamship (MacFarlane 1851:119)." This popularity and positive reputation garnered quickly after the introduction of the design to the U.S. shipbuilding industry can be attributed to multiple factors. As previously stated, the Philadelphia wheel's relatively simple design and construction required less iron and labor in the manufacturing process than its contemporaries, making Loper's design a more economical choice when fitting a vessel. Additionally, while the speed of Loper-style propellers proved comparable to contemporary designs in formal trials, they developed a reputation for causing less hull vibration than other propeller designs from the period (Dappert 2006:47). Reduced hull vibration decreased hull wear and damage over time, which would have made the Loper propeller an attractive option for shipbuilders. The ubiquity of the Philadelphia wheel during this time, and its continued presence in U.S. shipbuilding through the transition from wooden to iron-hulled vessels in merchant shipping, is a testament to the significance of the design in the maritime industrial landscape.

19th Century Screw Propeller Case Study Histories

Four mid-19th century screw steamships with extant propellers have been identified in the Great Lakes and on the southern Australian coast. Three propellers have been previously identified in archaeological investigations or the historical record. *Indiana* and *Monohansett* have been identified as Loper designs, while *Goliath*'s twin propellers have been identified as Ericsson designs. *Monumental City*'s propeller has been attributed to Francis Pettit Smith in both historical documentation and modern scholarship; however, comparison of the propeller with Smith's designs indicate a possible misattribution at the time of launching. All four steamships and propellers were relatively similar in form but lived varied working lives ranging from three to nearly 30 years of service in their respective industries. Whether the propellers remain on the wreck site or were removed for study and conservation, the vessels and their propellers can provide insight into the development of screw propeller form in the mid- to late 19th century and the potential impact of Richard Loper's propeller design on U.S. shipbuilding.

<u>*Indiana* (1848)</u>

The approximately 146-foot screw steamer *Indiana* (20US3) operated throughout Lake Superior from the time of its launch in 1848 to its loss in 1858 (Johnston and Robinson 1993). The wreck of *Indiana*, located nearly 120 feet below the surface off Crisp Point, Michigan, is in a stable condition and has remained largely intact outside of damage to the bow of the vessel sustained during its sinking. *Indiana*'s propeller, assigned the accession number 1979.1030, is currently housed and displayed in the Smithsonian's National Museum of American History in Washington, DC (Figure 2.4). The propeller is believed to have been built in the Loper style by ironworks company Spang & Co. out of Pittsburgh, Pennsylvania (NMAH 2020).

FIGURE 2.5. *Indiana*'s propeller, located in the Smithsonian National Museum of American History (Courtesy of the Smithsonian Institution; NMAH 2020).

Indiana was built in 1848 by shipbuilder Joseph M. Keating in Vermillion, Ohio for a group of five individuals from Ohio and New York looking to get into the Great Lakes shipping industry (Johnston 1995:325). Enrollment papers described *Indiana* as being a two-decked, single-masted screw propeller with a gross tonnage of nearly 350, a straight stem, and a rounded stern (Alpena County George N. Fletcher Public Library 2020b). The steamer made approximately 378 documented trips across its relatively uneventful decade of operation, frequently appearing in the maritime trade sections of regional newspapers throughout the southern Great Lakes (Johnston 1995:325). While *Indiana* changed hands several times during its career, either through complete sales to new owners or partial sales that transferred a portion of the vessel's ownership to a new individual, the vessel does not seem to have ever been employed by a transportation company. Instead, *Indiana*'s collective ownership by a handful of individuals meant that its cargo varied widely and could range from loads of ore to live hogs for any single trip. *Indiana* was lost on the night of 6 June 1858 on a trip to Cleveland, Ohio after a machinery malfunction split the sternpost, causing the vessel to rapidly gain water. Despite issues that arose when one of the small boats used to abandon the vessel struck the propeller as it was lowered to the water, all 21 crew members survived the sinking and were picked up by a passing schooner that transported them the remainder of the way to Cleveland (Johnston 1995:338-339). Accounts in the area in the days following *Indiana*'s sinking reported that parts of the vessel's superstructure had broken from the hull and could be seen floating on the surface of the lake.

Though the vessel's general location was recorded in final disposition records after its sinking in 1858, *Indiana* was not officially relocated until the early 1970s. Following communication with Pat Labadie of the U.S. Army Corps of Engineers, the decision was made to involve the Smithsonian Institution to record the site and potentially remove significant artifacts and machinery. In 1979, a joint force of archaeologists and divers representing the Smithsonian, U.S. Navy, U.S. Army Corps of Engineers, Bowling Green State University, and the State of Michigan removed *Indiana*'s propeller, along with the engine, rudder, boiler, and other related machinery from the wreck. Following the recovery of these artifacts, they were transported to the Smithsonian's National Museum of American History for conservation treatment and storage (Johnston and Robinson 1993:341-342). Archaeological research conducted on the site by the Smithsonian Institution from 1991 to 1993 allowed for detailed documentation of the site and sampling of hull timbers from the wreck. Since the 1993 field season, it does not appear that any extensive archaeological work has been conducted on *Indiana*.

Monohansett (1872)

Monohansett (2OUH56), a 168.4-foot-long wooden bulk carrier, sank off of Thunder Bay Island in Lake Huron, MI in 1907 (Dappert 2005). The wreck currently rests in only 18 feet of water within the boundaries of Thunder Bay National Marine Sanctuary and Underwater Preserve (TBNMS). In the years following the vessel's return to public consciousness, *Monohansett* has become one of the most well-known wrecks within TBNMS, largely in part to the wreck's propeller, believed to have been built in the Loper style, that remains attached to the stern assembly (Figure 2.5) (Dappert 2005).

FIGURE 2.6. Stern view of the shipwreck *Monohansett* and its propeller (Courtesy of TBNMS; Stephanie Gandulla, pers. comm.).

In 1872, Michigan shipbuilding company Linn & Craig launched *Monohansett*, initially named *Ira H. Owen*, under contract from the Lake Michigan Transportation Company (Dappert 2005:49). Linn & Craig built *Ira H. Owen* as a double-decked bulk freighter powered by both sail and screw propeller; however, specifics of the vessel's construction vary throughout the historical record (Alpena County George N. Fletcher Public Library 2020c; Dappert 2005:51-52). *Ira H. Owen* began its career as a bulk ore carrier in the spring of 1872, spending the next two decades in the iron ore trade throughout the Great Lakes region for several consecutive owners (Dappert 2005). During this period, *Ira H. Owen*'s name was changed to *Monohansett*. *Monohansett* was purchased in 1892 for use as a lumber carrier and purchased again in 1900 for use as a coal carrier (Dappert 2005:57-59). Late in the evening on 22 November 1907, a coal fire broke out below deck and quickly spread through the ship, largely due to the full load of coal it carried en route from Cleveland to Ontario (Dappert 2005:60). After several failed attempts to subdue the fire and salvage *Monohansett* and its cargo, the vessel sank to the bottom of Lake Huron on the morning of 23 November 1907 and was declared a complete loss (Department of Commerce and Labor 1908:382).

While wreck survivors and Michigan locals remained aware of the location of *Monohansett* in the years following the vessel's loss, knowledge of the shipwreck's identity faded as the 20th century progressed. The wreck reappeared in scholarly publications in 1975, when Michigan State University completed an archaeological survey of Thunder Bay Island and made mention of a wreck broken into three separate parts "at the southern end of Thunder Bay Island" (Dappert 2006:39; Warner and Holecek 1975:16). Several investigations of the shipwreck occurred within the first few years of TBNMS's establishment, including a 2001 preliminary survey providing a slightly more detailed description of the shipwreck and a 2003 side-scan sonar survey conducted jointly by NOAA and TBNMS (Dappert 2006:39). Possibly the most intensive archaeological work to date occurred in 2004, when ECU conducted a pre-disturbance survey of the wreck over the course of a summer field school, creating a scaled map of the vast majority of the wreck and surrounding debris field (Dappert 2006). Claire Dappert's master's thesis (2005) and subsequent report (2006) published through the university detail the methodology, historical background, and archaeological findings of the field school. Following investigations conducted by ECU in 2004, little to no extensive archaeological work has been conducted on *Monohansett*. Informal condition surveys conducted annually by TBNMS and NOAA consist of photographic and visual assessment when the site's mooring buoy is installed at the beginning of the diving season (Stephanie Gandulla, pers. comm.).

Monumental City (1850)

The approximately 180-foot screw steamer *Monumental City* enjoyed a notable, albeit short and relatively unsuccessful, career as a passenger and freight vessel on the United States West Coast and in the Pacific from the time of its launch in 1850 to its sinking in 1853 (Warren 1998). *Monumental City*'s screw propeller and shaft, engine components, and iron fittings are all that remains of the vessel on the reef outcroppings near Tullaberga Island in Victoria, Australia (Figure 2.6) (Staniforth 1986). *Monumental City*'s propeller is attributed to Francis Pettit Smith in newspaper articles published at the time of the vessel's launch; however, the propeller's four-bladed design suggests that it was likely misattributed (*American Railroad Journal* 1850; *Journal of the Franklin Institute* 1850). There is no indication in either the U.S. or British historic patent archives that Smith was granted a later patent for a more "traditional" four-bladed propeller design (William Davis, British Library, pers. comm.). While no historical documentation suggests that *Monumental City*'s propeller could have been made in an alternate wheel design, such as that of Richard Loper, the propeller does more closely resemble the "Philadelphia wheel" design than that of Francis Pettit Smith or John Ericsson.

FIGURE 2.7. *Monumental City*'s propeller and propeller shaft (Courtesy of Heritage Victoria; Culture Victoria 2016).

Monumental City, a two-masted, 737-ton screw steamer, was built in Baltimore, Maryland by shipbuilders Murray and Hazelhurst (*JFI* 1850). Hoping to capitalize on the California gold rush and the increased number of people migrating to the West Coast, investors decided to charter the vessel as a passenger and freight transport from Nicaragua to San Francisco. Following successful trials in Baltimore harbor in November 1850, the steamship departed for California; however, inclement weather and numerous mechanical difficulties lengthened the duration of the voyage and *Monumental City* did not arrive in San Francisco until the summer of 1851 (Hopkins 2000:62). *Monumental City*'s career as a chartered transport vessel along the Pacific coast was decidedly unsuccessful. Chartered only three times by the Empire

City and Vanderbilt Lines from San Juan del Sur to San Francisco, the steamship's frequent machinery issues and passenger overcrowding led to extended voyage durations and poor conditions aboard the vessel. Failing to receive a fourth charter in San Francisco in the early months of 1853, *Monumental City*'s owners chose to seek a new market in Australia. After a 65-day voyage, *Monumental City* arrived in Sydney on 23 April 1853, claiming the title of the first U.S. steamship to cross the Pacific Ocean, preceded only by the British vessel *Conside* in 1852 (Hopkins 2000:61). The vessel quickly began transporting passengers and cargo between Sydney and Melbourne, successfully completing one trip to Melbourne in early May 1853. On 13 May 1853, *Monumental City* began its return voyage from Melbourne to Sydney to complete its first transport voyage. In the early morning of 15 May 1853, *Monumental City* struck a rocky outcropping of Tullaberga Island at full speed. The impact caused the vessel to quickly take on water, causing chaos on board as passengers and crew attempted to launch safety boats (*Argus* (Melbourne) 1853). A line from the ship to Tullaberga Island was eventually established, allowing passengers and crew to climb to shore; however, many of the women and children were unable to cross before *Monumental City* was lost, claiming 37 lives of the passengers and crew (*Argus* (Melbourne) 1853; Hopkins 2000:64). The survivors, using a raft built from wreck salvage, reached the mainland two days later.

The tragic circumstances of *Monumental City*'s wrecking received immediate attention from Victorian citizens and government officials. A wooden lighthouse was erected on nearby Gabo Island soon after the wrecking event and later was rebuilt out of stone in an attempt to prevent more wrecks from occurring on the surrounding coastline (Staniforth 1986:32). A monument to the lives lost in the wreck was also established nearby. The public attention and preventive measures taken following the wreck ensured that knowledge of *Monumental City*'s general location persisted throughout the rest of the 19th and 20th century; however, it was not until 1982 that the Victoria Historic Shipwrecks Unit declared *Monumental City* a Historic Shipwreck and began preliminary investigative work on the site (Staniforth 1986). A three-day mapping and photographic survey of the wreck conducted in 1984 recorded *Monumental City*'s propeller, shaft, cylinders, anchors, engine, and other ironworks scattered around the site (Hopkins 2000:66). Continued investigations of the wreck's engine and machinery, as well as general monitoring of the site, is conducted by Heritage Victoria.

Goliath (1846)

The propeller *Goliath*, a 131-foot, approximately 280-ton wooden screw steamer, operated for a short span of time as a bulk cargo carrier in the eastern Great Lakes from the date of its launch in 1846 to its loss in 1848 (Gegesky 1985). Today, the steamer is located within the bounds of the Thumb Area Bottomland Preserve in eastern Michigan, at a depth of approximately 104 feet (Michigan Underwater Preserves Council 2020). While there is little to no official archaeological research conducted on the wreck of *Goliath*, it is a notable shipwreck due to the presence and relatively good condition of its two Ericsson-style propellers and machinery.

Constructed by Burton Goodsell in Palmer, Michigan as a single-masted package freighter, *Goliath* launched on the St. Clair River in April of 1846, purportedly becoming the first screw-propelled vessel built for cargo transport exclusively within the Great Lakes (Gegesky 1985:68). The first few months of *Goliath*'s operation proceeded without incident; however, five months after launching, a leak below deck forced the crew to ground the vessel to save it and its cargo (*Argus* (Kingston) 1846). Following the vessel's refloating, *Goliath* operated in the eastern Great Lakes without another incident for nearly two years. During the 1848 mining season, *Goliath* served almost exclusively as a cargo transport for a handful of mining companies along the Great Lakes, transferring ores and provisions between Buffalo, New York and Sault Ste. Marie, Michigan (Gegesky 1985:69). On the morning of 13 September, 1848, following *Goliath*'s departure from Buffalo with mining supplies and provisions for the companies around Sault Ste. Marie, a fire broke out aboard the vessel. Exacerbated by its flammable and volatile cargo, comprised in part of several tons of gunpower, hay, and lumber, the fire culminated in a large explosion on deck and *Goliath*'s rapid descent to the floor of Lake Huron. Several other vessels and bystanders witnessed the fire and subsequent explosion but were unable to lend aid due to high winds and surf. Nearly three weeks passed before local news sources could confirm the loss of *Goliath* and all eighteen members of the vessel's crew (Huron Signal 1848).

While some cargo washed ashore in the days following *Goliath*'s sinking, the depth of the wreck and violence of its sinking prevented extensive location and salvage efforts. It was not until 1984 that Undersea Research Associates, a private surveying company operating primarily on the Great Lakes, located the wreck using side-scan sonar, later identifying it as *Goliath* through a combination of historical research and investigative dives (Gegesky 1985). Undersea Research Associates' and subsequent divers' descriptions of the wreck indicate that the majority of the lower portion of the hull and engine machinery is intact, though not without significant fire damage, and in relatively stable condition (Gegesky 1985:71-72). As of June 2021, a 3D photogrammetric model of *Goliath* captured and created by Ken Merryman of the Great Lakes Shipwreck Preservation Society allows for the wreck to be viewed in full by the general public (3DShipwrecks 2021) (Figure 7). As previously stated, no official archaeological investigations have been conducted or published on Goliath to map or more precisely survey the current state of the wreck. However, its location within a Michigan Bottomland Preserve provides the vessel with some amount of legal protection from development and potential damage.

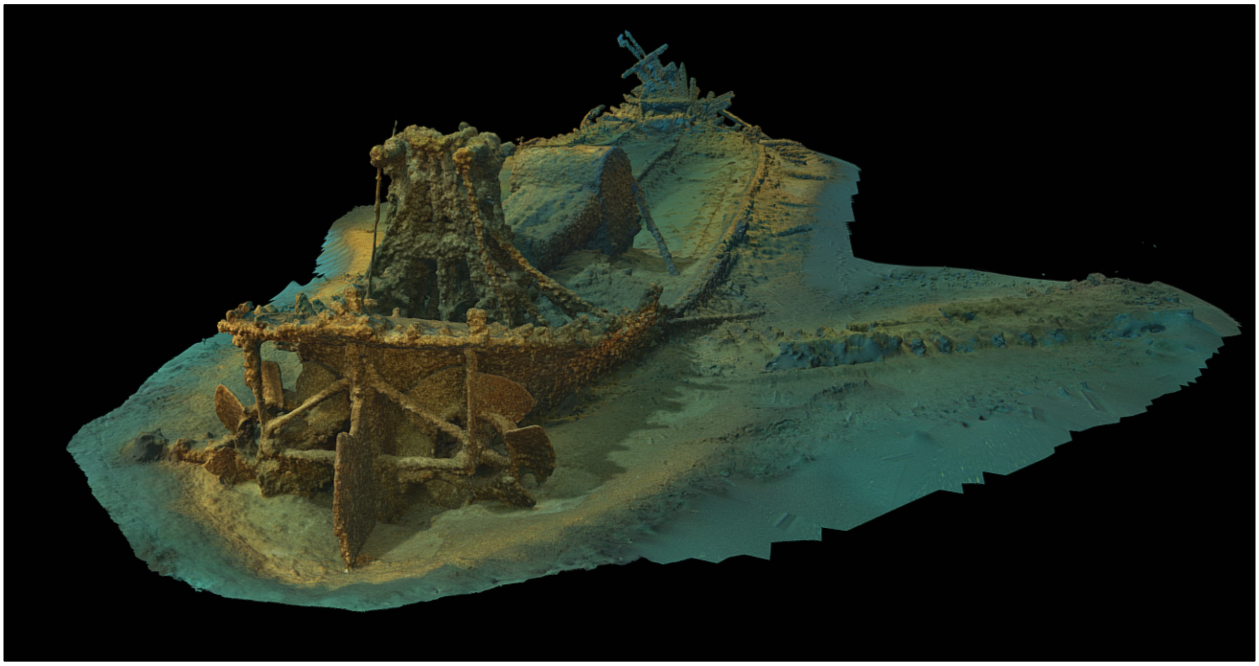

FIGURE 2.8. 3D photogrammetric model of *Goliath*, prominently featuring its twin Ericsson propellers (Modeled by Ken Merryman; 3DShipwrecks 2021).

Conclusion

At the turn of the 20th century, the screw propeller had cemented its place as the most common style of steam propulsion in the United States. Despite U.S. shipbuilders' hesitance to adopt screw propulsion on a major scale in the first half of the 19th century, it became clear in the 1850s and 1860s that screw propellers offered many economic advantages over the sidewheel, and wooden-hulled screw propellers became an increasingly common fixture in both naval and merchant fleets on U.S. rivers and lakes, as well along both the East and West coasts. However, due to the many problems and liabilities screw propellers presented to long-distance merchant shipping when constructed with a wooden hull, screw-propelled vessels would not become the dominant form of transoceanic shipping vessel until the widespread adoption of metal-hulled vessels in U.S. shipbuilding beginning in the late 1800s (Ridgely-Nevitt 1981:188). The variety of propeller designs invented and popularized in the early- to mid-19th century inspired a variety of developments in steam engines, shipbuilding methods, and steam vessel styles that made a significant impact on the “modernization” of U.S. maritime technology at the turn of the 20th century.

CHAPTER 3 - METHODOLOGY

Introduction

This study utilizes two primary methods, historical research and statistical analysis, to collect and analyze data on the presence of Loper propellers in the American Great Lakes. Historical research involved examination of contemporary and modern literature on the development of steam and screw propulsion in the United States, as well as a visit to the Library of Congress and communication with maritime museums and historical societies in the Great Lakes region and the East Coast. The Library of Congress visit and the maritime museum communication served to provide additional context for the development of the Loper propeller in the mid-19th century and primary and secondary source information otherwise unavailable to the author. Patent records in the U.S. and the U.K. were also consulted to obtain a greater understanding of contemporary propeller designs and their development alongside the Loper propeller in 19th century United States shipbuilding.

This thesis applies methods of statistical analysis to outline the growing application of Loper propellers, usually referred to in enrollment records and newspapers as a “Philadelphia wheel” or the “Philadelphia pattern,” in extant Great Lakes vessel records. Using data collected from the Gerald C. Metzler Great Lakes Vessel Database, this thesis tracks the presence of specific propeller designs in Great Lakes vessels from 1844 to 1874. Additional data collected on vessels’ ports of origin, working life, and dimensions provides additional information that may indicate propeller design popularity in certain ports, states, or vessel types. As propeller design styles were often not explicitly identified in enrollment and launch records, this thesis involves analysis of a large sample population to obtain the most relevant and accurate data possible.

Historical Research

Historical and archival research play a major role in outlining the development of screw propulsion in American steam engineering and Richard Loper's development and application of the Philadelphia wheel in the mid-19th century. Primary and secondary sources outlined the development of steam and screw propulsion in the United States' maritime landscape, the life and career of Richard Loper, and historical examples of steamships outfitted with popular mid-19th century propeller designs.

Initial research conducted in the summer and fall of 2020 revolved around identification of vessels built with Loper-style propellers and preliminary research into Richard Loper's designs and career. Following correspondence with the Smithsonian Institution's Paul F. Johnston in Summer 2020, information was collected on the propeller *Indiana*, along with several valuable historical sources on the development of screw propellers in the 19th century that became the foundation of the historical research for this thesis. Robert MacFarlane's 1851 *History of Propellers and Steam Navigation* contextualizes the development and popularity of the Loper propeller in the mid-19th century, as well as outlines the development of screw propeller designs in the United States and in Europe. *A Treatise on the Screw Propeller with Various Suggestions of Improvement,* a British treatise written by John Bourne in 1867, describes the evolution of screw propulsion from a British perspective. While Bourne's treatise makes no mention of Richard Loper's propeller design, it does place Ericsson's and Smith's designs into context within British steam development. Several contemporary journals related to steam propulsion and engineering, such as the *Journal of the Franklin Institute* and the *American Railroad Journal*, provide information on propeller trial runs and specifics of vessel construction.

Aside from contemporary treatises and journal articles on screw propulsion and the development of steam in the mid-19th century, historical newspapers form a large portion of the primary source material used throughout this thesis. Equipped with many of the contemporary names for Richard Loper's propeller design, intensive research was conducted on the presence of the Loper propeller throughout the Great Lakes region as it was represented in local newspaper articles during the period. The author browsed available document repositories and vessel databases for the Great Lakes region, searching for keywords including: "Loper propeller," "Loper pattern," "Loper design," "Philadelphia wheel," and "Philadelphia pattern." Many of the articles most relevant to the development of screw propulsion in the Great Lakes originated in publications from port cities in New York, such as Buffalo's *Daily National Pilot* and Oswego's *Oswego Palladium*. One such article in the *Oswego Palladium* on 4 August 1857 indicates the prolonged influence of Richard Loper's propeller design in the area while simultaneously suggesting local propeller inventors had begun to introduce competing designs. The majority of historical newspapers referenced in this thesis were found through the Maritime History of the Great Lakes (2020) online database. Managed through the Canadian project Our Digital World, the database features historical photos and artwork, smaller circulating publications concerning historical and archaeological research, and thousands of transcribed newspaper articles concerning historical maritime activity in the Great Lakes region from both Canadian and American news publications. Newspaper articles documenting vessel construction, accidents, and shipwrecks also provided a great deal of historical information on the five vessels examined as case studies.

Secondary source information on the development of screw-propelled steam vessels in the United States helped contextualize the relatively quick adoption of the screw propeller in the

Great Lakes, as well as the development of the Loper propeller as a competitor to popular contemporary screw designs. John Morrison's (1967) *History of American Steam Navigation* outlines the general development of steam vessels in the United States from the first successful attempts by John Fitch in the late 18th century to the turn of the 20th century. Cedric Ridgely-Nevitt's (1981) *American Steamships on the Atlantic* describes the evolution of steam vessels on the East Coast, tracking the transition from the early sidewheel steamers of the early- and mid-19th century to wood- and iron-hulled screw propellers that developed in the latter half of the 1800s. Ridgely-Nevitt examines several popular propeller designs throughout the work, including steam vessels equipped with early Loper propellers. *Ships for the Seven Seas: Philadelphia Shipbuilding in the Age of Industrial Capitalism* by Thomas Heinrich (1997) follows the growth of Philadelphia shipbuilding beginning around the middle of the 19th century, and includes a brief history of Richard Loper's shipbuilding partnerships and the ironworks companies he partnered with to construct early iterations of his propeller. Modern academic journals also provided historical and archaeological information on the development of U.S. screw propulsion in the mid-19th century and the five case study vessels. Articles from *The American Neptune*, the *International Journal of Maritime Archaeology* (*IJNA*), *Telescope*, and *Powerships* contained historical and archaeological data on several relevant shipwrecks and Loper's career following the development of his propeller.

Outside of the primary and secondary source information on the general development and adoption of screw propulsion in the Unites States, extant examples of propeller designs popular in the mid-19th century represent a significant element of the historical research conducted for this thesis. Locating shipwrecks and accessioned examples of contemporary propeller styles allowed for deeper research into available primary and secondary source information on the development of screw propellers in mid-19th century American shipbuilding both during the time period and in recent years.

Documentation on the 1848 screw propeller *Indiana* made up a large portion of the information shared with the author by Paul Johnston in Summer 2020. Machinery recovered from *Indiana*, including its propeller, are currently on display at the Smithsonian National Museum of American History. Artifact records kept on the propeller provided some specifics regarding its size and construction details (NMAH 2020). Journal articles provide the majority of the information on *Indiana*'s historical and archaeological context. Paul Johnston and David Robinson's 1993 interim report on the archaeological investigations conducted on the wreck of *Indiana*, published in *IJNA*, briefly outlines the history of *Indiana*'s career before describing archaeological data gathered in the years following the 1979 removal of the vessel's machinery from the wreck. Paul Johnston's 1995 article in *The American Neptune* further describes *Indiana*'s working life and the key figures in its construction and operation.

Located within the bounds of Thunder Bay National Marine Sanctuary (TBNMS), initial research on *Monohansett* coincided with research into TBNMS's management of the shipwreck as part of a Cultural Resource Management term paper for Dr. Lynn Harris in Fall 2020. Correspondence with TBNMS staff members Stephanie Gandulla and Wayne Lusardi provided photographs and current information on the wreck site's condition and management, as well as information on relevant primary and secondary source information useful to research on *Monohansett* and its propeller. Claire Dappert's 2005 thesis and subsequent 2006 field report provide large amounts of historical and archaeological data on *Monohansett*. While the field report and thesis convey much of the same information as products of the 2005 ECU Summer field school, some historical details are included in the thesis that are not present in the field report, making them both valuable resources.

Information regarding *Monumental City* appeared while researching Francis Pettit Smith and his propeller design. Daniel Warren's (1998) thesis on *Monumental City* outlined the vessel's working life and provided archaeological information on the wreck site gathered during a 1994 investigation by a group of ECU students. Fred Hopkins's (2000) article "First to Cross: The S.S. *Monumental City*" in *The American Neptune* further contextualized the vessel's historical narrative as the first U.S. steam vessel, and second steam vessel in general, to cross the Pacific. Additionally, Mark Staniforth's 1986 article for the magazine *Scuba Diver* clarified information on *Monumental City*'s discovery, management, and status as a historic shipwreck in Australia. Primary source information on *Monumental City* also provided important information on the vessel's supposed propeller style and ultimate loss. Articles in the *Journal of the Franklin Institute* (1850) and the *American Railroad Journal* (1850) provide contemporary accounts of the vessel's construction and specifications. The Melbourne, Victoria newspaper *Argus* (1853) details the events leading up to the wreck and loss of *Monumental City* on the Australian coast.

The wreck of the propeller *Goliath* was identified as one of the few intact Ericsson-style propellers remaining in the United States while researching extant examples of popular propeller styles in the mid-19th century. No archaeological investigations have been conducted on the wreck at the present time, but the available report on the discovery of the wreck and newspaper articles contemporary to the vessel's operation provide valuable information on *Goliath*'s working life and site history. An article in *Telescope* by Scott Gegesky (1985) provides valuable information on the discovery of the wreck by the private surveying company Undersea Research Associates. Newspaper articles detailing *Goliath*'s accidents added to the historical record established in Gegesky's discovery report. An article from the Kingston *Argus* (1846) details a major accident *Goliath* was involved in within the first year of its working life. The *Huron Signal* covered *Goliath*'s sinking in several newspaper articles through the month of September 1848, finally confirming the vessel's loss on 6 October 1848.

Utilization of case studies to visualize propeller designs and understand the working lives of mid-19th century screw propellers provides a tangible reference when discussing contemporary propeller designs, but knowledge of the contemporary patents for popular propellers allows further understanding and presents opportunities to investigate possible errors in the historical record. Patents granted in both the United States and England were obtained during the historical research process to identify key characteristics of popular mid-19th century screw propeller designs.

Patents granted in the United States are viewable on the United States Patent and Trademark Office's (USPTO) Patent Full-Text Database, which contains full-text records of patents granted since 1976 and digitized image records of patents granted from 1790 to 1975. However, due to the vast quantity of historical patents that have not been transcribed in full-text within the USPTO database, historical patents can only be found via their issue date, patent number, or classification (USPTO 2020). Searching for relevant propeller inventor names along with the keyword "propeller," the author initially utilized Google Patents to identify correct patent numbers for each relevant propeller design. Using the patent number provided, the patent was then located in the official USPTO database. The additional step of locating the patent on the official U.S. patent repository website assured that no information provided with the original patent, such as additional drawings or descriptions, was overlooked when studying the historical propeller designs. The official U.S. patents granted to John Ericsson (1845), Francis Pettit Smith

(1841), and Richard Loper (1844) provided important diagnostic information regarding the characteristics of each propeller style. Additionally, knowledge of the basic construction and form of contemporary propeller designs allowed for general recognition of extant propellers when conducting case study and database research.

Two of the propeller designs presented within this study, those belonging to Ericsson and Smith, were designed and patented in England prior to their migration to the United States' maritime landscape. Historical British patents granted to individuals between 1617 and 1899 are stored at the British Library and can be accessed via in-person research appointment (British Library 2021). However, due to the author's request for two individual patents and travel restrictions, digital copies of both propeller patents were obtained through correspondence with British Library patent collection staff. John Ericsson's (1836) original British patent was requested and obtained in February of 2021. Comparisons between Ericsson's 1836 British patent and 1845 U.S. Patent revealed several significant differences in the form and construction of his propellers that manifest in extant Ericsson propellers in and around the Great Lakes region. The research inquiry to locate Francis Pettit Smith's (1836) original British patent, conducted in September 2021, had an additional objective of identifying any later propeller patents that may have deviated from his original Archimedean screw-style design. Correspondence between the author and the responding British Library employee indicated that there were no additional propeller patents granted to Francis Pettit Smith in the years following his 1836 design. The presumed absence of a Smith patent that adopted a bladed propeller design in the patent records of both the U.S. and U.K. suggests that the identification of *Monumental City*'s propeller as a Smith design by the *American Railroad Journal* (1850) at the time of the vessel's launch was an error.

Throughout the research process, the author consulted with archaeologists and museum staff from the Great Lakes and coastal Northeast areas to gauge general knowledge of Richard Loper's propeller design and to look for potential propeller case studies. Beginning with correspondence with TBNMS's Stephanie Gandulla in October 2020, the author reached out to a multitude of maritime museums, historical societies, and maritime archaeological organizations requesting any relevant information available on Richard Loper, the Loper propeller, or the development of mid-19th century propellers on a more general scale.

The museum contact process was split in two major parts based on time, region, and inquiry goals. The first round of correspondence took place during the Winter and Spring of 2021 and was primarily directed towards maritime museums in the Great Lakes region. While knowledge of relevant historical documentation was welcome during this stage, the main goal of this correspondence was to locate any examples of mid-19th century propellers accessioned within Great Lakes maritime museums. Out of nine maritime museums and historical societies in Michigan, Wisconsin, Pennsylvania, Ohio, and Ontario that were contacted, eight responded. TBNMS's Wayne Lusardi provided further insight on the presence of propeller wheels on Great Lakes shipwrecks and the likelihood of locating accessioned propellers in museum collections. Unfortunately, the remaining seven maritime museums and historical societies were not able to provide any information on mid-19th century screw propellers. The second round of correspondence took place in August 2021 and was focused on locating relevant primary and secondary source information on Richard Loper and his propeller design along the U.S. East Coast. Out of five maritime museums contacted with the research inquiry, two responded; however, both responding museums were unable to provide any relevant information.

Ultimately, the museum contact process produced few leads for further research. One major impediment to the location of propellers or vessels with intact propellers from the mid-19th century is the durability of propellers themselves. As one of the most fragile external elements of a steam vessel, propellers often broke or were otherwise lost during wrecking events. In shallower waters of the Great Lakes, propellers were also frequent targets of salvage efforts in the immediate aftermath of a shipwreck (Wayne Lusardi, pers. comm.). This combination of fragility and frequent salvage from this historical period manifests itself in the relative rarity of intact propellers on shipwrecks in the Great Lakes. Propeller size represented another problem in the location of wheels in museum collections. Five of the maritime museums contacted specifically referenced propeller size as a limitation on their collections. Propellers attached to the larger ships of the mid-19th century could be as large as 10 feet in diameter, presenting major issues for the conservation, storage, and display in smaller museum environments. The general lack of known historical documentation on the Loper propeller, especially in collections from the Great Lakes region, is also not completely surprising. Loper's propeller design was given several nicknames over the course of the mid-19th century, potentially making information on the propeller style hard to track. Additionally, vessel records did not always include minor details such as specific propeller style. Many of the maritime museums contacted over the course of this study had little to no familiarity with Richard Loper or his propeller design, making the identification of relevant primary and secondary source information for a remote research inquiry difficult.

A significant opportunity for archival research presented itself in the Palmer-Loper family papers housed within the Library of Congress. The Palmer-Loper family papers is a large collection managed by the Library of Congress Manuscript Division consisting of business and personal correspondence, financial papers, ship's logs, and various other printed media related to the Palmer and Loper families from 1667 to 1994 (Library of Congress 2021). Letters, financial papers, and other primary source materials related to the life and shipbuilding career of Richard Loper make up a large portion of the collection. Other significant figures in the Palmer-Loper family papers include Nathaniel Brown Palmer, a contemporary of Richard Loper credited with the discovery of Antarctica in 1820, and merchant Andrew Smith Palmer. The collection consists of two parts further divided into nine series based on media type, subject matter, and time period. Part I of the collection is composed of thirteen boxes and nine microfilm reels, containing a diary belonging to Nathaniel Brown Palmer as well as general correspondence to and from the families throughout the 19th century, financial records, ship's logs, and miscellaneous print material. Part II of the Palmer-Loper family papers, spread across 21 boxes without microfilm copies, contains further correspondence among family members and business partners in addition to large amounts of miscellaneous and undated print material related to the activities of the Loper and Palmer families from the 18th century onward.

The bulk of the research conducted on the Palmer-Loper family papers occurred during a visit to the Library of Congress in Washington, DC on 16 October 2021. With the assistance of staff librarians, the author examined the contents of two boxes from Part II of the Palmer-Loper family papers. Documents of interest located in Box II: 2 consisted of business correspondence sent to, by, and regarding Richard Loper ranging in date from the late 1840s to 1881. Of the approximately 80 documents perused in this box, the author scanned five letters deemed to be potentially significant to the context of this thesis. The contents of Box II: 8 included miscellaneous print and handwritten materials, including documentation surrounding Loper's conflict with the U.S. War Department following the Civil War, an undated report written by

Richard Loper on the development of his screw propeller, and a eulogy written by Andrew Smith Palmer following Loper's death. Six documents containing potentially significant information to this thesis were scanned out of approximately 45 documents examined. Five microfilm reels from Part I of the collection, each containing over 500 pages of primary source information, were also perused during the on-site research appointment. These reels primarily contained ship's logs, letters, and miscellaneous paperwork belonging to the Palmer and Loper families. From the reels examined on-site, three documents containing relevant information to this thesis were saved. A biography of Richard Loper's life provides additional information on his career and reinforces information previously discovered about him. Transcripts from Richard Loper's Senate hearing clarifies the reasoning and resolution of Loper's accused crime of racketeering during the American Civil War. Lastly, letters concerning Richard Loper's cooperation with the U.S. Navy in building vessels for use in the Mexican-American War demonstrate his relationship with the U.S. Navy prior to the Civil War as well as his popularity as a shipbuilder in the mid-19th century.

Time constraints imposed by the research appointment schedule and prior damage to the housing of a potentially relevant microfilm reel necessitated additional research on the collection outside of the author's initial research appointment. Two microfilm reels from the collection, containing a chronological collection of general correspondence sent and received by various members of the Palmer and Loper families between the years 1822 and 1900, were requested via Interlibrary Loan to be loaned to ECU's Joyner Library for further study in November 2021, but were unable to be borrowed and examined.

Some of the most valuable primary sources found in the Palmer-Loper family papers during the visit to the Library of Congress provided additional context to the War Department controversy Richard Loper was involved in following the conclusion of the American Civil War. These sources, most notably a transcript of the Senate hearing in 1863 and letters to and from Richard Loper by government officials, indicated that the Senate investigation was initiated in response to rumors of racketeering from multiple government contractors, and that Loper himself was held in well regard throughout the investigation. Loper's [1844-1880] undated report on the development of his propeller also provided an interesting perspective on his design and the propeller's initial government trials. Outside of information regarding Richard Loper's life and involvement with the U.S. Navy, however, the Palmer-Loper family papers provided a very limited amount of information useful to the study of mid-19th century application of Loper propellers to vessels in the Great Lakes.

Statistical Analysis

Previous statistical studies of screw propulsion in the mid-19th century employed print registries, such as the Lytle List, to obtain statistically relevant vessel information (Dohrman 1976). While much of the data vital to analysis of the development of screw propeller use during the period is represented in federal registries, information essential to this thesis regarding propeller styles and vessel working life is not represented. In recent years, several online databases have been developed to gather remaining documentation on vessels operating on the Great Lakes from the 18th century onward. The Great Lakes Maritime Database, a joint project undertaken by TBNMS and Alpena County Library in Alpena, Michigan, compiles enrollment records and available vessel photographs to index tens of thousands of vessels that operated in the Great Lakes region from the 17th century to the latter part of the 20th century, with an emphasis on commercial vessels operating in the late 19th century (Alpena County George N.

Fletcher Public Library 2020a). Bowling Green State University's (BGSU) (2021) Historical Collections of the Great Lakes include several databases related to Great Lakes maritime history compiling information on vessels, ship owners, and ports historically involved in Great Lakes maritime activity. BGSU's vessel database, like the Great Lakes Maritime Database, contains information and photographs of over ten thousand vessels that operated in the Great Lakes region, but with particular emphasis on vessels from the 20th century. All of the available Great Lakes vessel databases contain valuable information on the thousands of recorded screw-propelled steamships operating in the region in the 19th century. However, for the purposes of this study's data collection, the Gerald C. Metzler Great Lakes Vessels Database provides an ideal combination of accessibility and relevant vessel data.

The Gerald C. Metzler Great Lakes Vessels Database (2020) is managed by the Wisconsin Maritime Museum in Manitowoc, Wisconsin. Originating in personal research conducted by former shipwreck diver Gerald Metzler, this online database compiles information found in enrollment records, newspaper articles, and other primary source media to form a cross-referenced index of over 14,000 vessels operating in the Great Lakes region under American, Canadian, French, and British flags during the 18th and 19th centuries. Depending on available documentation for individual vessels within the database, the information in each entry includes specific vessel type, nationality, year and place built, ship builder and owner information, each known record of enrollment, each known physical description of the vessel's dimensions and rig, and a record of known events involving the vessel. While digitization of Metzler's physical index to the online database is still in progress for vessels built after 1900, the available online index for vessels built in the 18th and 19th centuries has been completed and is considered to be one of the most comprehensive databases on early Great Lakes vessels (BGSU 2021).

The Metzler database was chosen to provide the data for this study due to the relative user-friendliness of the search function and the ease of browsing the database within the confines of the search, something that presented problems while browsing other available online databases. This database also provides short citations noting if information on the vessel was obtained through newspaper articles, enrollment records, or both. In its present state, the Metzler database does not include photographs or images for its vessel entries due to the historical era currently covered and the relative rarity of vessel images. While photographs or drawings of vessels would be a valuable addition to the database whenever available, they provide no additional data in the context of this study.

The sample population of this study includes all American wooden-hulled propellers built between 1844 and 1874 recorded in the Metzler database. Information was gathered on 923 vessels launched from American ports throughout the Great Lakes region during the thirty-year period. Data collected reflects identifying and dimensional information compiled in the Metzler database through the study of enrollment records and newspaper articles from the time of each vessel's operation as a screw propeller. Vessels built by or exchanged with Canadian shipbuilders or merchants during its working life were excluded from the sample population, as in many cases the documentation available to the database regarding their construction and working life under the Canadian flag is spotty or incomplete. Sample population data were first recorded and stored on a Microsoft Excel spreadsheet, then imported to the statistical analysis software IBM SPSS Statistics to conduct both descriptive and inferential statistical analysis.

The data collection process involved gathering and recording the information present in each vessel's database entry. Nineteen variables form the base dataset. Vessel name serves as the identifier of each individual sample. Launch year indicates the vessel's original launch date.

Shipbuilder names the individual, group, or shipbuilding company responsible for the construction of the vessel. Three variables relate to refit propellers that spend their career using different styles of propulsion. If a vessel's records indicate a refit over the course of its working life, the order of propulsion style and year the vessel formally began operation as a screw propeller are recorded. Two variables provide geographical information on the port and state in which the propellers were constructed. Seven variables describe the dimensions and physical characteristics of the sampled propellers: length, tonnage, mast number, deck number, propeller number, propeller diameter, and propeller style. Vessel type indicates if a vessel was noted in enrollment papers and contemporary news sources as simply a "propeller" or a more specific propeller subtype such as tug or barge. In relevant sampled vessel records, a variable represents propeller replacement due to damage or loss. Finally, the approximate length in years of each vessel's working life as a screw propeller is recorded. Any values absent in a specific entry were left blank, with the exception of propeller style which included a coded value for "unspecified" designs.

Following the collection of basic variable data for the entire sample population, four of the original base variables were recoded to obtain further information on vessels within certain date and size groupings. Vessel launch year was separated into three cohorts representing vessels launched in the periods 1844 to 1854, 1855 to 1864, and 1865 to 1874. Recoded vessel length and tonnage values categorize vessels by their relative size. The variable indicating propellers' working life was also recoded to indicate short, average, and long working lives. Simplifying these variables from numerical values to a handful of nominal categories allows for easier analysis of potential trends in vessel construction and use life.

After collection and data transfer into the statistical analysis software, basic descriptive statistical operations were conducted to summarize vessel characteristics and their relative frequencies within the sampled population. Simple numerical data and population frequencies describe the distribution of dimensional specifications and general information on propeller construction in the Great Lakes region during the mid-19th century and allow readers to more clearly understand the general characteristics of relevant vessels recorded in the Metzler database. Descriptive statistics provide a foundation for understanding further statistical operations conducted on the population that aim to determine relationships among the variables within the dataset.

In order to analyze statistical relationships between propeller style and other relevant vessel data, a series of multivariate statistical operations tested the strength of the collected variables. The first two methods of statistical analysis identify potentially significant relationships among the various types of data recorded in the sample population. Crosstabulation, or contingency table analysis, determined potentially significant relationships between propeller style and the non-numerical, categorical variables within the dataset, such as port of origin, vessel type, and refit status. Analysis of means, or ANOVA, testing examined potentially significant relationships between propeller style and variables with numerical values, such as length, tonnage, and working life. The final statistical operation, regression analysis, tested the strength of the relationships identified through the first two means of analysis, determining the ability of each potentially significant variable to explain variations in propeller style within the sample population. Throughout the multivariate statistical operations conducted, variables found to be significant at the .05 level or better are noted and further explored.

Statistical analysis performed on vessels recorded in the Metzler database is not without its biases and limitations. Available documentation on screw propellers within the database varies with each entry, meaning that many entries are incomplete and do not provide data for each desired variable. Propeller style, which is by far the most important variable in the statistical analysis conducted for this thesis, rarely appears in enrollment papers and newspaper articles cited in the Metzler database. This study's large sample size is representative of measures taken to obtain the largest possible population of vessel entries within the Metzler database with identified propeller styles, therefore minimizing the effects of bias as much as possible within the sample (Pyrczak 2014:98). Analysis of the sample population with identified propeller styles are supplemented with additional historical documentation when available; however, statistical data for vessels without propeller identification is presented as it appears within the Metzler database.

Conclusion

Historical research into the life of Richard Loper and the development of screw propulsion in the United States through examination of modern and 19th century literature contextualized the invention and spread of Loper's propeller design in the mid-1800s. Historical patent information obtained through archival research and correspondence with patent historians in both the United States and U.K. resulted in further context for the widespread adoption of screw propulsion in various regions of the United States in the late 1830s and early 1840s. Patent information also provided a valuable diagnostic tool for identifying relevant extant propellers located in maritime museums and on shipwrecks. Archival research and correspondence with maritime historians in the Great Lakes region provided additional information on representative case studies and contemporary screw propeller styles utilized in United States shipbuilding. Through examination and statistical analysis of Great Lakes vessel databases, the adoption of specific propeller styles can be tracked and examined through their relationships to other vessel characteristics and locational data.

While some relevant information on Richard Loper's life was obtained during the visit to the Library of Congress, little documentation was identified that expanded on the author's knowledge of the Loper propeller design and its relative popularity in United States shipbuilding. This dearth of historical documentation mirrors the paper trail left in Great Lakes shipbuilding and enrollment records, as the Gerald C. Metzler Great Lakes Vessel Database contains a relatively small number of vessels that explicitly reference a particular propeller style in their enrollment records and contemporary news coverage. Additionally, due to the scarcity of extant 19th century propellers both in museum collections and on known shipwrecks as well as the general obscurity of Richard Loper and his propeller design, correspondence between the author and maritime history-related institutions resulted in little additional information for the purposes of this thesis. However, the identification of common characteristics in screw steamships known to be equipped with Loper-style propellers through statistical analysis could assist in tracking the adoption of the Loper propeller and screw propulsion in general in the Great Lakes region during the mid-19th century.

CHAPTER 4 - RESULTS AND ANALYSIS

Introduction

Extant records of American vessels operating in the Great Lakes in the mid- to late- 19th century provide a range of data concerning their construction and design. Data collected from the Gerald C. Metzler Great Lakes Vessel Database was processed using IBM SPSS Statistics to identify possible relationships between vessel construction and operation characteristics and screw propeller designs in the period between 1844 and 1874. Overall, data from 923 American wooden-hulled steam propellers represent the general adoption of screw propulsion in the Great Lakes region during the period. Of this larger sample population, only eleven vessels were explicitly linked to a specific propeller design. Statistical analysis of the sample population as a whole, in addition to close historical examination of the smaller population of propellers with an identifiable design, suggests trends in propeller construction and use over the 30-year period. These statistical analyses can be combined with primary and secondary historical documentation discussing or alluding to screw propeller development in the Great Lakes region to outline the evolution of screw propulsion in the area in the latter half of the 1800s.

General Population Results

The data collected represents a wide range of vessel types, port cities, and levels of success in operating on the Great Lakes during the later 19th century. The Gerald C. Metzler Great Lakes Vessel Database compiles available historical documentation on known Great Lakes vessels, leaving some vessels within the sample population with less data than others. Several variables were found universally represented through sources like the Lytle List and basic enrollment records, such as vessel type, port and state of origin, shipbuilder, and working life.

Other variables were much less likely to be represented and were generally gleaned from newspaper articles or more detailed enrollment records, such as deck number and information on propeller style and size. Both types of representational data provide insight into mid- to late-19th century screw propeller construction and vessel documentation throughout the period.

Vessel launch year was, alongside vessel name, one of the few universally represented variables within the sample population. The number of screw-propelled vessels constructed for operation on the Great Lakes saw an overall increase as the latter half of the 19th century progressed, a predictable outcome given screw propulsion's introduction in the early 1840s and rapid growth in popularity as the century progressed (FIGURE 4.1). In 1844, the first year of collected data, only two screw-propelled vessels were constructed for use in and around the Great Lakes region. By 1874, the final year of the 30-year period examined in this study, 53 screw-propelled vessels were documented as being constructed for operation on the Lakes. The 1860s in particular saw many of the highest years of documented ship construction within the sampled population. This includes 1864, the year of highest documented vessel construction and launch that accounted for 8.2% of the entire sampled population. The creation of launch year cohorts into 10-year intervals also clearly shows the rapid growth of screw propeller use in the Great Lakes region from the middle of the 19th century onward. The first cohort grouping, containing vessels constructed and launched between 1844 and 1854, accounted for only 12.8% of the sample population. The next cohort grouping included vessels constructed and launched from 1855 to 1864 and accounted for 37.2% of the vessels in the dataset. The final cohort, containing vessels built and launched from 1865 to 1874, made up just over half of the population at 50.1% of the sampled vessels. Despite the final cohort's slightly smaller timeframe, the frequency of vessels launched in the late 1860s and early 1870s demonstrates the level of popularity that screw propulsion had reached in the Great Lakes region at the time.

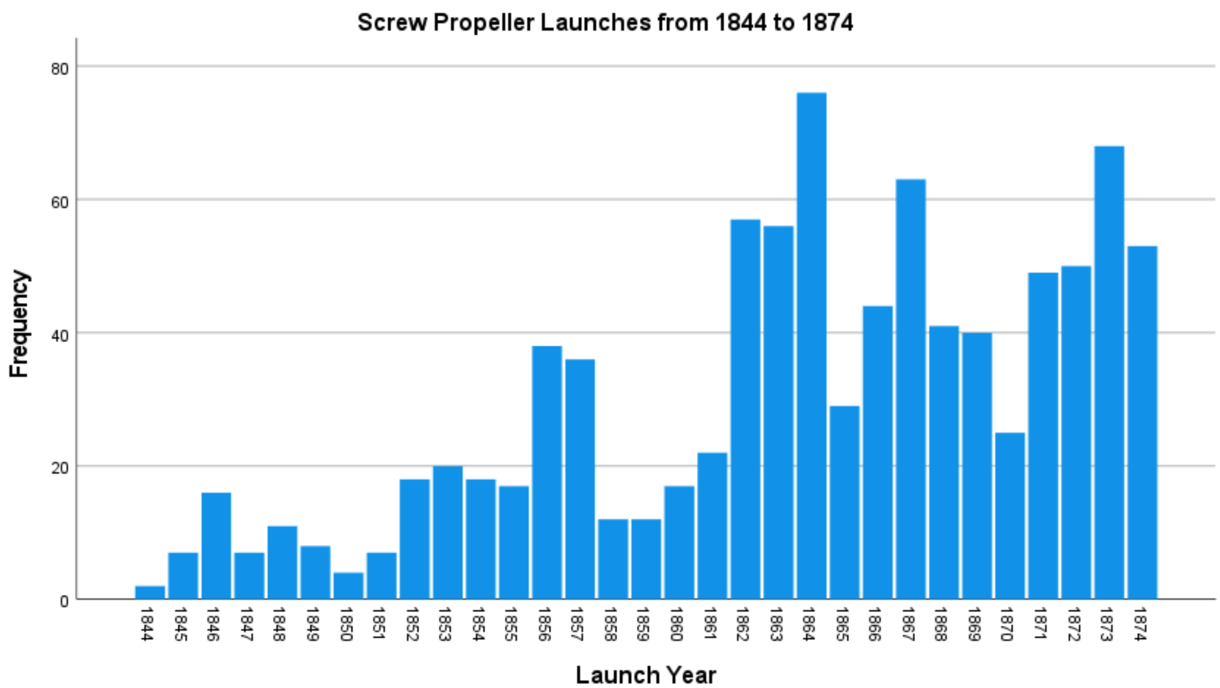

FIGURE 4.1. A graph displaying the frequency of screw propeller launches by year from 1844 to 1874 in the Great Lakes region, as documented in the Gerald C. Metzler Great Lakes Vessel database (Graph by author).

Dozens of shipbuilders constructed screw-propelled vessels in the Great Lakes region during the period between 1844 and 1874 and were credited on 82.7% of the sampled vessels. Many shipbuilders recorded in the database constructed a single vessel, but several notable shipbuilders operated throughout the period, amassing a large number of constructed screw propellers within the dataset. George H. Notter and C. A. Van Slyke were the most prolific screw propeller builders recorded in the Metzler database during this period, constructing 4.9% and 3.4% of the entire sampled population, respectively. Other notable shipbuilders include Bidwell and Banta of Buffalo, New York (2.4%), Luther Moses of Cleveland, Ohio (1.7%), Peck and

Masters of Cleveland, Ohio (1.8%), Quayle and Martin of Cleveland, Ohio (2.8%), and William Crosthwaite of Buffalo, New York (1.6%).

Screw propelled vessels constructed in the state of New York dominated the sampled population, with 426 vessels (or 46.3% of the total population) constructed in some area of the state. Michigan and Ohio were the second and third most common states of origin represented, making up 21.1% and 20.2% of the sampled population respectively. The Great Lakes-adjacent states of Wisconsin (5.9%), Illinois (4.7%), Pennsylvania (1.3%), and Indiana (0.2%) were also represented within the sample population, but at much lower frequencies than those of New York, Michigan, and Ohio. Vessels constructed in New Jersey (0.2%) and Maryland (0.1%) were also documented as operating in the Great Lakes region during the period, but at extremely low frequencies. Within their respective states of origin, the sampled population was built at over one hundred different port cities. The most common port of origin, Buffalo, New York, accounted for 39.4% of the sampled population's vessel construction. Other popular ports of origin for Great Lakes screw propellers at this time included Cleveland, Ohio (13.1%), Chicago, Illinois (4.6%) Detroit, Michigan (4.4%), and Milwaukee, Wisconsin (2.2%).

Vessel length and tonnage varied widely across the sampled population, coinciding with the diversity of vessel types and increasing popularity of screw propulsion in the Great Lakes during the latter half of the 19th century. Length measurements of screw propellers documented in the Metzler database during this time were present in 87.8% of the sampled population and ranged from a minimum of 18 feet to a maximum of 369 feet. Smaller vessels, or those that measured under 50 feet, accounted for 21.7% of the vessels with recorded lengths. Vessels ranging in length from 51 feet to 150 feet made up 54% of the population. Large vessels with a length of over 151 feet accounted for the remaining 24.3% of vessels with a documented length.

Tonnage was documented in all but six vessel database entries within the sample population, ranging from a minimum of 6 tons to a maximum of 1,742 tons. Lower capacity vessels with a tonnage of 50 or below made up 44.2% of the population of vessel with documented tonnage information. Vessels of middling capacity with a tonnage between 51 and 200 tons accounted for another 20.8% of the documented population. Lastly, high-capacity vessels with a tonnage of over 201 tons made up the remaining 35% of vessels with documented tonnage information.

The number of masts a screw propeller was fitted with at the time of launch was another commonly recorded element in contemporary ships' papers. Of the total sampled population, 680 vessel database entries (73.7%) included the vessel's mast number. Zero masts were the most commonly recorded, composing 65.1% of the subpopulation of vessels with documented mast number. Single-masted vessels constituted another 27.4% of the subpopulation. From there the frequency of vessels with multiple masts decreased significantly, with vessels documented with two, three, or four masts only making up 3.8%, 2.9%, and 0.7% of the subpopulation.

Ships' papers cited in the Metzler database entries often specified vessel type and purpose of particular screw propellers. Within the sampled population, 58.1% of the vessels were described as being of a specific vessel type. Tugs made up the largest portion of the specified vessel styles, making up over half of the total sampled population. Barges, the second most frequently identified vessel type, composed only 3.4% of the total population. The remaining 2.8% of vessels identified as being of a particular style and purpose vary widely. Vessels identified as ferry boats and steam yachts each account for 0.5% of the sampled population. Less common vessel types and purposes documented in the sample population include scow propellers, revenue cutters, and fish tugs. While 41.9% of vessels were not listed in ships' papers as being of a specific style, it is likely that many vessels were simply not categorized in their enrollment papers.

The length of a vessel's working life was documented in 85.9% of the sampled population, often gathered from insurance papers or news articles detailing a vessel's abandonment or loss. Approximately 1% of the vessels within the sample population represent the minimum working life observed within the sample population, operating for less than one year due to either accidents or decisions to refit from a screw propeller to another propulsion style. At the opposite end, *Gladiator* (1871) was the longest operating vessel recorded within the sample population, with a working life spanning 89 years. Within the subset of the sampled population that retained information regarding vessel working life, 26.7% of vessels operated as a screw propeller for ten years or less. The majority of vessels within the database with working life data, constituting 41.9% of the documented population, operated in the Great Lakes region for between 11 and 25 years. The remaining 31.4% of vessels with a documented working life operated in and around the Great Lakes for more than 25 years, with many vessels constructed in the latter years of the collected data set operating continuously through the turn of the 20th century.

Less commonly represented variable data included information on vessel refitting, deck number, and information on the vessels' propellers. Approximately 116 vessel database entries, or 12.6% of the recorded population, included documentation concerning refits over the course of a vessel's working life. The majority of these refits, constituting 81.9% of the sampled population that had refit documentation, were made from a screw propeller to another style of rigging or propulsion, potentially indicating a change in operational use. The remaining 18.1% of the refit vessels within the population were altered to become screw propellers in the years following their original launch. Very few vessels, representing just 3.8% of the sampled population, had extant documentation describing deck number. Of the 35 vessels, two decks were most commonly recorded, making up 65.7% of the vessels with relevant documentation available. Only two vessels in the sampled population were recorded as having three decks, representing 5.7% of vessels with deck information and only 0.2% of the sample population as a whole.

Propeller information was also relatively rare to find recorded in enrollment and vessel data within the database. Only 33 screw propeller database entries, or 3.6% of the total population sampled, indicated the number of propellers fitted to the vessel. Among the vessel entries that indicated propeller number, the population was split relatively evenly, with 54.5% of the vessels having a single propeller and 45.5% of the vessels fit with dual propellers. Propeller diameter was another rarely documented vessel characteristic, appearing in only 3.5% of the 923 vessel entries recorded. Within this small subpopulation, however, it does appear that propellers with a diameter of 11 and 13 feet were most common, each constituting for nearly 20% of recorded propeller diameters. Propeller replacement due to working accidents was also rarely recorded, with only 10 vessel entries across the entire sample population indicating an accident that necessitated a wheel's replacement. Lastly, propeller design style was extremely rarely indicated within the vessel database entries. Out of the sampled population of 923 vessels, a mere 1.2% identified the style of propeller wheel used on the vessel. Of these eleven vessels, the "Philadelphia pattern" designed by Richard Loper was recorded as being used on eight vessels. The remaining three vessels with recorded propeller styles represented lesser-known screw propeller patterns from the Great Lakes and Northeastern U.S. regions, referred to in ships' documents and news articles as the Merrick, New York, and Clyde patterns. No vessels sampled indicated being fit with an Ericsson-style propeller wheel.

General Population Analysis and Discussion

The general population of screw propellers sampled in this study demonstrates the growth and level of diversification in U.S. screw propellers built and operating in the Great Lakes region during the mid- to late-19th century. While some variables within the sampled dataset were not as heavily represented as others, the differences in documented vessel information and construction characteristics may suggest variations in enrollment documentation across the Great Lakes region or over the sampled period. By examining some of the commonly documented characteristics of wooden screw propellers operating under the U.S. flag during this period through simple statistical analysis processes like crosstabulation, this study can attain a better understanding of some of the general trends in screw-propelled shipbuilding that were developing in the second half of the 19th century in the Great Lakes region.

<u>Development in Great Lakes Port Cities</u>

By the middle of the 19th century, many of the major port cities along the U.S. shores of the Great Lakes had developed thriving maritime commercial and shipbuilding industries. However, documented construction and launch of screw-propelled vessels in the region were largely exclusive to these major established ports for the first several years of screw propulsion's development around the Lakes (TABLE 4.1). Crosstabulation of the relationship between vessel ports of origin and launch cohort indicate that Buffalo, New York and Cleveland, Ohio were extremely productive ports throughout the 30-year period but were almost exclusively producing screw propelled vessels during the first cohort period from 1844 to 1854. Only Ohio City, Ohio produced a comparable number of vessels within the first ten years of the studied period. The level of vessel production in these ports during this early period of screw propeller adoption in the area is likely due to their favorable locations on established maritime waterways. The completion of both the Erie Canal in 1825, connecting Lake Erie to the Hudson River at Buffalo, and the Ohio and Erie Canal in 1832, connecting Lake Erie to the Ohio River at Cleveland, allowed for increases in both migration and waterborne commerce in both ports and likely contributed to their willingness to begin adopting new steam technology (Labaree et al. 1998).

TABLE 4.1. Top producing ports of origin with screw-propelled vessels built separated by cohort (Data derived by author from Gerald C. Metzler Great Lakes Vessel Database 2020).

Port of Origin	**1844-1854**	**1855-1864**	**1865-1874**	**Total**
Buffalo, NY	38	169	157	364
Cleveland, OH	17	63	41	121
Chicago, IL	1	20	21	42
Detroit, MI	3	11	27	41
Marine City, MI	0	0	21	21
Milwaukee, WI	0	7	13	20
Ohio City, OH	17	0	0	17
Ogdensburg, NY	0	4	9	13
Port Huron, MI	2	2	9	13
East Saginaw, MI	0	1	11	12
Newport, MI	1	9	2	12
Oswego, NY	5	5	2	12
Sandusky, OH	0	4	8	12

With the increase in popularity of screw propulsion in the Great Lakes region as a whole, the second cohort period from 1855 to 1864 saw an explosion in wooden screw propeller construction across the Great Lakes region. During this cohort period, other developing port cities began to make significant contributions to screw propeller production on the Great Lakes, with ports like Chicago, Detroit, Milwaukee, and Oswego joining Buffalo and Cleveland in producing screw propellers. This can be seen as a result of widespread dissemination of shipbuilding practices as canal systems and Great Lakes maritime industries continued to develop.

The final cohort period, ranging from 1865 to 1874, indicates a shift in production practices across the region, with smaller Great Lakes port cities becoming much more active in the production of wooden screw-propelled vessels than either of the previous cohort periods. While no single port within the state of Michigan reached the level of wooden screw propeller production seen in the contemporary giants of Great Lakes shipbuilding, the combined production across the state of Michigan increased by nearly 500% in the late 1860s and early 1870s, second only to the state of New York in total statewide production. Both Buffalo and Cleveland's production during this period decreases, and while both ports are still producing large numbers of wooden screw-propelled vessels, the production decrease is quite noticeable when compared to the general increase in production in other ports across the region.

One possible explanation for the decreasing rate of wooden-hulled screw propellers in previously dominant Great Lakes port cities is the continued forward development of vessel technology in the wake of the Civil War. While experimental vessels constructed with composite or fully iron hulls were constructed in the early stages of screw propeller development, the adoption of metal hulls on commercial vessels, like the adoption of screw propellers on commercial vessels, began to rise in popularity on the Lakes during the latter half of the 19th century (Ridgely-Nevitt 1981). It is possible that by the late 1860s and early 1870s, production of wooden-hulled screw propellers decreased in major port cities like Buffalo and Cleveland due to shipbuilding trends shifting to use of composite and metal hulls in screw propeller construction, while wooden hulls continued to be the norm in smaller, still-developing port cities in the region.

Propeller Shipbuilders on the Lakes

As with the popularity of specific port cities for the construction of new screw-propelled vessels, many mid- to late-19th century shipbuilders were demonstrated as prolific in the U.S. Great Lakes shipbuilding industry according to the sampled population data. Shipbuilders like Frederick Nelson Jones, Bidwell and Banta, and Quayle and Moses mostly operated out of the three aforementioned major port cities producing wooden screw-propelled vessels in the first cohort period between 1844 and 1854.

The second cohort period continues the dominance of Buffalo- and Cleveland-based shipbuilders; however, there are several distinct developments in this period when compared to the first ten years examined in the study (TABLE 4.2). Luther Moses, previously working alongside Thomas Quayle, became a popular shipbuilder in his own right, while Quayle moved on to another shipbuilding partnership with Cleveland shipbuilder John Martin. Buffalo-based shipbuilder C. A. Van Slyke became increasingly prevalent during the period between 1855 and 1864, both as an independent shipbuilder and in partnership with George H. Notter. George Notter himself became an incredibly prolific shipbuilder in the final cohort period of this study ranging from 1865 to 1874, producing more wooden screw propellers in this single nine-year period than any other shipbuilder produced across the entire 30-year period of study.

TABLE 4.2. Top producing shipbuilders with vessels built separated by cohort (Data collected by author from Gerald C. Metzler Great Lakes Vessel Database 2020).

Shipbuilder(s)	**1844 - 1854**	**1855 - 1864**	**1865 - 1874**	**Total**
George H. Notter	1	4	40	45
C. A. Van Slyke	1	22	8	31
Van Slyke and Notter	0	22	4	26
Quayle and Martin	0	13	13	26
Bidwell and Banta	12	9	1	22
Peck and Masters	0	16	1	17
Luther Moses	2	14	0	16
William Crosthwaite	1	12	2	15
Frederick Nelson Jones	6	7	1	14
Carroll Brothers	0	0	11	11
Mason and Bidwell	0	7	2	9
B. B. Jones	5	4	0	9
Alvin A. Turner	0	1	7	8
Ira Laffrienier	0	4	4	8
Laffrienier and Stevenson	4	4	0	8

While shipbuilders in Buffalo and Cleveland continued to produce relatively large numbers of vessels, the third cohort period involves a significantly increased number of shipbuilders from smaller port cities across the Great Lakes region. As with the observations and hypotheses regarding the spread of Great Lakes maritime commerce over the latter half of the 19th century in the previous section, the dissemination of Great Lakes vessels and the popularization of the screw propeller in Great Lakes maritime landscape by the late 1860s and early 1870s likely lent itself to smaller-scale shipyards and shipbuilders trying their hand at screw propeller construction. In addition to the many individual shipbuilders making one-off screw propellers, dry dock companies began to appear as registered shipbuilders for some vessels during this final cohort period. While many Great Lakes dry dock and similar vessel repair companies emerged in the mid-19th century to service steam vessels operating in the region, it is unclear whether the documented launches by these companies represent completely new vessels or previously operating wooden vessels that were refit or rebuilt.

Data collected from the Gerald C. Metzler Great Lakes Vessel Database also suggests potential relationships between individual shipbuilding practices and vessel working life. While operation on the Great Lakes was unpredictable during the 19th century and accidents were common among all types of commercial vessels, the comparative frequency of certain shipbuilders' vessels to particular levels of operating longevity may indicate quality of construction or, alternatively, level of strenuous activity undertaken by certain wooden-hulled screw propellers. The general distribution of vessels constructed by shipbuilders Bidwell and Banta, C. A. Van Slyke, and Luther Moses, all operating in the early to middle portions of the studied period, suggest that the majority of their screw-propelled vessels operated for a relatively moderate amount of time (between 10 and 25 years) before their abandonment, loss, sale, or refitting. Other shipbuilders, notably George H. Notter of Buffalo, New York, appear to have built many highly successful vessels operating for over 25 years, whether due to quality of construction or general lack of risk in their standard operations. While vessel longevity in any maritime setting can be unpredictable and highly dependent on standard operations and vessel purpose, observation of the relationships between shipbuilder and screw propeller working life in this period suggest some level of success in individual shipbuilders' adoption of screw technology in the mid- to late-19th century.

Propeller Style Population Results

As stated in a previous section, vessel entries within the Metzler database indicating the use of a specific screw propeller design included only eleven vessels, making up a mere 1.2% of the total sampled population. These eleven vessels represent construction from throughout the 30-year period, with a particularly high number of vessels, representing 63.6% of the small subpopulation, built during the second cohort period between 1855 and 1864. The eleven vessels were built across five ports in three states, the most popular of which being Cleveland, Ohio (45.5% of the subpopulation) and Buffalo, New York (27.3% of the subpopulation). These vessels ranged in length from 88 feet to 251 feet, meaning none were included in the "small vessel" category of the general population. Tonnage also varied widely across the subpopulation, ranging from 128 tons to 1,223 tons with approximately 90.9% of the vessels falling within the "high capacity" tonnage category of the sampled population. Nine out of the eleven vessels with identified propellers also included documentation on mast number, but only one vessel within the subpopulation included information on deck number.

Documented information regarding the number and diameter of the vessels' screw propellers was noticeably more frequent within the subpopulation of vessels with identified propeller types. While less than 4% of the general sampled population included data on propeller number and size, over half of the vessels with identified propeller styles included information on these variables. The majority of the vessels within the identified subpopulation were not labeled as being of a specific vessel type in their ships' papers; however, the 18% of the subpopulation labeled as a specific vessel type were tugs. Working life among the vessels with identified propeller styles ranged from less than one year to 38 years, with over 80% of the vessels operating for less than 25 years.

While some data collected on the subpopulation of Great Lakes screw propellers with historically identified propeller designs can provide insight into differences in vessel documentation and potential regional trends, the subpopulation is much too small for substantial statistical analysis and is heavily affected by the variations in the Great Lakes maritime historical record. Understanding the characteristics of each of the vessels with historically identified screw propeller designs might be a better alternative to broad analysis to aid in comparisons and analysis of contemporary screw propeller development in the Great Lakes region during the mid- to late-19th century.

Globe (2nd) (1848)

Globe (2nd), also referred to in early documentation as *Odd Fellow*, was originally constructed in 1848 as a sidewheel steamer by shipbuilder Burton S. Goodsell in Trenton, Michigan. At the time of *Globe*'s original construction and throughout its documented working life, the vessel was recorded as having a length of 251 feet and gross tonnage of approximately 1,223 tons, making it the largest vessel in terms of both length and capacity within this study's subpopulation of screw propellers with identified wheel designs (FIGURE 4.2).

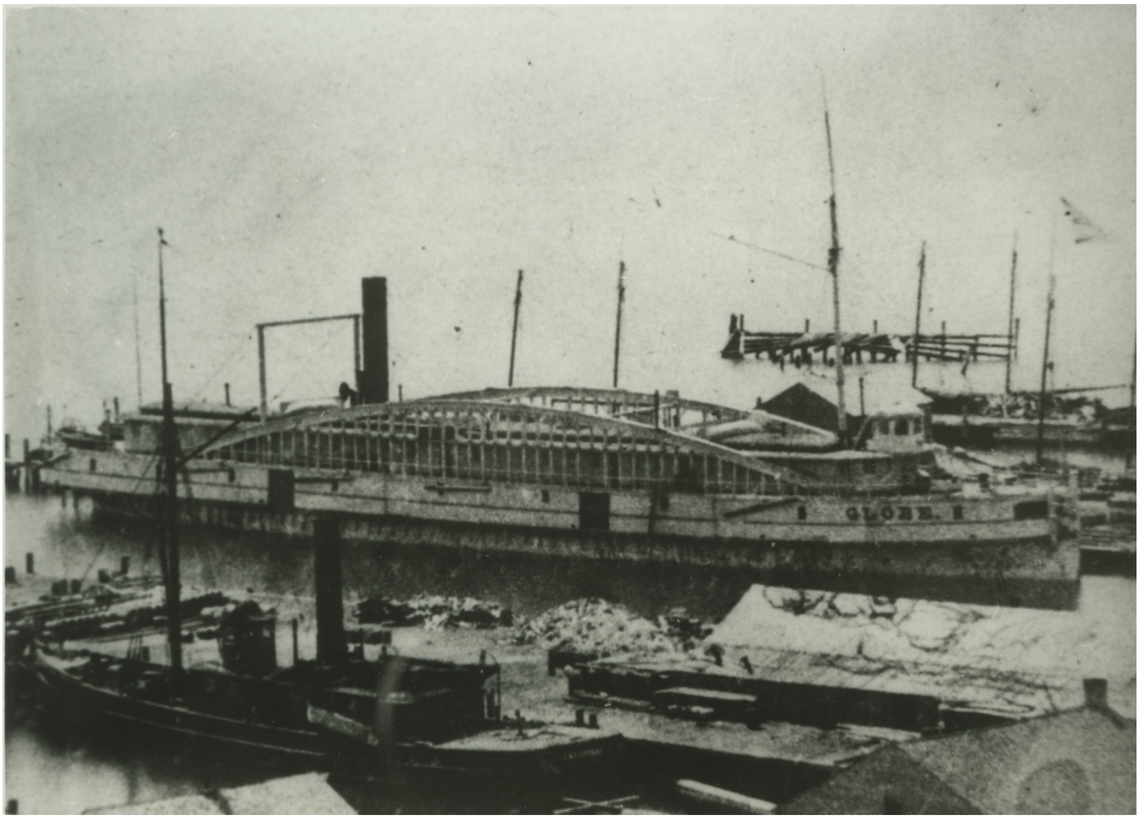

FIGURE 4.2. *Globe (2nd)* docked at Northpoint, Michigan (Courtesy of Alpena County George N. Fletcher Public Library 2021a).

In 1856, *Globe* was rebuilt by C. A. Van Slyke in Buffalo, New York and fitted to operate as a screw propeller. At this time, the vessel was equipped with one Philadelphia wheel measuring 10.5 feet in diameter. At an unknown point between the vessel's original enrollment documentation and its refit, the vessel was also fitted with a second mast, which was recorded in official documentation in 1856. *Globe* operated for only five years following its refit. In late 1860, an explosion in the boiler caused the vessel to sink while at a Chicago wharf, leading to 16 deaths and the total loss of the vessel (*Buffalo Morning Express* 1861).

Stillman Witt (1857)

Stillman Witt was constructed in Buffalo, New York in 1857 by shipbuilder Daniel O'Connor. Enrolled as a plain head screw tug, extant documentation indicates that *Stillman Witt* was not fitted with any masts during its working life. The smallest vessel included in this study's subpopulation of vessels with historically identified screw propeller design, *Stillman Witt* measured approximately 88 feet in length and had a gross tonnage of just under 128 tons. The vessel was fitted with machinery made at Franklin Iron Works in Albany, New York, and was equipped with a single Philadelphia pattern wheel of unknown size. *Stillman Witt* operated in the Great Lakes region for nine years before its abandonment in 1866 (Gerald C. Metzler Great Lakes Vessel Database 2021g).

City of Superior (1857)

City of Superior was constructed in 1857 by Ira Laffrienier and William Stevenson in Cleveland, Ohio. Descriptions of the vessel indicate that, while no specific vessel style or purpose was listed in enrollment or other ships' papers, *City of Superior* was outfitted for passenger transport (Gerald C. Metzler Great Lakes Vessel Database 2021c). The vessel's original enrollment papers describe *City of Superior* as a single-masted propeller measuring nearly 188 feet long, with a gross tonnage of approximately 579 tons. Two Philadelphia pattern wheels, each measuring 8 feet 10 inches in diameter, were fitted at the vessel's stern.

City of Superior is the only vessel within the study's subpopulation of vessels with identified screw propellers that is known to have operated for less than one year. From the documented date of enrollment in mid-September of 1857, *City of Superior* was in operation for less than three months when it ran aground on a reef and was lost in November of the same year (*Buffalo Daily Republic* 1857b).

Burlington (1857)

The propeller *Burlington* was constructed by Daniel O' Connor in Buffalo, New York and launched in May of 1857 (FIGURE 4.3). The plain head screw propeller was fitted with a single mast and measured approximately 137 feet in length with a gross tonnage of approximately 385 tons. *Burlington* was outfitted with at least one Philadelphia wheel of undisclosed size and was equipped with a steam engine and machinery made by Buffalo-based ironworks Swartz and Company (Gerald C. Metzler Great Lakes Vessel Database 2021b).

FIGURE 4.3. *Burlington* entering the harbor at Buffalo, New York c.1867-1872 (Photo by C. L. Pond; courtesy of Maritime History of the Great Lakes 2021).

Burlington is the longest operating vessel within the study's subpopulation of propellers with identified wheel patterns. During its working life, *Burlington* operated under several shipping lines including the Old Oswego Line, the Erie Railroad Line, New York Central Line, and the Western Coal and Dock Company Line. The vessel operated throughout the Great Lakes region for 38 years before a deck fire in September 1895 irreparably damaged Burlington's hull, leading to the total loss of the vessel.

Governor Cushman (1857)

Governor Cushman was constructed by Cleveland, Ohio shipbuilder Luther Moses and launched in the late summer of 1857. Measuring 152 feet long and with a gross tonnage of just under 385 tons, the screw propeller was constructed for both passenger and cargo shipping purposes with 40 passenger cabins and capacity to carry as many as 4500 barrels of flour (*Cleveland Leader* 1857). *Governor Cushman* was equipped with a steam engine and machinery built by Blish and Garlick of Detroit, Michigan and two Philadelphia wheels, each 7 feet in diameter. *Governor Cushman* operated in and around the Great Lakes region for 11 years. A boiler explosion in 1868 dealt significant damage to the hull, ultimately leading to its total loss during a later raising and salvage effort (Gerald C. Metzler Great Lakes Vessel Database 2021d).

Susquehanna (1858)

Susquehanna was constructed in 1858 by Luther and Philo Moses out of Cleveland, Ohio. At the time of the vessel's launch, it measured approximately 162 feet in length with a capacity of around 436 gross tons. Fitted with a single mast and listed as having two decks, *Susquehanna* is the only vessel within the subpopulation of vessels with recorded propeller style to have documentation regarding its deck number. *Susquehanna* is also the only vessel in the entire sampled population described as being fitted with a single Merrick patented propeller. Notably described as the first screw propeller to be equipped with such a wheel, *Susquehanna* was considered to be an experiment of the effectiveness of a new "flanged" propeller design (*Detroit Free Press* 1858). The vessel operated as a screw propeller for a respectable 22 years before having its steam engine and associated equipment removed before a refit as the schooner *May Richards*.

Akron (1859)

The propeller *Akron* was constructed in 1859 by shipbuilders Quayle and Martin in Cleveland, Ohio. At the time of the single-masted vessel's initial enrollment, the vessel measured approximately 135 feet in length and was listed as having a gross tonnage of just over 347 tons. While *Akron*'s original propeller is of unknown design, in 1867 it was equipped with new machinery and a single "New York patent" wheel (Gerald C. Metzler Great Lakes Vessel Database 2021a). It is unknown whether *Akron* was the first to be equipped with this propeller design or if the design had been applied to other vessels previously. The propeller *Akron* operated for 14 years, operating with the New York patent wheel for 6 years, before a fire on deck burned the vessel to the waterline in 1863 (*Detroit Free Press* 1873).

Satellite (1864)

Satellite was originally constructed in 1864 as a sidewheel tug by Quayle and Martin of Cleveland, Ohio. As with most Great Lakes tugs, the vessel was not fitted with any masts or rigging and was modestly sized, with an approximate length of 118 feet and a gross tonnage of

234 tons. *Satellite* operated as a sidewheel without notable incident for approximately one year before its refit to operate as a screw tug. At that time, the vessel was equipped with at least one Philadelphia wheel measuring 8.5 feet in diameter. *Satellite* operated as a screw tug in the Great Lakes region for approximately 14 years, throughout which the vessel was involved in several incidents and collisions that led to damage and necessary repairs to its wheel in at least one instance (Gerald C. Metzler Great Lakes Vessel Database 2021f). The vessel sank after springing a leak in July of 1879 while actively towing several vessels off of Whitefish Point, Michigan.

Yosemite (1867)

The propeller *Yosemite* was launched in 1867 by shipbuilder George Fordham out of Sandusky, Ohio. At the time of launch, the vessel measured 152 feet in length and had a capacity of approximately 310 gross tons. While no indication of vessel style is conveyed in available enrollment papers and notes compiled in the Gerald C. Metzler Great Lakes Vessel Database, contemporary news articles from the region suggest that *Yosemite* was constructed for use as a steam barge (*Chicago Inter-Ocean* 1874; *Detroit Post & Tribune* 1879). While available ships' papers do not describe the specifics of propeller style at the time of the vessel's launch, records indicate that in 1869, a Philadelphia pattern wheel was installed on *Yosemite* along with slight changes in the vessel's machinery (Gerald C. Metzler Great Lakes Vessel Database 2021h). *Yosemite* operated in and around the Great Lakes region for 25 years prior to its loss in 1892 in the aftermath of a fire.

Thomas A. Scott (1869)

Buffalo, New York shipbuilding firm Hitchcock and Gibson constructed the propeller *Thomas A. Scott* in 1869. The vessel's limited documentation from enrollment records and other ships' papers do not provide *Thomas A. Scott*'s recorded length; however, documentation does describe the vessel as having a capacity of 1,159 gross tons, suggesting a relatively large size. *Thomas A. Scott* is the only vessel in the sampled population documented with a single Clyde pattern screw propeller measuring 11 feet in diameter. This vessel was not the first to be outfitted with a Clyde pattern wheel, as an article in the *Detroit Free Press* from the previous year identifies an iron propeller *Philadelphia* as being equipped with a Clyde propeller of the same size (*Detroit Free Press* 1868a). *Thomas A. Scott* operated as a screw propeller on the Great Lakes for 8 years before a refit in Erie, Pennsylvania in 1877, operating as a four-masted schooner for the remainder of its career (*Cleveland Herald* 1877).

John Pridgeon Jr. (1874)

John Pridgeon Jr. was constructed in 1874 by shipbuilder John P. Clark in Detroit, Michigan for operation in the Great Lakes region as a single-masted screw propeller intended for both passenger transport and cargo shipping (*Buffalo Commercial Advertiser* 1875). Among the largest of the vessels sampled that noted propeller style, *John Pridgeon Jr.* measured just under 222 feet in length and, at the time of launch, was listed as having a tonnage of approximately 1,212 gross tons (FIGURE 4.4). The propeller was equipped with one Philadelphia pattern wheel measuring 11 feet in diameter. *John Pridgeon Jr*. enjoyed a fairly successful career within the Great Lakes region for the entirety of its 35-year working life, running for as many as eight different commercial shipping lines from 1875 to 1909 (Gerald C. Metzler Great Lakes Vessel

Database 2021e). The vessel was ultimately lost off Avon Point, Ohio in 1909 while carrying a shipment of lumber.

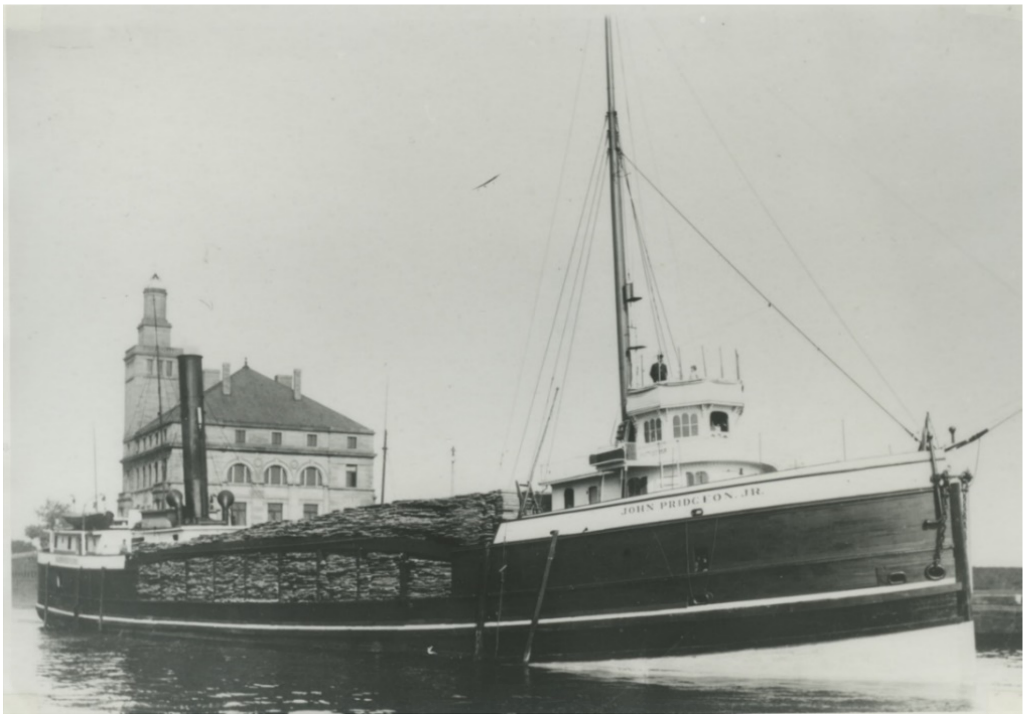

FIGURE 4.4. *John Pridgeon Jr.* laden with cargo c.1890s (Courtesy of Alpena County George N. Fletcher Public Library 2021b).

Propeller Style Population Discussion

The eleven recorded vessels with historically identified propeller styles found through this study represent some of the most highly detailed documentation provided in mid- to late-19th century enrollment papers and contemporary launch announcements within the sampled population. While the large size of the general population sampled in this study allows for some statistical analysis of developing trends in the U.S. Great Lakes maritime landscape as a whole, the small subpopulation of vessels documented as having a specific propeller style cannot yield reliable statistical results. Due to the size of the sampled population with identified propeller style, inferences about propeller design and popularity must be made in concert with deeper analysis of available primary and secondary historical sources regarding the vessels and their manufacturers. Broader application of propellers designed by Richard Loper and various others in the Great Lakes may be inferred through the shared characteristics of vessels with recorded propeller style from the 1850s-1870s.The screw steamships documented as having specific propeller designs found in the sampled population were built by a handful of individual and partnered shipbuilders working in Cleveland and Buffalo during the mid- to late- 19th century. Their approaches to screw propeller construction and general responses to the subsequent successes and failures of vessel operation throughout the latter half of the 1800s may suggest trends and opinions of the greater Great Lakes maritime shipbuilding and commerce landscapes regarding propeller style during the period.

Daniel M. O'Connor, builder of the propellers *Burlington* and *Stillman Witt*, operated out of Buffalo, New York during the 1850s and 1860s. As is likely with many contemporary wooden screw propeller builders in the Great Lakes region, his earliest documented work involved the construction of wooden-hulled sailing vessels, including the construction of the schooner *Antelope* in 1855 (*The Democracy* 1855). Through the late 1850s O'Connor was a popular producer of both sail- and screw-propelled vessels. In 1857 alone, O'Connor constructed seven vessels, of which five were screw propellers of varying size and general purpose (*Buffalo Daily Courier* 1857). O'Connor's propellers operated with relative success over the course of their respective working lives, ranging from the short 3-year working life of the propeller *La Crosse* to the remarkably successful 38-year working life of the propeller *Burlington*. Only two of the six documented propellers built by Daniel O'Connor are documented with a Philadelphia wheel; however, contemporary sources detailing the strengths of O'Connor's other screw propellers suggests that he collaborated with ironworks and steam machinery companies to ensure optimal performance in his vessels (*Buffalo Daily Republic* 1856b). His incorporation of Loper-designed Philadelphia wheels in his propeller construction indicates that the Philadelphia wheel sustained a level of esteem and popularity as a high-performing screw propeller design well past its introduction in the 1840s.

Thomas Quayle and John Martin's joint shipbuilding career began sometime around 1854, shortly after the dissolving of Thomas Quayle's shipbuilding partnership with Luther Moses. Across the duo's nearly 20-year partnership, they constructed dozens of sail-powered and steam-propelled vessels for Great Lakes maritime commerce and international maritime trade (Wright 1963:37). As with Daniel O'Connor, the late 1850s were a period of peak production for the shipbuilding duo, during which they constructed several schooners and barks and a handful of propellers, including the propellers *Akron* and *Iron City* (*Buffalo Commercial Advertiser* 1856). Quayle and Martin generally favored the construction of sailing vessels throughout their joint shipbuilding career; however, several steam vessels they launched indicate an attention to the developing trends in steam engine and screw propeller development across the latter half of the 1800s. *Akron*'s refitting in 1867 with a "New York pattern wheel," while vague in description, indicates that Quayle and Martin were continuing to experiment with the effectiveness of screw propeller design during a period where propeller design seemed to take a back seat to new innovations in steam propulsion. Around the same time as Akron's wheel replacement, Quayle and Martin were among the early adopters of a new compound steam engine design patented by Perry and Lay, which would become a staple in Great Lakes steam shipbuilding in the late 1860s and 1870s (*Detroit Free Press* 1868b; *Buffalo Morning Express*

1869). Regardless of wheel or engine design, the relative success of Quayle and Martin's vessels allowed them to continue operation long after their shipbuilding partnership dissolved in 1873.

Cleveland-based shipbuilder Luther Moses operated in the Great Lakes region as a member of shipbuilding partnerships Sanford and Moses (from 1844 to 1849) and Quayle and Moses (from 1849 to 1852) prior to his establishing of an independent shipbuilding firm with his brother Philo in 1852 (Wright 1963:36). Moses constructed a number of successful screw steamers, both independently and in partnership with his brother, over the course of the 1850s for varied purposes on the Great Lakes. He incorporated the Philadelphia wheel into several of his screw propellers built in the mid- to late-1850s, including the 1856 propeller *Racine* and the 1857 propeller *Governor Cushman* (*Buffalo Daily Republic* 1856a). Luther Moses also seemed willing to experiment with alternative propeller designs during what is possibly the most popular period of the Philadelphia wheel's application, constructing the first "Merrick wheel"-equipped propeller *Susquehanna* in 1858. While Moses's career in active shipbuilding seems to end in 1858, he remained an influential individual in the development of Cleveland's steam shipbuilding industry throughout the remainder of the 19th century.

Burton S. Goodsell maintained a shipbuilding business throughout the Great Lakes region from the earliest days of steam propulsion's application in the area. Goodsell was constructing vessels in the developing port cities of Vermillion and Huron, Ohio as early as 1838, launching sidewheel steamers *Vermillion* and *Great Western*, respectively (Wright 1963:66). Goodsell's shipbuilding career consisted largely of the construction of sidewheel steamers throughout the Lakes from the late 1830s into the 1840s; however, the handful of screw-propelled vessels constructed by Goodsell encapsulate the larger trends in shipbuilding and the growing application of screw propulsion in the Great Lakes during his career. Following the introduction of screw propulsion on the Great Lakes in 1841, Goodsell applied twin Ericsson-style propellers to *Goliath* in 1846 (Gegesky 1985). Soon after, however, it appears that Goodsell had moved on from the Ericsson-style propeller design. Goodsell's large propeller *Indiana*, launched in 1848, was equipped with a wheel that strongly resembles early iterations of Richard Loper's "Philadelphia wheel" (Johnston 1995). A combination of the general success of *Indiana*'s screw propulsion system and the growing popularity of the Philadelphia wheel in the region may have influenced the later refitting of one of Goodsell's sidewheel steamers, *Globe*, in 1856 by Buffalo's C.A. Van Slyke. The small number of screw propellers attributed to Burton S. Goodsell in the mid-1800s suggests the initial popularity of the Ericsson-style propeller wheel and the rapid adoption of the "improved" Loper propeller among established steam shipbuilders in the Great Lakes region.

While the vessels equipped with a Loper propeller from the 1850s onward recorded in the Metzler database were exclusively built in Cleveland and Buffalo, it seems likely that a combination of vessel movement around the region and nonspecific descriptions provided in new vessel enrollment records conceal the presence of vessels with Loper-style and other propeller wheel patterns throughout the period. An article in the *Oswego Palladium* in the late summer of 1857 discusses the widespread use and popularity of Loper-style Philadelphia wheels in the harbor at Oswego, New York, describing it as being used on all but one of the screw tugs in operation in the harbor that year (*Oswego Palladium* 1857). Many vessels constructed in the larger Great Lakes shipbuilding centers of the time were meant for use across the region or in smaller port cities, and while it is not made apparent in the data collected from the Metzler database, it is likely that vessels with Philadelphia wheels were built or refit in these smaller port cities as the screw technology continued to grow in popularity. The one-off ports of origin observed among the sampled vessels with historically identified propellers, such as Detroit and Sandusky, had been growing significantly over the course of the 19th century and it seems highly unlikely that other screw-propelled wooden vessels of similar styles were not in production in the 1860s and 1870s. Observations of shifting importance in the information conveyed by more detailed descriptions of newly launched vessels seems to indicate that as the screw propeller became the dominant type of steamship operating in the Great Lakes, emphasis on descriptions of the propeller wheels themselves decreased in favor of describing new innovations in steam machinery (*Daily National Pilot* 1845a; *Detroit Free Press* 1868b; *Detroit Post & Tribune* 1878).

Chronology of Loper Propeller Use in Great Lakes Region

From the time of the introduction of the first Ericsson-style screw propeller into the Great Lakes region in 1841, application of screw propulsion of various styles developed rapidly and became the most prevalent style of propulsion in commercial watercraft by the latter half of the 1850s (Dohrman 1976). While general screw propulsion has been traced through enrollment records and merchant vessel inventories published throughout the latter half of the 19th century, following one specific style of screw propulsion has, as evident through this study, proven to be significantly more difficult. A comprehensive overview of the adoption and use of Richard Loper's "Philadelphia wheel" propeller design within the Great Lakes region, therefore, must incorporate both statistical results available through vessel databases and primary and secondary historical sources detailing the design's popularity and application over the course of the latter half of the 19th century. Contemporary treatises published in the mid-1800s, newspaper articles, ships' papers, and modern investigations of 19th century Great Lakes shipwrecks can supplement inconsistent documentation of screw propeller design during the period to outline the presence of Loper propellers in the Great Lakes during the mid- to late-19th century.

Great Lakes Loper Propellers in the 1840s

Despite John Ericsson's reintroduction of the screw propeller as a mechanically feasible method of steam propulsion to the United States in 1839, it had yet to be truly considered a viable commercial propulsion style in oceanic and coastal shipping at the time of the Loper propeller's introduction to the maritime landscape. Richard Loper's 1844 screw propeller patent coincided with the experimental fitting of the U.S. revenue steamer *Spencer* with the newly developed propeller design. While *Spencer*'s performance in the Naval trials described by Alex Frazer was not deemed successful enough to garner great amounts of attention by the U.S. Navy or the merchant marine of the U.S. East Coast, the performance of the propeller design in a coastal setting did not deter experimental applications of the propeller within the U.S. interior (Frazer 1846). Interest in Richard Loper's design by Great Lakes shipbuilders was apparent immediately, with shipbuilders in Detroit anticipating possible test runs of the Loper propeller in late 1844 (*Detroit Daily Advertiser* 1844). Cleveland shipbuilder George W. Jones completed construction on the propeller *Phoenix* in April of 1845, becoming the earliest known screw steamer on the Great Lakes equipped with Richard Loper's Philadelphia wheel at time of launch (*Daily National Pilot* 1845a).

At the time of *Phoenix*'s launch, Ericsson pattern propellers were likely one of, if not the only, screw propeller designs in use within the Great Lakes region. Following the Oswego-built *Vandalia*'s introduction to the region in 1841, Ericsson-style propeller wheels were equipped on seven newly constructed screw steamers over the course of the following two years. By 1845, a total of nine registered screw steamers had been constructed in the Great Lakes region, all of which can be presumed to have Ericsson-style wheels (Dohrman 1976:11). Ericsson's propeller design had the advantage of being the first design to appear and become popular within the Great Lakes region; however, the improvements made in Loper's propeller design quickly incentivized the use of the Philadelphia wheel over the Ericsson wheel. The relative simplicity of the Loper propeller design compared to that of the Ericsson design necessitated the use of less iron in the wheel's initial production, which was believed to lend itself to increases in vessel speed, decreases in fuel consumption, and greater simplicity of the propeller repair process (*Chronicle & Gazette* 1844; *Daily National Pilot* 1845b). Vessels equipped with Ericsson-style wheels continued production in the Great Lakes region throughout the 1840s with the launch of vessels like *Goliath* in 1846; however, contemporary news sources throughout the Great Lakes region cease to provide substantial evidence of the presence of Ericsson propellers on newly built screw steamers past this point (Gegesky 1985).

While historical evidence of Ericsson's propeller design appears to decrease as the 1840s progress, evidence regarding the implementation of Loper's propeller design remains relatively sparse in the years following *Phoenix*'s launch. The propeller *Indiana*, built by Burton Goodsell in 1848, is recognized by modern historians and archaeologists as being equipped with an early iteration of the Philadelphia wheel; however, this identification is based more in morphological characteristics and manufacturers' information than contemporary identification of the vessel's propeller style (Robinson 1999:235). The anticipation of Loper's wheel felt in 1844 presumably corresponded in at least some use of the new propeller design in previously built screw steamers, but extant historical documentation cannot confirm that the Philadelphia wheel was applied to the approximately 38 screw-propelled vessels built in the Great Lakes region between 1846 and 1849 (Dohrman 1976:11).

Great Lakes Loper Propellers in the 1850s

Following the introduction of Richard Loper's propeller design to the Great Lakes in the 1840s and the construction of some of the earliest Great Lakes propellers with Philadelphia wheels, the 1850s saw a dramatic rise in the design's popularity. Out of the eight vessels equipped with Loper propellers identified in the Gerald C. Metzler Great Lakes Vessel Database between 1844 and 1874, five were constructed or refit during this period. While this is not a particularly high number when compared to the larger sample population examined in this study, the relative frequency of vessels with historically identified Loper propellers in the 1850s relative to the surrounding decades suggests a level of widespread popularity in the region. Vessels that, for one reason or another, were not identified as having a Loper propeller in the Metzler database but are historically documented with a Philadelphia wheel also increase in number rather dramatically in the 1850s. Newly constructed screw propellers *Racine*, *Fountain City*, and *Leviathan* count themselves among the formally announced steamships launched in the 1850s with Philadelphia pattern wheels; however, the construction of many more vessels outfitted with Philadelphia wheels that were not announced in contemporary newspapers, like the tugs *Ontario* and *William Morgan*, can be inferred through published discussions of screw propeller efficiency (*Buffalo Daily Republic* 1856a; 1857a; *Detroit Free Press* 1857; *Oswego Palladium* 1857). The 1850s is also the period in which contemporary treatises on steam propulsion and newspaper articles begin to describe the Philadelphia wheel as the dominant style utilized in U. S. screw steamship construction, both in the Great Lakes and in general steamship production on the U. S. coast (MacFarlane 1851:119; *Oswego Palladium* 1857). The anticipation described in the mid- to late-1840s surrounding Loper's propeller design and its introduction to the Great Lakes appears to have proven itself warranted, even in the early years of the new decade.

While the Philadelphia wheel itself emerged as a propeller design in competition with the newly introduced Ericsson propeller in the 1840s, few other propeller designs emerged in the Great Lakes region before the 1850s. In the same *Oswego Palladium* article from August of 1857 that described Loper-style Philadelphia wheels as the dominant propeller design applied to vessels in the Oswego harbor, a challenge was issued to compare the towing power of the now ubiquitous Philadelphia wheel to a newly developed "Talcott wheel" created by local Oswego inventors Talcott and Underhill (*Oswego Palladium* 1857). No description of the Talcott wheel was provided in the challenge article or prior articles describing *Hiram Perry Jr*., the vessel equipped with the newly developed propeller design, aside from its purported superiority when towing vessels.

Another competing propeller style emerging in the latter half of the 1850s was the Merrick pattern propeller design. Datus E. Merrick, operating out of Cleveland, Ohio, developed his screw propeller design and received a U.S. patent in July of 1858. Merrick's patented propeller design consists of three blades, also referred to as paddles in the text of the patent description, around a simple propeller hub. The distinguishing characteristic of the Merrick pattern wheel is the presence of "buckets" or "flanges" extending at a perpendicular angle from the outermost extremities of each blade (FIGURE 4.5). Merrick described this as a method of preventing "slippage" or momentum lost due to other screw designs directing water away from the rotating wheel at right angles. These flanges, Merrick claimed, would force all water taken in by the propeller wheel to be directed aft of the vessel, thus optimizing the propeller's effectiveness (Merrick 1858).

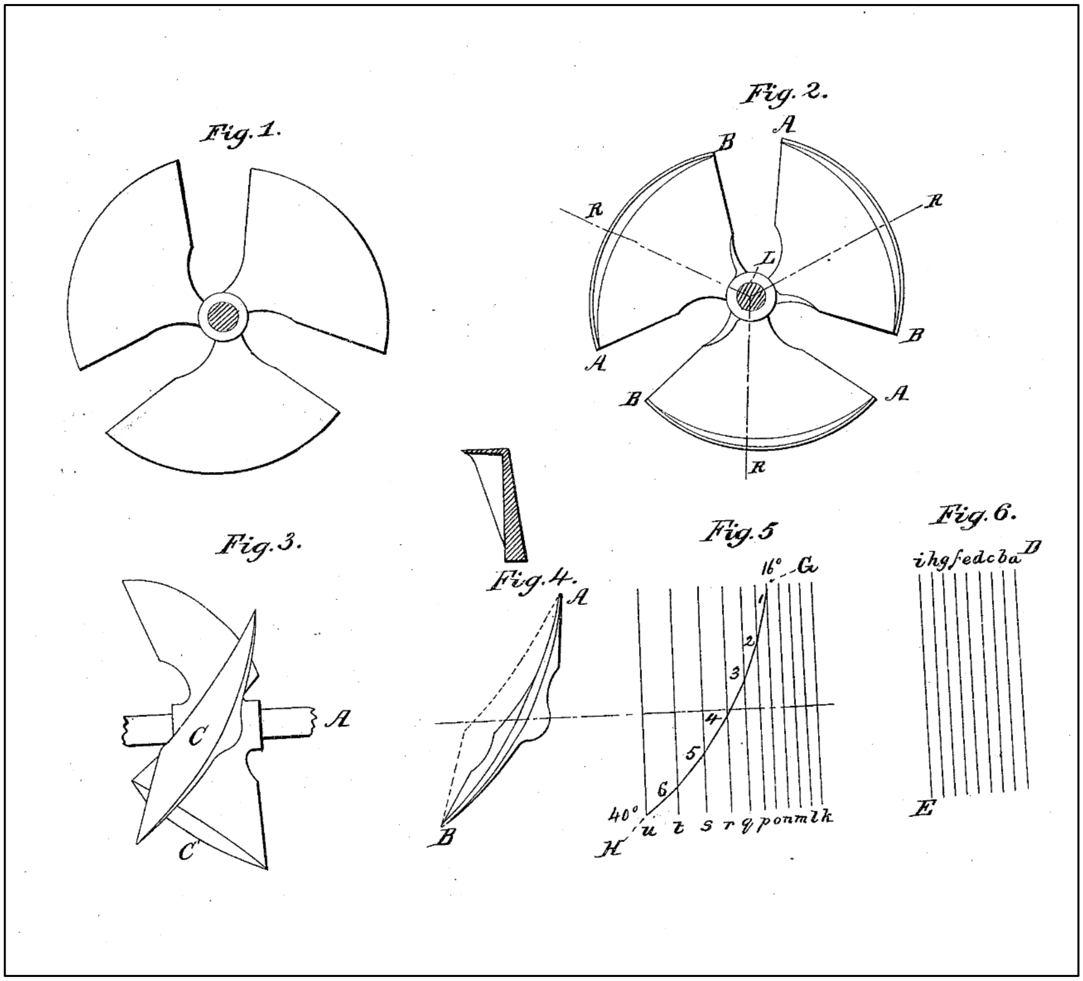

FIGURE 4.5. The patented Merrick pattern screw propeller. Fig. 2 and Fig. 3 most clearly show the "buckets" or "flanges" that distinguish the design from its contemporaries (Merrick 1858).

The Cleveland-built *Susquehanna* was the first vessel fitted with a Merrick-style screw propeller and, as stated in the earlier section describing the vessel, was publicly considered to be an experimental test of the design's effectiveness (*Detroit Free Press* 1858). While *Susquehanna* successfully operated with its Merrick-style propeller for 22 years before being refit to a non-steam vessel, no evidence could be found to suggest that the Merrick pattern wheel was utilized on other screw propellers. Competitive screw propeller designs continuously emerged in historical records through the 1850s onward, included in simple descriptions of newly launched vessels and in direct comparisons to Loper's Philadelphia wheel design. However, none of the developing screw designs seem to be able to attain the level of popularity enjoyed by the Philadelphia wheel.

Great Lakes Loper Propellers in the 1860s

As Great Lakes maritime shipbuilding and commerce progressed into the 1860s, screw propulsion continued to grow into the dominant form of steam propulsion in the region. With this ongoing adoption of screw-propelled vessels in commercial shipping on the Lakes, the Philadelphia wheel appears to have maintained the popularity that it had achieved in the prior two decades, arguably becoming even more of a fixture in Great Lakes screw propeller shipbuilding than the 1850s. Only two wooden-hulled vessels with Loper propellers identified in the Metzler database, *Satellite* and *Yosemite*, were launched during this decade; however, contemporary newspapers across the Great Lakes region frequently described new vessels equipped with Philadelphia wheels throughout the 1860s (*Buffalo Daily Courier* 1862; *Detroit Free Press* 1863; *Buffalo Daily Courier* 1866). As with references to the Loper propeller's popularity on the U.S. east coast in the 1850s, the design was still widely recognized and celebrated outside of the Great Lakes. Articles discussing alternative propeller designs in east coast ports regularly compare their performances to the Philadelphia wheel, suggesting that throughout the shipbuilding industries of the U.S., the Loper propeller had become the standard for speed, fuel consumption, and overall performance (*New York Times* 1862).

The continued popularity of Richard Loper's "Philadelphia wheel" design in the Great Lakes region did face minor challenges from competing designs in the 1860s. The "New York pattern" screw propeller appears in descriptions of the propeller Akron's maintenance and refitting in 1867. Another new screw propeller design referred to as the "Clyde pattern" was applied to at least two American-built vessels, *Philadelphia* and *Thomas A. Scot*t, on the Great Lakes in the late 1860s (*Detroit Free Press* 1868a). Both propellers measured 11 feet in diameter and sported 4 fixed blades; however, no contemporary U.S. patents can be traced to that name. Both the "Clyde pattern" and "New York pattern" described in vessel enrollments and contemporary newspaper articles may have been regional nicknames for the designs, much like "Philadelphia wheel" was a commonly used nickname for Richard Loper's propeller design. The two patterns could also have been unpatented experimental designs that were not applied to other vessels following their initial trial applications; however, in the case of the "New York pattern," elements of the design may have been incorporated into later propeller designs in the 1880s (*Marine Record* 1884). Generally, patented screw propeller designs from the 1860s continued the trends of the two previous decades in their attempts to improve screw steamship performance by altering propeller style and blade shape. Many of the designs, while justified within the text of the patents themselves, sport design elements echoing those of earlier patents like Ericsson and Smith, while others took on completely original forms (Stanley 1860; Colborn 1865; Baylis 1861; Jacob 1865). While these patented screw designs were developed throughout both the Great Lakes and eastern coast of the U.S., none appear to have been used in the Great Lakes region. Despite the continued emergence of competitive screw propeller designs evidenced in U.S. issued patents and potentially unofficial designs applied to vessels on the Great Lakes, the Philadelphia wheel maintained its position as the most commonly referenced propeller style during the decade.

Great Lakes Loper Propellers after 1870

Continuing the momentum of the 1850s and 1860s, Richard Loper's Philadelphia wheel maintained popularity and esteem throughout the 1870s and 1880s. Despite this maintained level of popularity, the Philadelphia wheel appeared less frequently in launch and maintenance announcements published in local newspapers. Among the vessels catalogued in the Gerald C. Metzler Great Lakes Vessel Database, *John Pridgeon Jr.* was the only vessel launched in the 1870s with a Philadelphia wheel explicitly identified in its ships' papers. Several other vessels not identified in the Metzler database launched with Philadelphia wheels in the 1870s, including the tug *Andrew J. Smith* and steam barges *David Ballentine* and *Chauncy Hurlbut*; however, explicit mentions of a "Philadelphia pattern" wheel noticeably decreased in this decade (*Buffalo Commercial Advertiser* 1873a; 1873b; *Cleveland Herald* 1876). Other vessels not documented with a specific propeller style that launched in the 1870s, including the propeller *Monohansett*, operated for a considerable amount of time in the region with a propeller that has been recognized by modern archaeologists and historians as the Philadelphia wheel design (Dappert 2006). The 1880s continued the trend of decreasing references to the Philadelphia wheel when announcing new vessel launches and screw propeller replacements. While it is apparent that the Loper propeller design was still in use throughout the Great Lakes in this decade, as evidenced by records of propeller replacements made to vessels in 1884 and 1888, it seems that extended discussion regarding the Philadelphia wheel was no longer necessary (*Marine Record* 1884a; 1888).

At least some of the obscurity regarding Richard Loper's "Philadelphia wheel" design past the 1880s could be attributed to the expiration of the propeller patent in the previous decade. Once Loper's original propeller design patent expired in 1861, it became part of the public domain, opening the design up to production and application without explicit permission or recognition of the design's origins. While the commonly utilized "Philadelphia wheel" remained a recognizable term for Loper's wheel design that can be traced well past the date of the patent's expiration, it was likely more of a term referring to a recognizable style of screw propeller than any active attempt to credit its designer. The existence of later designs, such as the "Buffalo pattern" described in 1884 that implemented elements of multiple older propeller designs, suggest the probable fate of Richard Loper's "Philadelphia wheel" design as U.S. screw shipbuilding progressed into the 20th century (*Marine Record* 1884b). As the design continued to age past its patent expiration date, shipbuilders began incorporating elements of the once immensely popular design into propellers of their own. Like the available historical record documenting vessels equipped with Philadelphia wheels themselves, detailed information regarding screw propeller design in the 1890s and early 1900s appears infrequently; furthermore, the lack of legal incentive to credit an expired patent makes it virtually impossible to trace the impact of Loper's 1844 design in the screw propellers of the late 19th and early 20th centuries. Despite the continued references and introduction of competitive screw propeller designs in the years following the introduction of Loper's design to the United States' Great Lakes region, none can be easily traced in the historical record as gaining a level of widespread use and popularity in the same way that Richard Loper's had in the mid- to late-19th century.

Conclusion

Observable trends in screw propeller construction in the U. S. Great Lakes region during the mid- to late-19th century demonstrate the rapid growth of the Great Lakes screw shipbuilding industry and the regional spread from large port cities and shipbuilding centers to smaller ports and shipyards over the course of a 30-year period. While general trends regarding the adoption of wooden-hulled screw propellers in commercial shipping in the U.S. Great Lakes can be identified and explored through data gathered from the Gerald C. Metzler Great Lakes Vessel Database, historical documentation concerning propeller styles associated with those vessels are scarce and hindered substantial statistical analysis of the relationships between propeller style and other vessel characteristics. Instead, the combination of vessel data and historical source material found in newspapers published throughout the U.S. and Canadian Great Lakes regions provide a chronological outline of the use of Richard Loper's "Philadelphia wheel" design on the Lakes, from its anticipated arrival at the time of the design's patent in 1844 to the latest mention of the style in 1888. While inconsistent documentation of vessel characteristics and propeller styles obscure a significant portion of the development and adoption of Richard Loper's screw propeller design during this period, the broad outline obtained through a combination of vessel database examination and deeper historical research suggests that the Philadelphia wheel was a fixture in the Great Lakes maritime landscape throughout the latter half of the 1800s.

CHAPTER 5 - CONCLUSION

Introduction

The previous chapters discussed the historical background of Great Lakes screw propulsion as well as historical and statistical methodologies applied to identify the impact of Richard Loper's screw propeller design in the Great Lakes region in the mid- to late-19th century. This concluding chapter answers the proposed research questions, discusses the study's limitations, and provides suggestions for further research into Loper's propeller design and the development of screw propulsion in the 19th century United States.

Answering Research Questions

The main objective of the thesis involved identification and tracking of Richard Loper's "Philadelphia wheel" design through the Great Lakes region from the time of its creation in 1844 to the latest historical references to its use. Identification of contemporary vessels constructed and refit throughout the period with Philadelphia wheels were also intended to aid in outlining the propeller style's presence in the Great Lakes and lend insight into the advantages presented by Loper's design.

In-depth historical research into the development and adoption of screw-propelled vessels in the 19th century was conducted in this thesis to measure the impact of Richard Loper's design in the Great Lakes region and the broader United States. Many historical newspaper articles published in the Great Lakes region and abroad provided valuable information on vessels constructed throughout the period, as well as general opinions of the public on screw propeller development and popular designs. Historic newspapers were the most reliable source of information on Loper's propeller design, most commonly referred to through its various nicknames, from the 1840s well into the 1880s. Personal and family documents belonging to Richard Loper and his family, currently housed in the Library of Congress, provided more information on the events in Loper's life that were believed to have made an impact on the development and popularity of his propeller design in the latter half of the 18th century. Lastly, examination of historic patents issued in both the United States and in Britain supplemented comparisons of contemporary propeller designs utilized in screw propeller construction throughout the 19th century and supported discussions found in other historical sources surrounding the purported advantages of the Loper propeller over some of its competitors.

Using data collected from the Gerald C. Metzler Great Lakes Vessels Database, information on the general trends and development of screw propulsion in the Great Lakes region was gathered and analyzed for its relationship to the adoption of specific propeller styles. While inconsistencies in vessel documentation and propeller identification limited the scope of this study's statistical analysis, the overarching information regarding increases in screw propeller construction from the 1840s to the 1870s allowed for further research into prolific Great Lakes shipbuilders and popular port cities that could be connected to the use of Philadelphia wheels and other propeller styles in the period. The small subset of vessels found in the dataset with historically identified Loper propellers were also researched and examined for their relationship to the greater narrative of screw propeller development and the adoption of the Loper propeller in the Great Lakes region.

Lastly, the information gleaned from database research, general statistical analysis, and historical research into the development of screw propulsion in the Great Lakes region was combined to form a historical overview of Richard Loper's screw propeller design as it was implemented in the mid- to late-19th century Great Lakes region. This thesis utilized references made to the Loper propeller throughout the 19th century, combined with historical source materials concerning the general development of screw propulsion, to better understand the application of the Philadelphia wheel in early Great Lakes screw propellers within the wider context of contemporary shipbuilding development within the region. This study found that the historical presence of Loper propellers in the 19th century Great Lakes region generally ran parallel to the early development of screw-propelled vessels within the region and, in comparison to contemporary propeller styles, remained one of the most popular methods of propulsion for wooden-hulled screw propellers through the latter half of the 19th century.

<u>How long did it take for this new style of propeller to gain popularity? How did the Loper propeller come to be so much more popular in the Great Lakes region than it seemed to be in the coastal Northeast, where it was developed?</u>

Coming off the relatively unremarkable performance of *Spencer* in the propeller's official U.S. Navy trials, shipbuilders on the East Coast remained hesitant to apply Loper's propeller deign to steam vessels built for coastal and oceanic shipping in the 1840s. While this thesis focused on the Loper propeller's presence in the Great Lakes region specifically, several historical sources indicated that Loper's design eventually became popular among shipbuilders along the East Coast of the United States; however, the relatively slow development of screw propulsion in U.S. coastal and transoceanic shipping limited the Philadelphia wheel's popularity in the latter half of the 19th century. Further historical research of the Loper propeller's presence in U.S. East Coast shipbuilding may provide greater detail concerning screw propeller adoption in the mid- to late-19th century.

Alternatively, rumors of the relative strengths of Loper's design spread quickly in the Great Lakes region and the propeller arrived in the area with much anticipation soon after it was patented. Shipbuilders in the Great Lakes port cities of Buffalo, Cleveland, and Detroit were constructing screw-propelled vessels following the introduction of John Ericsson's propeller design to the lakes in 1841; however, news of the purported increased power and decreased costs of Richard Loper's design led many to anticipate the arrival of Loper's design to the area within mere months of its official patent date. While the historical record remains unclear on exactly when the Loper propeller design was first applied to a screw steamship in the Great Lakes, the launch of *Phoenix* in May 1845 indicates that use of the propeller design had officially spread into the region. As indicated in MacFarlane's (1851) observation of the design's widespread popularity in the region, the Loper propeller had become the dominant propeller style utilized in the Great Lakes within six years.

<u>How long was the Loper propeller the dominant style of propeller in the Great Lakes region? Is there a particular propeller design that replaced it as the dominant propeller in the region? If so, what characteristics gave it an advantage over the Philadelphia wheel?</u>

When Loper's patented design was first introduced to the Great Lakes in the mid-1840s, wooden shipbuilding presented unique limitations to the application of screw propeller wheels. As composite and metal-hulled vessels became more popular in the Great Lakes and beyond, vibration and vessel size constraints that had limited the effectiveness of propeller designs in wooden-hulled vessels were no longer of great concern in the development of new screw propeller designs. Historical documentation does not provide a specific year or decade in which the Philadelphia wheel lost its status as the dominant propeller design in the Great Lakes;

however, the rate at which vessels are identified with a Philadelphia wheel markedly decreases in the latter half of the 1870s and early 1880s. This slow decline of historical references to Loper's propeller design coincides with a steady increase of metal-hulled vessels constructed in the region. The continued infrequency of explicitly identified propeller styles during these decades makes it difficult to determine if any one propeller style overtook the Philadelphia wheel in popularity during this period; however, a newspaper article from the 1880s discussing a new screw propeller pattern that borrowed design elements from the Loper propeller suggests that the design was simply incorporated into newer propeller designs as shipbuilding technology continued to advance. The Loper patent's expiration in the early 1860s would have facilitated this incorporation of design elements into new propellers, allowing inventors to improve upon the Philadelphia wheel's design as they saw fit without legal obligation to credit the design or designer.

<u>As they increased in popularity, did shipbuilders across the Great Lakes region utilize the Loper-style propeller design? Or was the Philadelphia wheel a popular propeller design in specific cities or Great Lakes shipbuilding centers?</u>

The Loper propeller arrived in the region just four years after the first screw-propelled vessel launched at a U.S. Great Lakes shipyard. The design's relatively early introduction to the region during the preliminary stages of the Great Lakes' adoption of screw propulsion allowed Loper's design to quickly gain popularity and a reputation as an effective and economical propeller design. This made it a very attractive option for shipbuilders beginning to construct screw propellers throughout the Great Lakes region. Information gleaned from Great Lakes vessel databases and contemporary historical sources indicate that as an early arrival to the Great

Lakes, the Loper propeller's popularity can be seen as developing parallel to the general popularity of screw propulsion in the region. While limited historical documentation remains concerning the propeller designs applied to individual vessels in smaller port cities throughout the mid- to late-19th century, the widespread use of Philadelphia wheels in both larger and smaller port cities suggested in contemporary shipbuilding treatises and newspapers indicates that the Philadelphia wheel was most likely utilized throughout the region instead of being limited to the largest port cities of the Great Lakes.

How popular were Richard Loper's other patented shipbuilding designs?

Richard Loper patented several shipbuilding designs relating to the construction and propulsion of screw propellers and other styles of vessels over the course of his career. Aside from his popular propeller design, Loper patented designs for composite shipbuilding and steam engine machinery as he became more involved with the construction of vessels involved in his commercial shipping enterprises.

While his other patented designs were undoubtedly utilized in vessels of Loper's own construction in Philadelphia, there is no historical evidence to suggest that the other patented shipbuilding designs were applied to vessels in the Great Lakes region. Composite and iron-hulled vessels were beginning to gain popularity in the latter half of the 19th century in both the Great Lakes and on the eastern coast of the United States, but the designs patented by Richard Loper regarding such vessel construction had likely expired before composite and iron shipbuilding became commonplace. Richard Loper's propeller design gained popularity alongside the general development of screw propulsion in the Great Lakes region over the course of nearly twenty years, which may have allowed the design to maintain a certain level of integrity after the expiration of the design's patent. Loper's other patented designs may have been utilized in vessels outside of the Great Lakes region; however, further historical research would be required to better understand the impact of the other designs on U.S. shipbuilding.

If his propeller design was as widely utilized in the United States as contemporary sources such as MacFarlane (1851) claim, is there a historical precedent for Richard Loper's general absence from 19th-century American maritime history?

Despite the prolific nature of Richard Loper's screw propeller design in both the Great Lakes region and the United States' east coast, Richard Loper's name is rarely mentioned in historic documentation describing the application or wider popularity of his design. Published descriptions and announcements regarding vessels outfitted with a Loper-style wheel referred to the screw propeller almost exclusively as a "Philadelphia wheel" within just a few years of the design's introduction to the Great Lakes region. Vessel and propeller descriptions originating in regional newspapers in the mid- to late-1840s explicitly mention Richard Loper by name; however, this approach to design credit seems to fall out of style in the following decade in favor of referring to the propellers as "Philadelphia pattern" wheels. Contemporary propeller designs appear to frequently take on nicknames based on their cities of origin; however, it is unclear when this phenomenon began and why the Philadelphia wheel was so quickly separated from its inventor. Preliminary research conducted in this thesis involving communication with maritime museums throughout the Great Lakes region and east coast of the U.S. found that Richard Loper remains a relatively unknown figure in U.S. maritime history, despite the apparent impact his propeller design had on early screw propeller development both in coastal and interior settings. While Loper's general absence from Great Lakes maritime history can be at least partially explained by the rapid rebranding of his propeller design to the "Philadelphia pattern," further research into Loper's and the Loper propeller's presence on the U.S. East Coast may be necessary to better understand the ongoing lack of knowledge about one of the most popular screw propeller inventors of the mid-19th century.

Limitations and Suggestions for Future Research

Major limitations imposed on travel restricted access to both U.S. and international archaeological sites and archival collections that may have been potentially useful in the study of 19th century screw propeller development. In addition, variability in historical documentation of 19th century vessels included in accessible Great Lakes vessel databases limited the scope of the statistical analysis conducted on Great Lakes wooden-hulled screw propellers in this thesis. It is likely that the researcher exercised some biases in their vessel database selection and in the parameters of the sampled population; however, the data collection process remained objective and represented the most reliable and easily accessible information on Great Lakes screw propulsion in the 19th century.

The historical basis of this thesis could be expanded upon through a variety of methods. Research and examination of historical patents conducted in this study allowed for a general understanding of the differences between popular screw propeller designs in the mid- to late-19th century Great Lakes region; however, in-depth artifact analysis of extant screw propellers located in museum collections and on submerged archaeological sites in the Great Lakes and around the world would provide further detail into the design elements of the Loper propeller and other 19th century screw propeller designs. Additional historical research outside of the Great Lakes region concerning Loper's partnerships with manufacturers and shipbuilding companies may provide greater knowledge of his other patented designs, as well as expand upon the historical data gathered in this thesis concerning the production of Loper propellers by shipbuilding and ironworks companies outside of Philadelphia. Historical sources like the Palmer-Loper Family Papers housed in the Library of Congress may contain information more relevant to the presence of Philadelphia wheels along the coastal United States than the Great Lakes. An expanded historical study of the application of Loper propellers in the 19th century outside of the Great Lakes region, particularly along the eastern coast of the United States, would further expand upon this study's identification of the propeller design's popularity during the period.

Additionally, information available to academics and the general public through the several Great Lakes vessel databases also provide avenues of future research regarding the development of certain trends in 19th century shipbuilding and steam machinery. While the variations in data collected for this study prevented effective statistical analysis of several variables within the dataset, several other potential variables became apparent in the data collection process that may prove valuable to future researchers. Documentation regarding vessel characteristics such as bow style were present in a large number of vessel database entries, opening up possible research avenues for tracing the development of bow morphology in early screw propellers and differences in bow style across the latter half of the 19th century. Other documented characteristics, such as steam engine and machinery styles and the frequency and nature of vessel repairs, were not present across the entire sampled population but could provide insight into various aspects of mid- to late-19th century screw propeller construction and maintenance. While researchers utilizing this data will encounter similar issues of variation in detail within available historical documentation as those in this study, the data recorded within the Gerald C. Metzler

Great Lakes Vessel Database (as well as other Great Lakes vessel databases) would provide an excellent base for further historical research and examination.

Conclusion

This thesis established the historical basis for the popularity of Richard Loper's "Philadelphia wheel" design in the United States' Great Lakes region during the mid- to late-19th century. Judging from contemporary opinions on the propeller's design, historical documentation of various propeller styles, and the modern identification of 19th century screw steamers, the Loper propeller became a mainstay in Great Lakes wooden screw propeller construction and operations soon after the design's migration into the region; furthermore, the design remained in use well into the period of transition between wooden-hulled and metal-hulled commercial shipping vessels in the late 19th century.

Historical and archaeological examinations of early steamship and screw propeller development are often hindered by the relative lack of remaining steam machinery and propeller wheels present in maritime museums and at contemporary shipwreck sites. The research conducted throughout this thesis demonstrates the ability of historical documentation gathered from mundane sources like newspapers to fill in the gaps of scattered historical and archaeological records. Physical and digitized archival collections containing historical newspapers, ships' papers, and shipbuilding information have proven themselves throughout this study as invaluable tools in the study of early technological development that may not have been frequently documented and recorded in more commonly referenced or widely published sources. Ongoing digitization of such historical sources may further aid in the preservation of historical information that may no longer exist in other mediums. Additionally, continued upkeep and historical research for Great Lakes vessel databases can provide both researchers and the general public with information on individual vessels operating in the region, as well as provide a basis for larger examinations of developments in shipbuilding and vessel use throughout the Great Lakes region from the earliest days of maritime industry to the present.

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Appendix A. Great Lakes Vessel Database Statistical Analysis Codebook

VNAME (Vessel Name)

LAUYR (Launch Year)

COHORT (Launch year cohorts)

0 = 1844-1854, 1 = 1855-1864, 2 = 1865-1874

SHPBLDR (Shipbuilder)

REFIT (Vessel Refit?)

0 = No, 1 = Yes

REFITTO (Was vessel refit to a propeller or from a propeller?)

0 = Not refit, 1 = To propeller, 2 = From propeller

PROPYR (What year did vessel begin operation as a propeller?)

PORG (Port of Origin)

SORG (State of Origin)

(See state codes)

LENGTH (Approximate Propeller length in feet)

RLENGTH (Recoded length)

0 = Under 50 feet, 1 = Between 51 and 150 feet, 2 = Over 150 feet

TONNG (Approximate Propeller Tonnage)

RTONNG (Recoded tonnage)

0 = Under 50 tons, 1 = Between 51 and 200 tons, 2 = Over 201 tons

MASTS (Mast Number)

DECKS (Deck Number)

PROPS (Propeller Number)

PROPDIA (Propeller Diameter in feet)

VTYPE (Vessel type)

0 = Unspecified, 1 = Tug, 2 = Barge, 3 = Other

VTYPEOTHER (If VTYPE is other, what is it?)

PROPREP (Was propeller replaced during working life?)

0 = No, 1 = Yes

WKGLIFE (Approximately how many years did vessel operate as a propeller?)

RWKGLF (Recoded working life)

0 = 10 years or less, 1 = 11 to 25 years, 2 = 26 years or more

PROPSTY (Propeller Style)

0 = Unspecified, 1 = Ericsson, 2 = Loper, 3 = Other

PROPSTYOTHER (If PROPSTY is other, what is it?)

STATE CODES

01 = Minnesota

02 = Wisconsin

03 = Illinois

04 = Indiana

05 = Michigan

06 = Ohio

07 = Pennsylvania

08 = New York

09= Maine

10 = New Hampshire

11 = Massachusetts

12 = Rhode Island

13 = Connecticut

14 = New Jersey

15 = Delaware

16 = Maryland

17 = Virginia

Appendix B. Nominal Frequency Data of Sampled Population

LAUNCH COHORT					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1844 to 1854	118	12.8	12.8	12.8
	1855 to 1864	343	37.2	37.2	49.9
	1865 to 1874	462	50.1	50.1	100.0
	Total	923	100.0	100.0	

WAS VESSEL REFIT?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Refit	807	87.4	87.4	87.4
	Refit	116	12.6	12.6	100.0
	Total	923	100.0	100.0	

WAS VESSEL REFIT TO OR FROM SCREW PROPELLER?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Refit	807	87.4	87.4	87.4
	Refit To	21	2.3	2.3	89.7
	Refit From	95	10.3	10.3	100.0
	Total	923	100.0	100.0	

STATE OF ORIGIN					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wisconsin	54	5.9	5.9	5.9
	Illinois	43	4.7	4.7	10.5
	Indiana	2	.2	.2	10.8
	Michigan	194	21.0	21.1	31.8
	Ohio	186	20.2	20.2	52.1
	Pennsylvania	12	1.3	1.3	53.4
	New York	426	46.2	46.3	99.7
	New Jersey	2	.2	.2	99.9
	Maryland	1	.1	.1	100.0
	Total	920	99.7	100.0	
Missing	System	3	.3		
Total		923	100.0		

RECODED LENGTH					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Under 50 feet	176	19.1	21.7	21.7
	Between 51 and 150 feet	437	47.3	54.0	75.7
	Over 150 feet	197	21.3	24.3	100.0
	Total	810	87.8	100.0	
Missing	System	113	12.2		
Total		923	100.0		

RECODED TONNAGE					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Under 50 tons	405	43.9	44.2	44.2
	Between 51 and 200 tons	191	20.7	20.8	65.0
	Over 200 tons	321	34.8	35.0	100.0
	Total	917	99.3	100.0	
Missing	System	6	.7		
Total		923	100.0		

MAST NUMBER					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	443	48.0	65.1	65.1
	1	186	20.2	27.4	92.5
	2	26	2.8	3.8	96.3
	3	20	2.2	2.9	99.3
	4	5	.5	.7	100.0
	Total	680	73.7	100.0	
Missing	System	243	26.3		
Total		923	100.0		

DECK NUMBER					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	10	1.1	28.6	28.6
	2	23	2.5	65.7	94.3
	3	2	.2	5.7	100.0
	Total	35	3.8	100.0	
Missing	System	888	96.2		
Total		923	100.0		

PROPELLER NUMBER					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	18	2.0	54.5	54.5
	2	15	1.6	45.5	100.0
	Total	33	3.6	100.0	
Missing	System	890	96.4		
Total		923	100.0		

VESSEL TYPE					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Non-specific	387	41.9	41.9	41.9
	Tug	479	51.9	51.9	93.8
	Barge	31	3.4	3.4	97.2
	Other	26	2.8	2.8	100.0
	Total	923	100.0	100.0	

VESSEL TYPE OTHER					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		897	97.2	97.2	97.2
	Canal Propeller	1	.1	.1	97.3
	Canal Steam Propeller	1	.1	.1	97.4
	Canal Tug	1	.1	.1	97.5
	Ferry	1	.1	.1	97.6
	Ferry Boat	5	.5	.5	98.2
	Fish Tug	2	.2	.2	98.4
	Revenue Cutter	1	.1	.1	98.5
	River Tug	1	.1	.1	98.6
	Schooner-Rigged	1	.1	.1	98.7
	Scow	4	.4	.4	99.1
	Steam Yacht	5	.5	.5	99.7
	Tug and Ferry Boat	1	.1	.1	99.8
	Yacht	2	.2	.2	100.0
	Total	923	100.0	100.0	

PROPELLER REPLACED?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Replaced	10	1.1	100.0	100.0
Missing	System	913	98.9		
Total		923	100.0		

RECODED WORKING LIFE					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	212	23.0	26.7	26.7
	1	332	36.0	41.9	68.6
	2	249	27.0	31.4	100.0
	Total	793	85.9	100.0	
Missing	System	130	14.1		
Total		923	100.0		

PROPELLER STYLE					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not specified	912	98.8	98.8	98.8
	Loper	8	.9	.9	99.7
	Other	3	.3	.3	100.0
	Total	923	100.0	100.0	

PROPELLER STYLE OTHER					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		920	99.7	99.7	99.7
	"New York patent"	1	.1	.1	99.8
	Clyde Pattern	1	.1	.1	99.9
	Merrick	1	.1	.1	100.0
	Total	923	100.0	100.0	